Eco. Env. & Cons. 29 (1) : 2023; pp. (170-174)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i01.027

Effect of Zinc Fertilization on Yield, Zinc Biofortification and Indices of Wheat Varieties

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(Received 12 August, 2022; Accepted 4 October, 2022)

ABSTRACT

A field experiment was conducted during winter (*rabi*) season of 2017–18 at Varanasi, Uttar Pradesh to study the effect of zinc fertilization on yield and zinc concentration of wheat varieties. The experiment was laid out in a randomized block design (factorial) with 7 wheat varieties (HUW 234,V_1; HUW 510,V_2; HUW 468,V_3; HD 2967,V_4; PBW 343,V_5; PBW 373,V_6; and PBW 154,V_7) and 2 zinc levels (0 kg Zn ha^{-1}, Z_0; and 5 kg Zn ha^{-1},Z_1). HUW 234 and application of zinc @ 5 kg/ha recorded significantly higher effective tillers, 1,000-grain weight, yield, zinc uptake, partial factor productivity (PFP), agronomic efficiency (AE) and recovery efficiency (RE) over the other treatments. Varieties and zinc levels also interacted positively and highest effective tillers, ear length, test weight and grain yield was obtained with $V_1 \times Z_1$; however, the longest ear length (17.37 cm) was obtained with PBW 154 + 5 kg Zn ha^{-1} while highest number of grains per spike was recorded with HUW 468 + 5 kg Zn ha^{-1}.

Key words: *Variety × zinc interaction, Zinc concentration, Zinc fertilization, Zinc uptake and agronomic efficiency*

Introduction

Wheat (*Triticum aestivum* L.) is staple cereal of the world and the second most important cereal crop after rice in India (Pradhan *et al.,* 2014). The wheat crop covers an area of 30.44 m ha with the production of 92.61 m tonnes and the average productivity of 3042 kg ha^{-1} during 2015-16 (www.agricoop.nic.in). Zinc (Zn) has diverse physiological functions in biological systems, interacts with a large number of enzymes and other proteins and performs critical structural, functional and regulatory roles. It is estimated that about 10% of all the proteins in the human body, corresponding to nearly 3000 proteins, are Zn-dependent (Andreini *et al*., 2006; Krezel and Maret, 2016). About a third of the world's population is estimated to be at risk of Zn deficiency, which is especially prevalent in children under 5 years of age because of their relatively large demand for Zn to support growth and development (Wessells and Brown, 2012). Zinc Use Efficiency in wheat cultivars has been related to their enhanced Zn uptake and translocation capacity into shoots (Cakmak *et al.*, 1998).

Materials and Methods

The field experiment was conducted during 2017-18 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi

