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Effect of nitrogen and zinc application on growth, grain quality and nutrient indices of direct seeded rice (*Oryza sativa* L)

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ABSTRACT

A field experiment was conducted during the rainy *(kharif)* season of 2014 - at Varanasi, Uttar Pradesh, to study the effect of nitrogen (N) and zinc (Zn) application on yield and zinc content in direct-seeded rice (DSR). The experiment was laid out in factorial randomized block design with replication thrice. The treatments included 4 N rates (0, 90, 120 and 150 kg/ha) and 4 Zn application (0 kg $ZnSO_4.H_2O$, 0.3% $ZnSO_4.H_2O$ spray at anthesis, 0.3% $ZnSO_4.H_2O$ spray at early milk, 0.3% $ZnSO_4.H_2O$ spray at dough stage). The highest growth attributes (plant height, tillers/running meter, fresh weight, dry weight and RGR), grain yield and agronomic indices of N and Zn in DSR were recorded with application of 150 kg N/ha, However among zinc scheduling 0.3% $ZnSO_4.H_2O$ spray at anthesis led the highest value of all the growth attributes. For grain quality, the combination of 150 kg N/ha and 0.3% $ZnSO_4.H_2O$ spray at dough resulted in the maximum grain protein content and protein yield.

Key words: Direct seeded rice, growth attribute, grain quality, nutrient indices, nitrogen and zinc scheduling.

Rice (*Oryza sativa* L.) production is a key to world food security as rice constitutes principal staple food for >50% of world population (Das and Chandra, 2013).

India need add 1.7 million tonnes of additional rice every year to secure food for ever growing population and increased productivity should come from diminishing resources, particularly water (Das *et al.* 2017). Out of the total 44 million ha of rice area in the country, 18.8 million ha is under rainfed condition, of which 67% lies in the eastern India (Mohapatra *et al.* 2013), which is mainly covered by DSR. In India mostly puddled transplanted rice is grow which is labour intensive, high water demanding, cumbersome, more CH_4 emitting and require lot of expenditure during raising nursery, uprooting, and transplanting. The shortage of labour during the peak period of transplanting, the uncertain supply of irrigation water and increasing production cost necessitate the search for an alternative option of conventional puddled transplanting of rice. Thus DSR provides an opportunity to combat all problems of puddled transplanted rice. The success of DSR strongly depends on nutrient management, especially on nitrogen and zinc.

Nitrogen is important nutrient for plant growth and development. It has positive association with grain yield because; it is involved in many biosynthesis processes (Fageria and Baligar, 2005). The efficient use of N in DSR

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has been recognized as an important factor for grain production. After N, Zn is the second most yield-limiting nutrient in rice (Quijano-Guerta *et al*. 2002). Zn plays multiple roles in basic biochemical processes such as protein synthesis, auxin metabolism, chlorophyll production and energy dissipation. On an average, 50% of the Indian soils are deficient in zinc (Zn), particularly calcareous soils due to the formation of insoluble zinc hydroxide and its carbonate. It can be corrected by Zn application in soil or on plant as foliar spray. Zn fertilization through foliar spray is a good option due to quick plant response and better economics. Keeping in view the possible N × Zn interactions, present study was aimed to identify optimum doses of N and Zn for growth attributes, grain yield, quality and agronomic indices of DSR.

Materials and Methods

A field experiment was conducted at the BHU, Varanasi, Uttar Pradesh, during the kharif season of 2014. The climate of the area typically subtropical with temperature ranging from 5 to 40.6°C and rainfall during crop period was 563.6 mm. Soil of the experimental site was sandy clay loam (52.2, 21.1 and 26.6% sand, silt and clay, respectively), organic carbon 0.45%, pH 7.4, available N, P, K 197.6, 21.2, 220.2 kg / ha, respectively and available zinc 0.51 ppm. The experiment was laid out in a randomized block design (factorial experiment) with 3 replications. The treatment consisted of 4 N levels (N_0- Control, N_1- 90, N_2-120, N_3-150 kg / ha) and 4 Zinc scheduling (Control-Zn_0, Zn_1-0.3% $ZnSO_4.H_2O$ spray at anthesis, Zn_2-0.3% $ZnSO_4.H_2O$ at early milking and Zn_3-0.3% $ZnSO_4.H_2O$ at dough stage). The plot size was 12 m^2. Rice cultivar 'HUR 105' was directly sown under unpuddled field condition with 20 cm row-to-row spacing on 10 August 2014, using 40 kg seed / ha. Light irrigation was given 4 days after sowing (DAS) for proper seed germination. The constant rate of P_2O_5 and K_2O at 60 and 60 kg / ha respectively, was applied. N and Zn were applied in the form of urea and Zn-sulphate respectively. N applied in 2 split doses-first at the time of sowing and the second dose at 40 days after sowing (DAS). For recording biometric observations at a regular interval five plants from the net plot area were randomly selected and tagged. However, for the dry matter accumulation, five plants were randomly selected from the sample rows (border plot area) at regular interval. While; for observations of yield attributing parameter s, five tagged plants were harvested. The plants were then tagged and brought to the laboratory for the study. The crop was harvested at maturity stage with using a sickle. Grain yield thus obtained from each net plot was converted to kg / ha. For plant analysis, samples were cleaned properly by repeated washing followed by 0.1 N HCl, solutions. Samples were dried under shade followed by in hot air oven at 60 ±1°C for 48 hours. Samples were then subjected to chemical analysis for N and Zn indices.

