ZINC BIO-FORTIFICATION IN WHEAT AND IMPACT ON YIELD AND GRAIN CONTENTS UNDER RAIN FED CONDITIONS OF PAKISTAN

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Hidden hunger is emerging as a major contest for agricultural researchers as world population is increasing at high pace and food production is augmenting. Metals deficiencies (micronutrient malnutrition), especially Zn and Fe, are affecting over half of global population because they are depending cereal crops mainly wheat rice and maize for their daily diet. (Zn) deficiency is a common disorder of humans and its deficiency caused by inadequate dietary intake is a global nutritional problem, particularly in developing countries. Therefore, zinc bio-fortification of wheat is being urgently addressed as the wheat is major staple food crop of Pakistan and its consumption is 110kg/capita/annum. Efforts are being made to supplement wheat whole grain with the addition of Zinc as a dietary complement. To address the issue an investigation was carried at NARC, Islamabad during 2018 having a RCBD (split plot) with three replications. Six Zinc management treatments (viz., T1=No Zinc application in soil and no foliar application, T2= No Zinc in soil + Foliar application of 0.44 Kg/ha at booting, T3=No Zinc in soil + Foliar application of 0.44 Kg/ha at booting & after anthesis, T4=11 Kg Zinc /ha in soil at planting, T5=11 kg Zinc/ha in soil + Foliar application of 0.44 Kg/ha at booting and T6=11 kg Zinc/ha in soil + Foliar application of 0.44 Kg/ha at booting & after anthesis and Three Wheat varieties including an advanced line (Zincol-2016, Pakistan-2013 and NR-443) were tested for this purpose.

From the analyzed data it was revealed the Application of Zinc in soil at planting and foliar application at booting had significant effect on plant height, spike length, no of spikelet/spike, NDVI value, Tillers/m^2, biological yield and effect grain yield (3330.0 kg/ha, 41.54% more as compared to control) of wheat at NARC, Islamabad. Significant trend was also found in varieties for all traits including leaf area. From the wheat grain analysis, it was observed that maximum zinc in grains (48.556 mg/kg) was obtained in T5 and in varietal nutrient analysis advanced line NR 443 absorbed maximum Zinc and Iron (45.889 mg/kg, 43.111 mg/kg respectively). From the analyzed work it can be stated that by agronomic foliar management, zinc can be enhanced in

grain contents and instead of using medicinal supplements, wheat flour enriched with zinc can be used and can be part of dietary intake in the areas having zinc deficiency.

Keywords: Zinc Bio-fortification, Wheat, Foliar application, Booting Stage, Yield, Grain Analysis

INTRODUCTION

Soils of Rice-Wheat Cropping system are deficient in few of the major micronutrients such as zinc, boron, manganese and iron etc. In the area of southern Punjab, 70% of wheat cultivated soils are deficient in zinc [Maqsood *et al.,* 2015]. Zinc plays a vital role in the health, the functioning of the immune system, the signaling of the intestine and growth (Wessels *et al.,* 2019). This is the reason that its deficiency can lead to many health issues, such as an increase in infection rate, impaired learning, and abnormal immune system function (Wessels *et al.,* 2019). Malnutrition is a world-wide issue as almost one-quarter of the world population is influenced by one or extra micronutrient malnutrition disorders (Kumssa *et al.,* 2015). In Islamic Republic of Pakistan, 12 million children are stunted, and 22.1% of women and 18.6% of children (under the age of five) have a deficiency of Zn. In the case of Zn deficiency in women, Punjab has the maximum share (24.1%), observed via way of means of Baluchistan (23.4%), and Sindh (21.4%), while Khyber Pakhtunkhwa has the lowest prevalence (15.9%) (MNHS 2018). However, the Zn nutritional illness can be controlled by bio-fortification, which is an operative and economical method (Farooq *et al.,* 2018 and Hussain *et al.,* 2020). The agronomic and genetic approaches comprise of suitable plant and soil fertilizer solicitation for zinc bio-fortification (Cakmak 2018). Agronomic bio-fortification is not only important for the development but also in the utilization potential and mobilization of micronutrients (Cakmak 2018, Rehman 2018, a,b,c). Bouis and Saltzman [2017] asserted that the crops produced by bio-fortification are consumed by 20 million people around the world.