1, 3, 4 and 5 – Research Scholar, 2 - Associate Professor

($25^0 20'$N, $83^0 03'$E, 75.5 m above MSL). The soil of the experimental field was Ustochrepts (Gangetic alluvium) of Inceptisols. It was low in organic carbon (0.48%), available nitrogen (188.10 kg ha^{-1}), medium in available phosphorus (14.78 kg ha^{-1}) and available potassium (114.35 kg ha^{-1}). The soil DTPA-extractable Zn in soil was 0.68 mg kg^{-1} with the pH 7.8. The total rainfall received during crop season (03 December, 2017- 08 April, 2018) was 9.4 mm which was received in first week of April. The weekly maximum and minimum temperature ranged from 16.1 to 35.4 °C and 5.9 to 20.0 °C, respectively. The experiment was laid out in a randomized block design (factorial) with 3 replications. The treatments comprised of 7 wheat varieties HUW 234 (V_1); HUW 510 (V_2); HUW 468 (V_3); HD 2967 (V_4); PBW 343 (V_5); PBW 373 (V_6); and PBW 154 (V_7) and 2 zinc levels 0 kg Zn ha^{-1} (Z_0); and 5 kg Zn ha^{-1} (Z_1). The uniform dose (5 kg ha^{-1}) of zinc (Zn) in the form of zinc sulphate monohydrate ($ZnSO_4.H_2O$) was applied in all plots except Zn control plots. A uniform dose of N_2 (120 kg ha^{-1}), P_2O_5 (60 kg ha^{-1}) and K_2O (60 kg ha^{-1}) were also applied in all plots in the form of urea, DAP and MOP, respectively. The nitrogenis applied in three split doses i.e., 50 % at sowing (60 kg ha^{-1}) stage, 25% (30 kg ha^{-1}) at maximum tillering stage and remaining 25 % (30 kg ha^{-1}) at flowering stage in all the plots whereas the full dose of phosphorous and potassium were applied as basal. The seven wheat varieties were sown on 7 December, 2017 under well pulverized soil and harvested on 05 April, 2018. At maturity, wheat crop was harvested manually. Grain and straw yields were recorded from a net area of 7.75 m^2 from the experimental plots. Grain and straw samples of wheat collectedfor chemical analysis from each plot, were air dried at 70 °C in a hot-air oven. The dried samples were crushed with mortar and pestle for analysis of Zn content in grain and straw. Agronomic indices of Zn *i.e.* agronomic efficiency (AE), partial factor productivity (PFP), apparent recovery efficiency (ARE) and nutrient harvest index (NHI), computed and data were statistically analysed as per standard statistical procedure (Gomez and Gomez, 1984).

Results and Discussion

The maximum number of effective tillers (439.33 m^{-2}) (Table 1) was obtained with HUW 234. This might be due to the fact that the number of tillers per square meter with HUW 234 was so high that even after mortality, it remained higher than other varieties and this consequently led to more number of panicle bearing tillers. The longest ear length of wheat was recorded with PBW 154 (17.2 cm) (Table 1) while the smallest ear length (13.92 cm) was obtained with HUW 510. The maximum number of grains per spike (52.05) (Table 1) was obtained with HUW 468 while the lowest number of grains per spike (39.8) was recorded with HUW 510. Mainly test weight of wheat is controlled by genetic makeup of the variety, and therefore, the test weight varied significantly within various varieties. The maximum test weight (51.13 g) (Table 1) was obtained with HUW 234 and the minimum test weight (40.67 g) was recorded with PBW 373. It is a well-known fact that grain yield is the function of more number of effective tillers per unit area and test weight. As the yield is directly related to all the yield attributing characters, the variety which had higher values of these characters had maximum yield, and these characters were maximum with HUW 234 and recorded grain yield of 3.48 t ha^{-1} (Table 1) although the highest straw yield (5.17 t ha^{-1}) was recorded with PBW 343. Harvest index was also affected with different varieties in a significant way and the maximum harvest index (44.03%) (Table 1) was found with PBW 154. Zinc content (ppm) of grain and straw and its uptake as influenced by different varieties significantly. The maximum zinc content (20.38 ppm) (Table 1) was recorded with PBW 373 in grain also zinc uptake (0.067 kg ha^{-1}) in grain was found maximum with the same variety while in straw it was recorded highest (21.53 ppm) (Table 1) with PBW 154 and maximum zinc uptake (0.090 kg ha^{-1}) (Table 1) in straw was found maximum with the same variety. Partial factor productivity, agronomic efficiency and apparent recovery efficiency were influenced non-significantly by the varieties although the maximum value for partial factor productivity (373.33 kg grain kg^{-1}) (Table 1) was obtained with HUW 234, for agronomic efficiency maximum value (68.89 kg grain increase per kg zinc) (Table 1) and for apparent recovery efficiency the highest value (1.02%) (Table 1) were obtained with HUW 468. However, nutrient harvest index was found significant amongst the varieties. The maximum value (22.95%) (Table 1) of nutrient harvest index was obtained with PBW 373.

