Biofortification: Effect of Zn and Fe application on wheat genotypes in Bangladesh

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Abstract— Biofortification of zinc (Zn) and iron (Fe) will be an important effort for the combat of malnutrition in Bangladesh. The experimental site was Bangladesh Agricultural University (BAU) farm to increase the Zn and Fe content in wheat grain. The design of the experiment was split-plot and replicated thrice. Ten varieties and seven advanced lines were tested under 3 treatments: control, Zn and Zn + Fe; for the study. For control plots, the grain Zn concentration varied from 20.3 – 30.5 µg g⁻¹, across the genotypes, with the highest performance by advanced line BAW 917 and the lowest performance by variety Sufi. The average grain Zn concentration over the 17 genotypes was noted as 26.3 µg g⁻¹. When Zn was applied to soil, the grain Zn concentration ranged from 29.1 - 40.9 µg g⁻¹ with a mean of 34.2 µg g⁻¹. The Fe content ranged from 20-35 µg g⁻¹ with a mean of 30.5 µg g⁻¹. The protein content also increases due to the Zn application. The Zn application increase the Zn content in grain as well as increase the yield with protein content. Among the genotype, there are some potential varieties for biofortification.

Keyword— Zinc, iron, grain yield and wheat.

I. INTRODUCTION

One of the very important micronutrient is zinc (Zn) for both human as well as plant and insufficient availability become a global health issue now by covering half of total population in earth (Hotz and Brown 2004; Stein 2010). The zinc deficiency in human and soil is very near that overlap geographically (Alloway 2008; Cakmak 2008) and show that there are a very close relationship between soil, food crops and human (Welch 2008). The people with cereal based food habitant are mainly suffering from Zn deficiency (Cakmak 2008; Gibson 2006) as bioavailability of Zn is low in cereal (Cakmak et al. 2010a).

As reported in Bangladesh by Islam et al. (2013), around 60% Zn and 55% Fe is provided from cereals in daily consumption. Anemia is widespread in Bangladesh especially to children and women due to inadequate Fe uptake. Increasing cropping intensity from 143% in 1971-72 to 194% in 2015-16 (BBS, 2018) declining soil fertility resulted micronutrient deficiency in Bangladesh. Among the micronutrient, Zn deficit is the top complication for crop growth. This element deficiency in the country was identified in late 1970s (Jahiruddin et al., 1981) and with advancement of time its extent has increased. In Bangladesh, about 70% of the arable land is found Zn deficit (Jahiruddin and Islam, 2014).

Biofortification means to prepend micronutrients to food crops by improving breeding lines as well as fertilization methods that will create a opportunity for the rural people to get food intake with Zn as they could not afford fortified foods (Bouis, 2013). In Bangladesh, “baby zinc” tablet developed by icddr’b (Brooks, 2005) reduced child mortality from diarrhea.

Iron (Fe) is an essential plant nutrient and its deficiency causes chlorosis, nutritional disorder and reduces crop yield. It will be very important if Fe could be increased in main food crops which can reduce common deficiency among the general people (Cakmak, 2002). Micronutrient deficiency is now a big challenges for the world population specially Zn and Fe (WHO, 2007). The grain yield and grain Zn concentration generally found have inverse
relationship between them (McDonald et al. 2008). This inverse relationship problem can be address by breeding, transgenic technology or agronomic approaches. To increase the micronutrients in food grain an combined approaches needs to undertaken by both breeding (Potential genotype) and fertilizer management approaches for mitigation of Zn insufficiency among the general people (Cakmak et al., 2004). This experiment was undertaken to increase the Zn and Fe content in wheat grain by fertilizer application and variety selection.

**II. MATERIALS AND METHODS**

**Experimental Site**

The experiment site was Bangladesh Agricultural University farm (BAU), Mymensingh, Bangladesh (location: 24°42’ 56.04’’ N and 90°25’ 31.01’’ E) and the agro-ecological zones (AEZs-9) is namely Old Brahmaputra Floodplain (FRG, 2018). The physical and chemical properties of soil at experiment sites are present at Table 1.

| Textural Class | OC (%) | pH | Total N (%) | Avail. P (mg kg⁻¹) | Exch. K (cmol kg⁻¹) | Avail. S (mg kg⁻¹) | Avail. Zn (mg kg⁻¹) | Avail. Fe (mg kg⁻¹) |
|---------------|--------|----|-------------|--------------------|---------------------|--------------------|---------------------|---------------------|
| Silt loam     | 1.14   | 6.5| 0.11        | 7.5                | 0.12                | 14.0               | 0.78                | 55.4                |

**Treatments and design**

In these experiments there were three treatments of zinc and iron viz. ZnFe₀, ZnFe₀ and ZnFe₄ subscripts represent the dose nutrients in kg ha⁻¹. All other fertilizers like N, P, K, S and B were applied at N₁₂₀P₃₀K₁₅₀Sr₂₂B₁₅ kg ha⁻¹ to the all plots. The split plot design was used and replicated thrice.