Zinc deficiency is among the top five micronutrient deficiencies and have rigorous impacts on one-third of the world's population, especially rural communities (Hotz and Brown, 2004; Stein, 2010). Insufficient intake of food having low zinc amounts is a major contributor to the occurrence of zinc deficiency in humans. The daily Zn requirement of adult and pregnant/lactating women ranges from 8 to 11 mg and 11 to 13 mg, respectively (Bhowmik et al., 2010); while, 8–18 mg/day daily iron (Fe) intake is recommend depending on age, gender

and body weight, and 27 mg/day. Zn deficiency is associated with several health problems such as impaired learning, abnormal immune system, increased infection rate, and impaired physical growth (Gibson, 2006; Prasad, 2007; Wessels and Rink, 2020).

Wheat is one of the three major cereal crops worldwide and is a main dietary source of calories, proteins and micronutrients for the majority of world's population, especially in the developing world (Shewry 2009). Wheat contributes up to 70 % of daily calorie intake of the population living in rural regions and an important source for Zn for human beings residing in the developing world (Cakmak 2008).

MATERIALS AND METHODS

To address the issue of zinc deficiency, an investigation was carried at NARC, Islamabad, (33° 42' N, 73º 10' E) during 2018 having a RCBD (split plot) with three replications. Six Zinc management treatments were in main plots and three wheat cultivars in sub plots, i.e Zinc management treatments (viz., T1=No Zinc application in soil and no foliar application, T2= No Zinc in soil + Foliar application of 0.44 Kg/ha at booting, T3=No Zinc in soil + Foliar application of 0.44 Kg/ha at booting & after anthesis, T4=11 Kg Zinc /ha in soil at planting, T5=11 kg Zinc/ha in soil + Foliar application of 0.44 Kg/ha at booting and T6=11 kg Zinc/ha in soil + Foliar application of 0.44 Kg/ha at booting & after anthesis and Three Wheat varieties including a n advanced line (Zincol-2016, Pakistan-2013 and NR-443) were tested for this purpose.

At planting, Zinc sulphate (27% Zn) along with phosphatic and nitrogenous fertilizer was broadcasted and incorporated in respective plots with cultivator. Afterwards respective wheat cultivar was planted with seed rate of 125 Kg /ha. According to treatment plan, foliar applications of $ZnSO_4$ (27% Zn) were done at the booting stage and one week after anthesis. Trials were harvested at maturity and grain yield data was obtained through a threshing of 2 m^2 sample.

Data was collected during the cropped season on various traits like plant height, spike length, no of spikelet/spike, NDVI value, Tillers/m^2, biological yield and grain yield. At the harvesting stage i.e. physiological maturity, 30 spikes from each plot were harvested manually , threshed and were sent to Turkey Lab (Cakmak Lab, Turkey) for grain analysis, where they analyzed the

samples and report was sent back to Pakistan. Data was put for analysis of variance technique at 5% alpha level as described by Steel & Torrie, 1997.

RESULTS AND DISCUSSION

AGRO-CLIMATIC CONDITIONS DURING 2017-18

The area received total 256.15 mm of Rainfall and maximum temperature recorded was 30.60 at the physiological maturity month (April, 2018), whereas minimum mean temperature noted was 2.19 in the month of January, 2018. Similarly Average wind Speed was maximum in February, 2018 and max evaporation was in the month of April, 2018 (143).