The maximum value (412.86 m^{-2}) (Table 1) for effective tillers was recorded with 5 kg Zn ha^{-1} and was found significant over application of zinc @ 0 kg

Table 1. Effect of zinc fertilization on yield attributes, yield, zinc content and agronomic indices of zinc of wheat varieties

Treatment	Effective Tillers/ m^2	Ear Length (cm)	Grains per spike	Test weight (g)	Yield (t ha^{-1})		Harvest Index (%)	Zinc content (ppm)		Zinc uptake (kg ha^{-1})		Agronomic indices of zinc			
					Grain	Straw		Grain	Straw	Grain	Straw	PFP (kg grain/ kg of nutrient)	AE (kg grain/ kg of nutrient)	NHI (%)	ARE (%)
Variety															
HUW 234	439.33	14.78	45.57	51.13	3.49	4.82	42.00	15.50	16.65	0.054	0.080	373.33	48.90	20.17	0.427
HUW 510	347.33	13.92	39.8	45.88	2.38	4.23	35.47	14.15	14.52	0.033	0.062	297.78	66.67	17.50	0.619
HUW 468	400.00	14.05	52.05	40.88	2.56	4.39	36.42	16.45	17.47	0.042	0.077	322.22	68.89	17.61	1.020
HD 2967	371.33	14.82	49.48	42.83	3.12	4.28	42.19	15.75	16.48	0.049	0.071	335.56	46.67	20.65	0.436
PBW 343	314.00	14.77	40.4	43.97	3.07	5.17	37.49	17.45	19.70	0.054	0.103	321.11	27.78	17.71	0.561
PBW 373	414.00	14.97	44.84	40.67	3.28	4.27	43.50	20.38	18.27	0.067	0.078	350.00	43.33	22.95	0.733
PBW 154	423.33	17.2	43.37	49.55	3.31	4.22	44.03	16.13	21.53	0.053	0.090	351.11	41.11	18.83	0.568
SEm ±	20.53	0.49	2.08	1.28	0.13	0.24	1.36	0.91	0.89	0.003	0.006	21.13	14.08	1.00	0.267
CD (P=0.05)	59.71	1.42	6.04	3.71	0.37	0.69	3.95	2.63	2.59	0.010	0.019	NS	NS	2.91	NS
Zinc application															
0 kg Zn ha^{-1}	361.24	14.19	41.46	43.27	2.70	4.30	38.38	15.72	16.74	0.042	0.072	0	0	18.57	0
5 kg Zn ha^{-1}	412.86	15.67	48.69	46.70	3.36	4.67	41.94	17.37	18.86	0.058	0.088	671.75	98.10	20.13	1.246
SEm ±	10.98	0.26	1.11	0.68	0.06	0.13	0.73	0.48	0.48	0.002	0.004	11.29	7.53	0.54	0.143
CD (P=0.05)	31.92	0.76	3.23	1.98	0.19	0.37	2.11	1.41	1.38	0.005	0.010	32.83	21.88	1.56	0.415
Variety × Zinc	S	S	S	S	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Zn ha^{-1}(Z_0). Similar results were found by Chowdhury *et al.* (2018). The maximum value (15.67 cm) (Table 1) for ear length was recorded with 5 kg Zn ha^{-1}as compared with no application of Zinc. Similar results were found by Nautiyal *et al.* (2011). The maximum value (48.69) (Table 1) for number of grains per spike was recorded with 5 kg Zn ha^{-1}as compared to control. Similar results were found by Chowdhury *et al.* (2018) and Nautiyal *et al.* (2011). The maximum value (46.7 g) (Table 1) for test weight was recorded with 5 kg Zn ha^{-1}over no application of Zinc (43.27 g). Similar results were found by Singh *et al.* (2014). The maximum value (3.36 t ha^{-1}) (Table 1) for grain yield was recorded with 5 kg Zn ha^{-1}as compared with no application of Zinc (2.70 t ha^{-1}). Similar results were found by Zou *et al.* (2012). The maximum value (4.67 t ha^{-1})(Table 1) for straw yield was recorded with 5 kg Zn ha^{-1}as compared to 0 kg Zn ha^{-1}. Similar results were found by Shaheen *et al.* (2007). The maximum value (8.03 t ha^{-1}) (Table 1) for biological yield was recorded with 5 kg Zn ha^{-1}as compared with no application of Zinc (6.99 t ha^{-1}). Similar results were found by Jan *et al.* (2013). The maximum value (41.94 %) (Table 1) of harvest index was obtained with application of 5 kg Zn ha^{-1} as compared to 0 kg Zn ha^{-1} (Z_0). Similar results were found by Jan *et al.* (2013). The highest zinc content in grain (Table 1) (17.37 ppm) was recorded with 5 kg Zn ha^{-1}as compared to control treatment. Similar results were found by Maqsood *et al.* (2009). The highest zinc content in straw (18.86 ppm)(Table 1) was obtained with application of 5 kg Zn ha^{-1} and recorded significantly higher value than control. Similar results were found by Liu *et al.* (2019) and Srivastava *et al.* (2013). The maximum zinc uptake in grain (0.058 kg ha^{-1}) (Table 1) was recorded with 5 kg Zn $ha^{-1}$and the value was significantly higher than the control. Similar results were found by Srivastava *et al.* (2015). The maximum zinc uptake in straw (0.088 kg ha^{-1}) (Table 1) was recorded with application of zinc @ 5 kg ha^{-1} and showed significant variation with control. Similar results were found by Srivastava *et al.* (2015). Partial factor produc-