**Crop and Soil Management**

There were 10 varieties and 7 advanced lines of wheat were tested for grain Zn & Fe concentrations as well as grain yield. The wheat varieties and advanced line were: Shatabdi (V₁), Sufi (V₂), Bijoy (V₃), Prodip (V₄), BARI Gom 25 (V₅), BARI Gom 26 (V₆), BARI Gom 27 (V₇), BARI Gom 28 (V₈), BARI Gom 29 (V₉) and BARI Gom 30 (V₁₀), and Rawal 87 (L₁), Vijay (L₂), BAW 917 (L₃), Fery 60 (L₄), BL 1040 (L₅), KRLI-4 (L₆), BL 1883 (L₇). Wheat seeds were sown on 16 November 2016 and the crop was harvested on 12 March 2017. The mature harvested crops were threshed, cleaned and processed for chemical analysis.

**Chemical analysis**

The soil samples of the experimental site were collected following standard procedure and processed by air-drying, ground and sieving in a 2-mm sieve. The soil texture, soil pH, organic matter, total nitrogen, exchangeable potassium, available phosphorus, sulphur, zinc and iron were measured following standard methods.

**Analysis of plant sample**

The harvested grain sample was collected from each plot and were analysed for N, Zn and Fe concentrations. The collected samples were dried in an oven at 65°C for about 48 hours and then ground by grinding machine to pass through a 20-mesh sieve to obtain homogenous powder. The prepared plant samples were kept in paper bags into desiccators for further analysis for the determination of N, Zn and Fe content.

**Statistical analysis**

The statistical analysis of the different plant parameters as well as soil and plant analysis data was done through computer based program (Statistics 10) and was followed the basic principles, as outlined by Gomez and Gomez (1984). For the determination of analysis of variance (ANOVA) of the significant effects of treatments, genotypes and their interaction were compared at 5% level of significance by Duncan’s Multiple Range Test (DMRT).

**III. RESULTS**

**Biofortification of Zn in wheat grain**

Zinc fortification in wheat grain differed due to the treatments as well as to the different genetic makeup. The Zn concentration of wheat grain varied significantly with the genotypes (varieties and breeding lines) and with the Zn & Fe fertilization.

**Genotypic effects**

Different Zn content are found among the genotype used in the experiment. The treatment T₁ (control plots) presents a wide range of Zn concentration where the grain Zn concentration varied from 20.3 - 30.5 µg g⁻¹, across the genotypes. The highest Zn concentration was found in two advanced lines BAW 917 and Vijoy (30.5 µg g⁻¹) whereas in variety Sufi obtained lowest (20.3 µg g⁻¹) zinc concentration. The average grain Zn concentration over the 17 genotypes was noted as 26.3 µg g⁻¹ (Table 2)

**Fertilizer effect**

The Zn concentration of the different genotype varied significantly due to the zinc fertilizer application. In
treatment T2, the grain Zn concentration ranged from 29.1 - 40.9 µg g⁻¹ and the highest concentration was found in advanced lines BAW 917 (40.9 µg g⁻¹) and the lowest Zn concentration was found in variety Shatabdi (29.1 µg g⁻¹). The average Zn concentration was found 34.2 µg g⁻¹ (Table 3) and the highest increase in Zn concentration in advanced line BL1883 is 11.7 µg g⁻¹ whereas the lowest increase is 3.5 µg g⁻¹ is found in variety BARI Gom 30. The mean increase in Zn concentration in treatment T2 is 7.99 µg g⁻¹ which is very noticeable. Regarding treatment T3 where both Zn and Fe was applied, the maximum increased of Zn concentration was obtained from variety Sufi is 12.2 µg g⁻¹ and the lowest increase in Zn concentration was found in variety BARI Gom 29 that is 2.8 µg g⁻¹. The mean increase in Zn concentration in treatment T2 is 7.54 µg g⁻¹ which is also very noticeable.