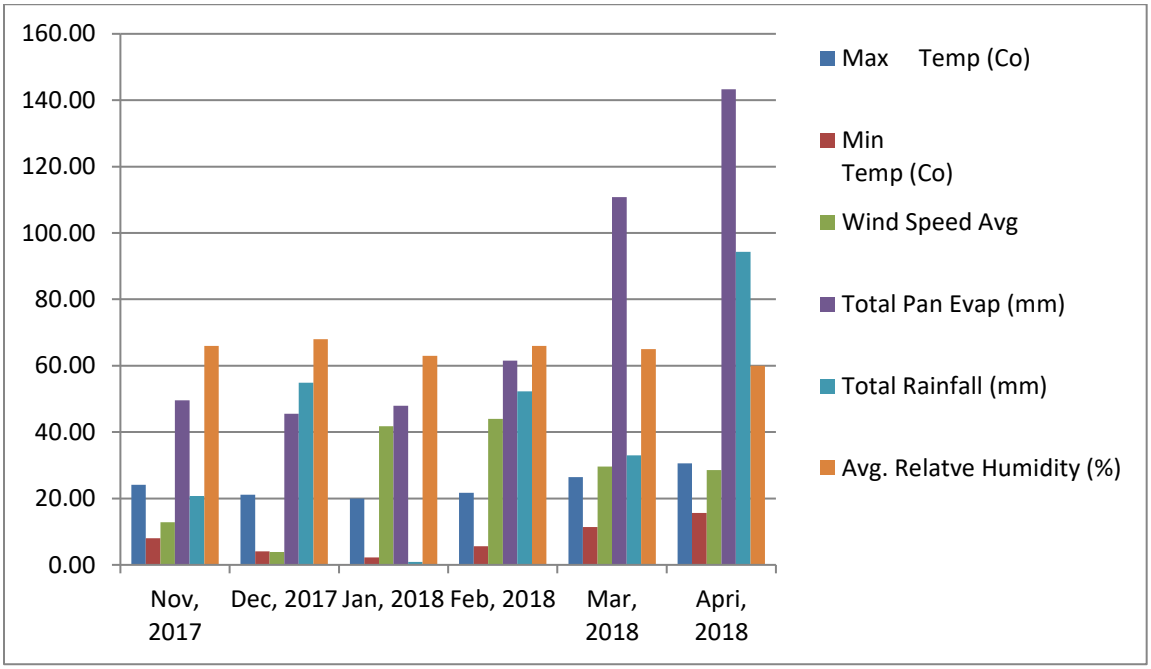

Figure I. Agro-Climatic Conditions during 2017-2018

Table (1) of means showing impact of zinc on various traits

Treatments	Plant Height (cm)	Spike Length (cm)	No of spikelet /spike	Leaf Area (cm^2)	Tillers/ m^2	NDVI	Biological yield kg/ha	Grain yield kg/ha
1	96.52 b	16.989 b	18.333 b	31.378	338.58 c	0.7922 b	5478.9 b	1946.7 c
2	98.00 ab	17.200 ab	19.000 ab	34.967	444.89 ab	0.8000 ab	7353.3 a	2732.2 abc
3	97.30 ab	17.178 ab	19.667 a	32.156 A	374.93 bc	0.7956 b	6068.9 ab	2273.3 bc
4	99.09 ab	17.500 ab	19.000 ab	34.100	413.58 abc	0.8000 ab	7292.2 ab	2811.1 abc
5	99.49 ab	17.689 ab	18.556 b	33.678	507.56 a	0.8122 a	7521.1 a	3330.0 a
6	100.71 a	17.811 a	19.667 a	34.822	438.76 ab	0.8033 ab	7446.7 a	3122.2 ab
LSD 5%	4.0893	0.7296	0.8765	N. S	96.728	0.0137	1832.1	983.06

Application At Time of Planting

Zinc applied to the soil at planting enhances early root development, leading to better establishment of the wheat seedlings. Improved root systems, increase nutrient and water uptake, which supports early growth and overall plant vigor. Adequate zinc levels at the beginning of the growth cycle ensure that the young plants have sufficient micronutrients to support key physiological processes, leading to more robust early growth. However, this initial boost often translates into taller and stronger plants.