N, P and K contents in grain and straw were estimated using standard procedure as described by Rana *et al.*, 2014. The concentration of zinc was estimated by Atomic Absorption Spectrophotometer (Lindsay and Norvell 1978). Protein content (%) in grain was worked out by multiplying the nitrogen content in grain by the factor 6.25 (A.O.A.C., 1970). The protein harvest (kg / ha) was obtained by the following formula.

$$\text{Protein harvest (kg/ha)} = \frac{\text{Protein content} \times \text{Yield}}{\text{Weight of rough rice}} \times 100$$

Fertilizer use efficiency *viz*. PFP, AE, PE, RE and NHI of nitrogen and zinc was computed by formula given by Fageria and Baligar (2003).

Partial factor productivity defined as grain production per unit nutrient applied.

$$\text{PFP (kg/ha)} = \frac{\text{Grain yield (treated plot)}}{\text{Plant nutrient applied (treated plot)}}$$

Agronomy efficiency is the ratio of yield to nutrient supply.

$$\text{AE (kg/ha)} = \frac{\text{Grain yield (treated plot)} - \text{Grain yield (control plot)}}{\text{Plant nutrient applied (treated plot)}}$$

Physiological efficiency is representing as the ability of a plant to transport nutrient acquired from fertilizer into economic yield.

$$\text{PE (kg/ha)} = \frac{\text{Grain yield (treated plot)} - \text{Grain yield (control plot)}}{\text{Nutrient uptake (treated plot)} - \text{Nutrient uptake (control plot)}}$$

Recovery efficiency is the ratio of plant nutrient to per kg nutrient applied.

$$\text{RE (\%)} = \frac{\text{Nutrient uptake (treated plot)} - \text{Nutrient uptake (control plot)}}{\text{Plant nutrient applied (treated plot)}} \times 100$$

Nutrient harvest index is the ratio of nutrient uptake in grain to total nutrient uptake or defined as portioning of total plant nutrient into grain.

$$\text{NHI (\%)} = \frac{\text{Nutrient accumulated in grain (kg/ha)}}{\text{Nutrient accumulated in above ground dry matter (kg/ha)}}$$

The data were analysed statistically as per the standard procedure for "Analysis of Variance" as described by Gomez and Gomez (1984). The difference in the treatment mean were tested by using critical difference (CD) 5% level of probability.