![Fig. 1 Amount of zinc content of different wheat genotype](image)

**Table 2 Effects of Zn and Fe application on grain Zn concentrations (µg g⁻¹) of different genotypes of wheat**

| Genotypes     | T₁ (Control) | T₂ (Zn) | T₃ (Zn + Fe) | T₂-T₁ | T₃-T₁ |
|---------------|--------------|---------|--------------|-------|-------|
| V₁: Shatabdi  | 23.6 f-i     | 29.1 g  | 30.8 d       | 5.50  | 7.20  |
| V₂: Sufi      | 20.3 i       | 31.3 d-g | 32.5 cd      | 11.00 | 12.20 |
| V₃: Bijoy     | 22.6 g-i     | 32.6 d-g | 29.7 d       | 10.00 | 7.10  |
| V₄: Prodig    | 25.2 d-h     | 34.1 cd  | 31.3cd       | 8.90  | 6.10  |
| V₅: BARI Gom 25 | 25.8 c-g     | 31.2 d-g | 31.1 cd      | 5.40  | 5.30  |
| V₆: BARI Gom 26 | 27.1a-f     | 33.6 c-e | 34.6 bc      | 6.50  | 7.50  |
| V₇: Gom 27    | 25.1 d-h     | 30.3 e-g  | 29.2 d       | 5.20  | 4.10  |
| V₈: BARI Gom 28 | 21.9 hi      | 30.0 fg  | 31.7 cd      | 8.10  | 9.80  |
| V₉: BARI Gom 29 | 26.8 b-f     | 33.2 c-f  | 29.6 d       | 6.40  | 2.80  |
| V₁₀: BARI Gom 30 | 27.4 a-e     | 30.9 d-g  | 31.6 cd      | 3.50  | 4.20  |
| L₁: Rawal 87  | 28.6 a-d     | 39.1 ab  | 37.8 ab      | 10.50 | 9.20  |
| L₂: Vijay     | 30.5 a       | 37.6 ab  | 37.1 ab      | 7.10  | 6.60  |
| L₃: BAW 917   | 30.5 a       | 40.9 a   | 39.3 a       | 10.40 | 8.80  |
| L₄: Fery 60   | 29.7 ab      | 38.9 ab  | 36.9 ab      | 9.20  | 7.20  |
| L₅: BL 1040   | 29.0 a-c     | 36.6 bc  | 38.2 a       | 7.60  | 9.20  |
| L₆: KRLI-4    | 24.7 e-h     | 33.5 c-e | 34.5 bc      | 8.80  | 9.80  |
| L₇: BL 1883   | 27.5 a-e     | 39.2 ab  | 38.6 a       | 11.70 | 11.10 |
| Max           | 30.5         | 40.9     | 39.3         | 11.70 | 12.20 |

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Table 3 Effects of Zn and Fe application on grain Fe concentrations (µg g⁻¹) of different genotypes of wheat

| Genotypes        | T1 (Control) | T2 (Zn) | T3 (Zn + Fe) | T3-T1 |
|------------------|--------------|---------|--------------|-------|
| V1: Shatabdi     | 26.5         | 27.9    | 33.2         | 6.70  |
| V2: Sufi         | 23.8         | 25.8    | 33.0         | 9.20  |
| V3: Bijoy        | 26.5         | 28.4    | 33.9         | 7.40  |
| V4: Prodip       | 24.0         | 23.4    | 30.5         | 6.50  |
| V5: BARI Gom 25  | 29.7         | 28.7    | 36.6         | 6.90  |
| V6: BARI Gom 26  | 24.7         | 26.3    | 31.9         | 7.20  |
| V7: BARI Gom 27  | 28.8         | 27.3    | 34.8         | 6.00  |
| V8: BARI Gom 28  | 23.9         | 26.5    | 33.4         | 9.50  |
| V9: BARI Gom 29  | 26.6         | 23.9    | 32.1         | 5.50  |
| V10: BARI Gom 30 | 23.7         | 26.5    | 32.7         | 9.00  |
| L1: Rawal 87     | 27.4         | 28.1    | 36.3         | 8.90  |
| L2: Vijay        | 29.4         | 28.9    | 37.5         | 8.10  |
| L3: BAW 917      | 25.7         | 28.0    | 36.1         | 10.40 |
| L4: Ferry 60     | 27.5         | 29.8    | 36.6         | 9.10  |
| L5: BL 1040      | 28.3         | 31.8    | 39.7         | 11.40 |
| L6: KRLI-4       | 28.6         | 27.1    | 36.0         | 7.40  |
| L7: BL 1883      | 29.4         | 32.4    | 36.7         | 7.30  |
| Max              | 29.7         | 32.4    | 39.7         | 11.40 |
| Min              | 23.7         | 23.4    | 30.5         | 5.50  |
| Mean             | 26.7         | 27.7    | 34.8         | 8.03  |

Zinc efficiency of wheat genotypes

The increase in grain Zn concentrations of different wheat varieties and genotype differed in their response to Zn and Zn + Fe fertilization. Based on the % Zn efficiency [(Control Zn concentration / Treatment Zn concentration) x 100], the wheat genotypes could be classified into four groups (Fig. 2): inefficient (responsive to Zn application), moderately inefficient (moderately responsive), moderately efficient (moderately unresponsive) and efficient (unresponsive).