Table 2. Interaction effect of zinc fertilization and wheat varieties on yield attributes and yield

Treatments	Effective Tillers/m²		Ear Length (cm)		Grains per spike		Test weight (g)		Grain yield (t ha⁻¹)	
	Z_0	Z_1	Z_0	Z_1	Z_0	Z_1	Z_0	Z_1	Z_0	Z_1
HUW 234	378.00	500.67	14.46	15.09	42.57	48.57	50.1	52.17	3.24	3.73
HUW 510	274.67	420.00	12.00	15.85	39.60	40.00	39.87	51.90	1.78	2.98
HUW 468	388.00	412.00	12.03	16.07	39.33	64.77	39.67	42.10	1.90	3.22
HD 2967	394.67	348.00	14.32	15.32	46.33	52.63	43.23	42.43	2.89	3.36
PBW 343	288.00	340.00	14.64	14.89	39.87	40.93	43.30	44.63	2.93	3.21
PBW 373	394.67	433.33	14.87	15.07	43.45	46.23	39.60	41.73	3.07	3.50
PBW 154	410.67	436.00	17.04	17.37	39.07	47.67	47.13	51.97	3.10	3.51
SEm ±	29.05		0.69		2.94		1.81		0.18	
CD (P=0.05)	84.45		2.01		8.54		5.25		0.52	

tivity, agronomic efficiency, nutrient harvest index and apparent recovery efficiency were influenced significantly by the zinc application and the maximum value for partial factor productivity (671.45 kg grain kg^{-1}), agronomic efficiency (98.10 kg grain increase per kg zinc), nutrient harvest index (20.13%) and apparent recovery efficiency (1.14%) (Table 1) obtained with 5 kg Zn ha^{-1}.

The interaction effect of variety and zinc application were observed in effective tillers, ear length, test weight and grain yield and was recorded maximum with HUW 234 + 5 kg Zn ha^{-1}. However, the longest ear length (17.37 cm) (Table 2) was obtained with PBW 154 + 5 kg Zn ha^{-1} while highest number of grains per spike was recorded with HUW 468 + 5 kg Zn ha^{-1}.

Based on present findings we conclude that HUW 234 can be recommended as this variety fetched significantly higher grain yield, biological yield, zinc content and uptake in grain. 5 kg Zn ha^{-1} can be recommended as this level of zinc fetched significantly higher grain yield, biological yield, zinc content and uptake in grain. There was significant interaction between variety and zinc application for effective tillers, test weight, grains per spike, ear length and grain yield with HUW 234 + 5 kg Zn ha^{-1}.

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