Results and Discussion

Growth attributes

The results manifested that N and Zn scheduling significantly influenced to growth attributed of DSR (Table 1). Significantly higher plant height *viz*. 48, 83,115 and 120 cm at 30, 60, 90 DAS and at harvest stage was recorded with application of 150 kg N/ha over application of 90 kg N/ha and 0 kg N/ha, however it was found at par with 120 kg N/ha at 60 DAS. This might be due to rapid growth and development of plant cells due to adequate nitrogen supply. In cash of zinc scheduling, significantly higher plant height *viz*. 46, 77, 110 and 120 cm at 30, 60, 90 DAS and at harvest stage was recorded with application of 0.3% $ZnSO_4.H_2O$ spray at anthesis, over control; however it was found at par with application of 0.3% $ZnSO_4.H_2O$ spray at early milking stage. Highest number of tillers per running meter *viz*. 50, 119, 80 at 30, 60 and 90 DAS was recorded with application of 150 kg N/ha, which was significantly higher than all treatment except application of 120 kg N/ha at 30 DAS. While, 0.3% $ZnSO_4.H_2O$ spray at anthesis recorded highest tillers number per running meter *viz*. 47, 120 and 75 at 30, 60 and 90 DAS over all remaining treatments (Table 1). Leaf area index (LAI) was also influenced by different N levels and Zn scheduling. Significantly higher LAI *viz*. 0.59, 3.32 and 3.56 at 30, 60 and 90 DAS was recorded with application of 150 kg N/ha followed by 120, 90 and 0 kg N/ha. However amongst Zn scheduling, application of 0.3% $ZnSO_4.H_2O$ spray at anthesis recorded the highest LAI *viz*. 0.57, 2.79 and 3.16 at 30, 60 and 90 DAS, but it was found at par with application of 0.3% $ZnSO_4.H_2O$ spray at early milking at 60 and 90 DAS. This indicates that Zn application at early growth stage contributes more in growth and development of crop. Fresh and dry weight at different growth stages was also influenced significantly, resulting highest in the fresh weight *viz*. 27, 255, 565 and 692 g/running meter at 30, 60, 90 DAS and at harvest stage was reported with application of 150 kg N/ha followed by 120, 90 and 0 kg N/ha. While among Zn scheduling's, application of 0.3% $ZnSO_4.H_2O$ spray at anthesis recorded highest fresh weight *viz*. 26, 227, 545 and 626 g/running meter at 30, 60, 90 DAS and at harvest stage, however it was found at par with application of 0.3% $ZnSO_4.H_2O$ spray at early milking at 30 and 90 DAS. Similarly as fresh weight, dry weight was also influenced by N and Zn scheduling's. The higher dry weight of shoot *viz*. 3.69, 64, 178 and 220 g/running meter was recorded with application of 150 kg N/ha followed by 120, 90 and 0 kg N/ha. However among Zn scheduling's, the highest dry weight of shoot *viz*. 3.5, 50, 166 and 192 g/running meter at 30, 60, 90 DAS and at harvesting stage was recorded with application of 0.3% $ZnSO_4.H_2O$ spray at anthesis over to control, but it was found at par with application of 0.3% $ZnSO_4.H_2O$ spray at early milking at 30, 60 and 90 DAS. The increase of all growth attributes of DSR might be owing to involvement of N in many metabolic reactions, *viz*. proteins, nucleic acids and chlorophyll formation and of zinc in N-metabolism of the plant. Similar findings were also reported by Puteh and Mondal (2014).

Crop Growth Rate (CGR)

Crop growth rate was significantly influenced by different N levels and Zn scheduling (Fig. 1 and 2). The highest CGR *viz*. 0.12, 2.01 and 3.81 g/running meter/day at 30, 60 and 90 DAS was recorded with application of 150 kg N/ha followed by 120, 90 and 0 kg N/ha, however it found at par with 120 and 90 kg N/ha at 90 DAS. Among Zn scheduling's, application of 0.3% $ZnSO_4.H_2O$ spray at anthesis recorded significantly highest CGR *viz*. 0.11, 1.45 and 3.98 g/running meter/day at 30, 60 and 90 DAS over to application of 0.3% $ZnSO_4.H_2O$ spray at dough stage and control, however it was found at par at 60 and 90 DAS with application

Table 1. Growth yield attributes of DSR under different nitrogen levels and zinc scheduling.

Treatments	Growth attributes																	
	Plant height (cm)				No of tillers (running m^{-1})			LAI			Fresh weight of shoot (g running m^{-1})				Dry weight of shoot (g running m^{-1})			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
N- levels																		
N_0	37	60	90	95	42	99	59	0.45	1.84	2.19	20	164	404	424	3.	32	126	132
N_1	43	69	99	106	45	105	67	0.52	2.05	2.57	22	205	446	511	3	42	137	158
N_2	45	75	109	112	50	110	72	0.56	2.64	3.12	23	229	516	592	3.15	51	155	178
N_3	48	83	115	120	50	119	80	0.59	3.32	3.56	27	255	565	692	3.69	64	178	220
Zinc scheduling																		
Zn_0	39	62	98	102	41	98	58	0.49	2.16	2.45	21	195	402	492	2.7	45	131	160
Zn_1	46	77	110	119	47	120	75	0.57	2.79	3.16	26	221	545	626	3.5	50	166	192
Zn_2	42	74	103	106	46	106	73	0.53	2.49	3.06	25	219	494	554	3.4	47	153	171
Zn_3	44	73	101	104	42	109	72	0.53	2.42	2.76	21	210	490	546	2.9	46	147	163
SEm ±	1.66	2.40	2.52	3.52	2.89	2.62	2.41	0.06	0.32	0.35	1.28	6.74	16.3	16.50	0.18	1.94	7.15	5.00
CD (P= 0.05)	5	7	7	10	7.82	7.59	6.97	0.06	0.32	0.35	3.6	19.4	47	47.6	0.5	5	21	14
N×Zn	NS	NS	NS	NS	NS	SIG	NS	NS	NS	NS	NS	NS	NS	SIG	S	NS	NS	S