Targeted Nutrient Delivery

Likewise, Foliar application at the booting stage provides a direct and rapid supply of zinc to the leaves and growing points, where it is quickly absorbed and utilized and can be regarded as targeted nutrient delivery. This timing (Booting Stage) is critical as the plant is entering the reproductive phase and has high nutrient demands. Zinc application at booting also enhances chlorophyll production and photosynthetic efficiency, leading to better energy production and growth. Improved photosynthesis during this stage supports the plant's transition to reproductive development, contributing to overall height and biomass.

Combined Effect of Soil and Foliar Application

The combination of soil application at planting and foliar application at booting provides a synergistic effect, ensuring that zinc is available throughout critical growth stages. This dual approach helps maintain consistent and adequate zinc levels, supporting uninterrupted growth

and maximizing growth of the plant

Table (2) of Means having Entries/ Varieties

Variety/ Lines	Plant Height (cm)	Spike Length (cm)	No of spikelet /spike	Leaf Area (cm^2)	Tillers/m^2	NDVI	Biological yield kg/ha	Grain yield kg/ha
Zincol-16	99.36 a	16.944 b	18.667 b	33.050 b	375.47 b	0.7894 b	7956.1 a	2962.2 a
Pak-13	96.08 b	18.178 a	20.000 a	36.128 a	410.79 b	0.8133 a	6240.6 b	2628.3 ab
NR-443	100.12 a	17.061 b	18.444 b	31.372 b	472.89 a	0.7989 b	6383.9 b	2517.2 b
LSD 5%	2.4145	0.4140	0.5921	1.8772	56.040	0.0118	991.90	420.08

From the above table it is evident that among varieties Zincol-2016 gave highest biological yield :7956.1 kg/ha while it was followed by NR-443. Biological yield is the indicator for good food and non-food products.

Zinc is an essential micronutrient for wheat and other crops, playing a crucial role in various physiological and biochemical processes and its concentration in wheat grain is significant because wheat is a staple food for many populations. From the analyzed data it was revealed the Application of Zinc in soil at planting and foliar application at booting had significant effect on plant height, spike length, no of spikelet/spike, NDVI value, Tillers/m^2, biological yield and effective grain yield (3330.0 kg/ha, 41.54% more as compared to control) of wheat at NARC, Islamabad. Significant trend was also found in varieties for all traits including leaf area. From the wheat grain analysis, it was observed that maximum zinc in grains (48.556 mg/kg) was obtained in T5 and in varietal nutrient analysis advanced line NR 443 absorbed maximum Zinc and Iron (45.889 mg/kg, 43.111 mg/kg respectively). From the analyzed work it can be stated that by agronomic foliar management, zinc can be enhanced in grain contents and instead of using medicinal supplements, wheat flour enriched with zinc can be used and can be part of dietary intake in the areas having zinc deficiency.

Table 3 Zinc Application and Nutrient Analysis of Grains

Treatments	**Zinc (mg/kg)**	**Phosphorus (%)**	**Magnesium (%)**	**Iron (mg/kg)**	**Copper (mg/kg)**	**Calcium (mg/kg)**	**Potassium (%)**
1	42.000	0.2760	0.1123	35.767 b	5.4000	543.70b	0.3630
2	44.133	0.2793	0.1177	35.867 b	5.6667	596.30 ab	0.3640
3	42.700	0.2853	0.1137	39.433 ab	5.7333	591.33 ab	0.3687
4	48.222	**0.3144**	0.1189	38.333 ab	6.0000	**615.89 a**	0.3733
5	**48.556**	0.3000	**0.1200**	**43.111 a**	**6.2222**	576.78 ab	0.3678
6	43.778	0.2889	0.1167	37.111 ab	5.4444	584.78 ab	**0.3733**

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