N_0 = 0 kg N / ha (control) , N_1 = 90 kg N / ha, N_2 = 120 kg N / ha, N_3 = 150 kg N / ha; Zn_0 = 0 kg Zn / ha (control), Zn_1 -0.3% $ZnSO_4$ spray at anthesis, Zn_2- 0.3% $ZnSO_4$ spray at early milking , Zn_3-0.3% $ZnSO_4$ spray at dough stage.

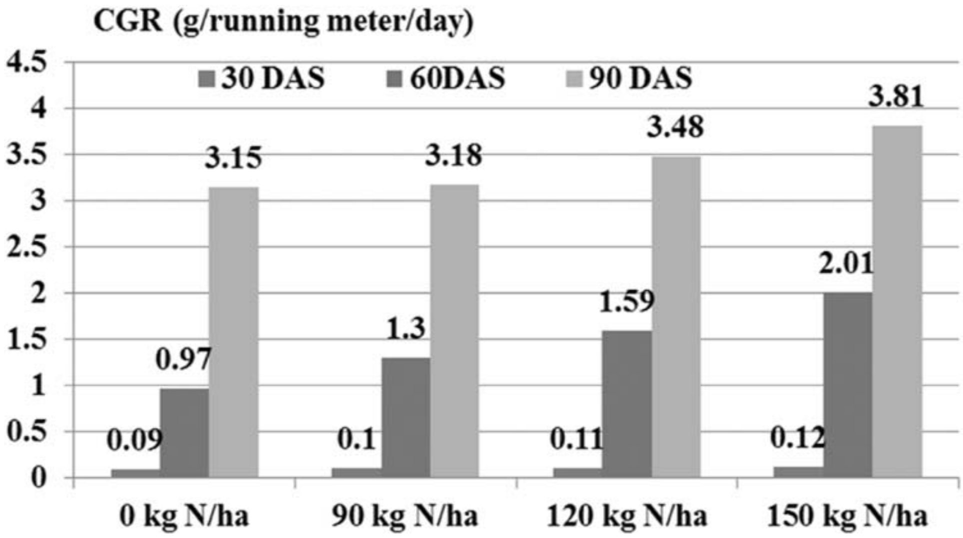

Fig. 1. Crop growth rate (CGR) under different N levels

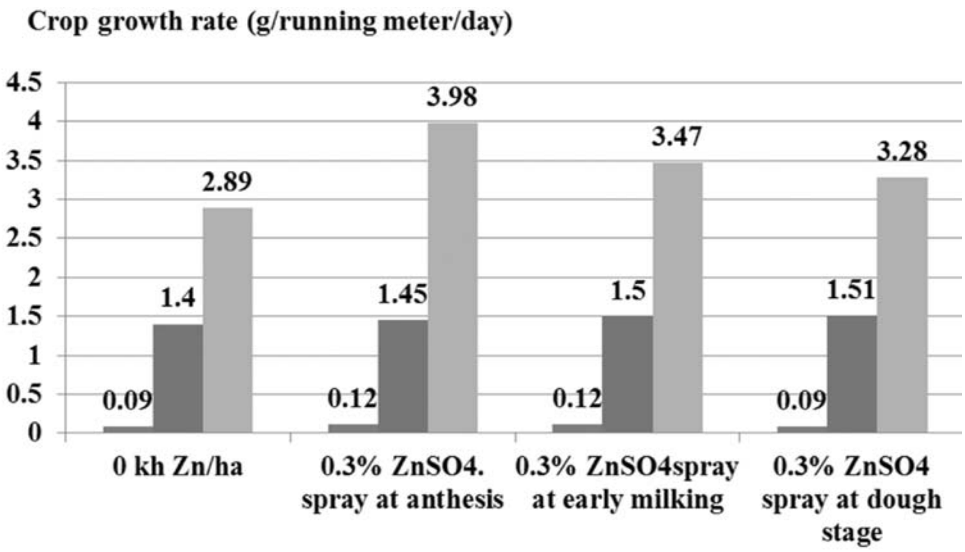

Fig. 2. Crop growth rate (CGR) under different Zn scheduling's

of 0.3% $ZnSO_4.H_2O$ spray at early milking.

Grain yield and quality

Grain yield, protein yield and protein content of DSR were significantly influenced by N levels and Zn scheduling's (Table 2). The maximum grain yield (4340 kg / ha) was recorded with application of 150 kg N / ha, which was significantly higher than all remaining treatments. Application of 120 and 90 kg N / ha also resulted significantly higher grain yield over to control (Fig. 1). Among zinc scheduling's (Fig. 2), highest grain yield (4368 kg / ha) was recorded with application of 0.3% $ZnSO_4.H_2O$ spray at anthesis. However, the Zn application at later growth stages *viz*. 0.3% $ZnSO_4.H_2O$ spray at early milking and at dough stage, also found superior to the control. Higher dose of N with Zn at early stage contributing more in growth and development resulted higher grain yield. This might be owing to the fulfilment of the requirement of N and Zn and a positive interaction between nitrogen and zinc. These findings also corroborate the finding of Meena *et al.* (2017). Protein content of DSR was

Table 2. Grain yield, quality and agronomic indices of DSR under different N and Zn scheduling

Treatments	Grain yield (kg/ha)	Protein content (%)	Protein yield (kg/ha)	Nutrient removal (kg/ha)		Agronomic indices of N and Zn									
						PFP (kg grain/kg of nutrient)		AE (kg grain/kg of nutrient)		RE (%)		NHI (%)		PE (kg grain/kg nutrient uptake)	
				N	Zn	N	Zn	N	Zn	N	Zn	N	Zn	N	Zn
N- levels															
N_0	3046	5	156	41	0.31	0.00	1653	0.00	517	0.00	9.47	59.76	23.58	0.00	5523
N_1	3626	6.2	229	55	0.39	40.29	1959	6.44	582	15.7	11.68	65.72	24.67	9.27	4954
N_2	3952	7.3	296	74	0.44	32.93	2157	7.55	724	22.8	14.74	63.71	26.15	26.87	4150
N_3	4340	9.3	415	99	0.53	28.94	2397	8.63	907	38.9	21.32	67.28	30.15	18.36	3561
Zinc scheduling															
Zn_0	2717	4.9	136	35	0.20	18.59	0.00	3.77	0.00	5.4	0.00	61.59	29.79	16.13	0.00
Zn_1	4368	6.9	315	78	0.40	29.52	2912	6.50	1100	25.1	13.33	64.12	25.53	15.30	9576
Zn_2	4026	7.5	313	76	0.48	27.45	2684	5.87	872	23.8	18.28	64.99	24.71	14.83	5374
Zn_3	3852	8.4	333	79	0.59	26.62	2568	6.48	756	23.0	25.61	65.78	24.52	22.89	3239
SEm ±	98	0.3	12	2.6	0.02	0.78	60	0.88	88	3.1	1.45	2.59	1.47	1.62	654
CD (P= 0.05)	285	0.9	36	7.6	0.06	2.25	174	2.55	255	9	4.18	7.49	4.25	4.73	1890
N×Zn	S	S	S	S	NS	S	S	NS	NS	S	NS	NS	NS	NS	NS

N_0 = 0 kg N/ha (control), N_1 = 90 kg N/ha, N_2 = 120 kg N/ha, N_3 = 150 kg N/ha; Zn_0 = 0 kg Zn/ha (control), Zn_1 -0.3% $ZnSO_4$ spray at anthesis, Zn_2- 0.3% $ZnSO_4$ spray at early milking, Zn_3-0.3% $ZnSO_4$ spray at dough stage; PFP- Partial factor productivity, AE- Agronomic efficiency, RE- Recovery efficiency, NHI- Nutrient harvest index, PE- Physiological efficiency.

Table 3. Interaction effect of N level and zinc application on N removal, protein content and protein yield

Treatments	Grain quality											
	Nitrogen removal (kg/ha)				Protein content (%)				Protein yield (kg/ha)			
	N_0	N_{90}	N_{120}	N_{150}	N_0	N_{90}	N_{120}	N_{150}	N_0	N_{90}	N_{120}	N_{150}
Zn scheduling's												
0% $ZnSO_4$ spray (control)	28.66	32.52	40.52	39.91	4.42	4.50	5.31	5.52	99	120	157	166
0.3% $ZnSO_4$ spray at anthesis	45.20	58.10	83.89	126.45	4.73	6.35	7.25	9.48	168	254	312	526
0.3% $ZnSO_4$ spray at early milking	46.76	66.24	84.36	110.27	5.58	6.98	8.19	9.56	187	270	353	441
0.3% $ZnSO_4$ spray at dough stage	44.77	65.05	86.34	122.65	5.50	7.06	8.50	12.69	171	272	361	528
SE m±		5.27				0.66				25.07		
C.D. (P=0.05) of NxZn		15.22				1.91				72.40		

significantly improved with increased dose of N and highest (9.3%) was recorded with application of 150 kg N / ha over to all. The application of 120 and 90 N / ha also recorded significantly higher protein content than control. However among Zn scheduling, highest protein content was recorded with application of 0.3% $ZnSO_4.H_2O$ spray at dough stage followed by and anthesis. Similarly highest protein yield (415 kg / ha) was recorded with 150 kg N / ha, 0.3% $ZnSO_4.H_2O$ spray at early milking which was significantly higher than application of 90 and 0 kg N / ha and at par with 120 kg N / ha. Among zinc scheduling's, highest protein yield was recorded with application of 0.3% $ZnSO_4.H_2O$ spray at dough stage, however it was found at par with all treatment except control. The above results indicated that higher N dose with Zn application at later growth stage contributing in more protein content and yield of DSR. Devi and Sumathi, (2011) also reported the highest protein content in grain with increasing levels of N.

Nutrient Removal

Significantly higher quantity of N and Zn removal was recorded with higher dose of N *viz*. 150 kg N / ha and Zn application at later growth stage viz. 0.3% ZnSO4.H2O spray at dough stage followed by 150 kg N / ha and 0.3% $ZnSO_4.H_2O$ spray at early milking stage. Interaction effect of N and Zn on N removal was found significant, consequently maximum N removal was found with combined application of 150 kg N / ha and 0.3% $ZnSO_4.H_2O$ spray at dough stage. It might be due to higher dose of N with Zn application at later growth stage contribute more in nutrient content and uptake resulted in higher nutrient removal. These findings also corroborate the finding of Meena *et al.* (2018).

Agronomic indices of N and Zn

The maximum PFP (kg grain / kg of nutrient applied) of N was reported with application of 90 kg N / ha which was found superior to all treatments, however among Zn scheduling, 0.3% $ZnSO_4.H_2O$ spray at anthesis recorded maximum but it was found at par with 0.3% $ZnSO_4.H_2O$ spray at early milking. Maximum AE of N (8.63) and Zn (907) was recorded with application of 150 kg N / ha, but it was found at par with application of 120 kg N / ha, however among Zn scheduling application of 0.3% $ZnSO_4.H_2O$ spray at anthesis was found superior to all. Similarly, highest RE (%) of N and Zn was recorded with application of 150 kg N / ha, which was found superior to all remaining treatments, however among Zn scheduling's, maximum RE of N and Zn was recorded with application of 0.3% $ZnSO_4.H_2O$ spray at anthesis and at dough stage respectively. Significantly higher NHI (%) of N was recorded with application of 150 kg N / ha over control, but it was found at par with 120 and 90 kg N / ha application, however, among Zn scheduling it was recorded highest with 0.3% $ZnSO_4.H_2O$ spray at dough stage but it was found at par with all treatments including control. While maximum NHI of zinc was recorded with independent application of 150 kg N / ha and 0% $ZnSO_4.H_2O$ spray. Significantly higher PE (kg grain / kg of nutrient uptake) of N was recorded with application of 120 kg N / ha followed by 150 and 90 kg N / ha, while among Zn scheduling it was recorded highest with application of 0.3% $ZnSO_4.H_2O$ spray at dough stage over to all. NHI of zinc recorded highest with independent application of 0 kg N / ha and 0.3% $ZnSO_4.H_2O$ spray at anthesis. Above results indicated that nitrogen levels and zinc scheduling's not interacting significantly in all N and Zn indices except PFP.

Conclusion

Based on the present findings it is concluded that application of 150 kg N / ha and 0.3% $ZnSO_4.H_2O$ spray at anthesis were found to be optimum for enhancement of growth attributes, grain yield and agronomic indices of N and Zn in DSR. For grain quality, 150 kg N / ha and 0.3% $ZnSO_4.H_2O$ spray at dough stage, recorded the maximum protein content and protein yield.

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