It is appearing that 2 genotype (variety Sufi and Bijoy) were found to be Zn inefficient (<70% Zn efficient), 8 genotype (2 varieties and 6 lines) moderately Zn inefficient (71-80% Zn efficient), 7 genotype (6 varieties and 1 line) moderately Zn efficient (81-90% Zn efficient) and no genotype are found Zn efficient (>90% Zn efficient). Varieties Shatabdi, BARI Gom 25, 26, 27, 29, and 30 are found moderately Zn efficiency with advanced line Vijoy.

Thus, the results of two locations reveal that variety BARI Gom 26, breeding lines BAW, BL 1883 & BL 1040 were observed as commonly Zn efficient or moderately Zn efficient in which plots, Zn supplement was not done.
Biofortification of Iron

The iron (Fe) was applied in treatment T3 with the Zn fertilizer and result showed that the grain Fe concentration of 17 genotypes ranged from 23.7 - 29.7 µg g⁻¹, with the mean value of 26.7 µg g⁻¹. This result was obtained when Zn fertilizer was not used. The highest Fe concentration was found from variety BARI Gom 25 and variety BARI Gom 30 did the lowest. The grain Fe concentration increased by about 2 µg g⁻¹ over Zn or Fe fertilized plots.

In the Zn fertilized plots, the grain Fe concentration was found as 23.4 - 32.4 µg g⁻¹, mean 27.7 µg g⁻¹ (Table 3). Among the Fe treated plots, the Fe concentration increased in all the genotypes and it ranged from 30.5 to 39.7 µg g⁻¹ and the mean is 34.8 µg g⁻¹. The Fe concentration increased from 5.50 to 11.40 µg g⁻¹ with a mean of 8.03 µg g⁻¹ which is noticeable increment of Fe in wheat grain. The highest increase of Fe concentration was found from BL 1040 and BARI Gom 29 accumulated the lowest.

Protein content

The protein content of different varieties and advanced line are presented in Table 4.3. Obviously, the N concentration is considerably differed due to the genotype and has positively responded to the Zn fertilization. The effect of genotypes and Zn or Fe fertilization was the same for grain

protein % since protein% was calculated as a multiple of 5.85 over grain N %.

The grain protein content of wheat, varied from 7.68 - 8.23%, the mean value being 7.91% (Table 4) when Zn or Fe fertilizer was not applied (control). Advanced line BL
1883 demonstrated the highest grain protein% and BAW 917 did the lowest.

The grain protein concentration of wheat, whether varieties or lines, markedly increased due to Zn fertilization; however, no effect was observed for Fe application. In Zn fertilized plots, the protein% varied from 8.67 - 9.87% with a mean of 9.14% and the Zn and Fe treatment plot lied between 8.78 - 9.69% with a mean of 9.02% (Table 4). This result indicates that Zn has influence on protein synthesis and plants take up these two elements (N and Zn) at a proportionate amount. The average increase in protein percentage is 1.23% when Zn fertilization was done.

Table 4 Effects of Zn and Fe application on protein content on grains of wheat genotypes

| Genotypes   | T₁ (Control) | T₂ (Zn)  | T₃ (Zn+Fe) | T₂-T₁ | T₃-T₁ |
|-------------|--------------|----------|------------|-------|-------|
| V₁: Shatabdi | 7.80         | 9.59     | 9.52       | 1.79  | 1.72  |
| V₂: Sufi    | 7.74         | 9.01     | 9.20       | 1.27  | 1.46  |
| V₃: Bijoy   | 7.98         | 9.32     | 9.03       | 1.35  | 1.05  |
| V₄: Prodip  | 7.82         | 9.13     | 8.99       | 1.31  | 1.17  |
| V₅: BARI Gom 25 | 8.17    | 9.87     | 9.69       | 1.70  | 1.52  |
| V₆: BARI Gom 26 | 8.00    | 9.48     | 9.24       | 1.48  | 1.25  |
| V₇: BARI Gom 27 | 8.11    | 9.56     | 9.52       | 1.44  | 1.40  |
| V₈: BARI Gom 28 | 7.92    | 9.79     | 9.46       | 1.87  | 1.54  |
| V₉: BARI Gom 29 | 8.00    | 9.48     | 9.17       | 1.48  | 1.17  |
| V₁₀: BARI Gom 30 | 8.21   | 9.77     | 8.97       | 1.56  | 0.76  |
| L₁: Rawal 87 | 7.76         | 8.93     | 8.85       | 1.17  | 1.09  |
| L₂: Vijay   | 8.23         | 9.42     | 9.46       | 1.19  | 1.23  |
| L₃: BAW 917 | 7.68         | 8.76     | 8.89       | 1.07  | 1.21  |
| L₄: Fery 60 | 8.15         | 8.89     | 8.78       | 0.74  | 0.62  |
| L₅: BL 1040 | 8.11         | 9.32     | 8.93       | 1.21  | 0.82  |
| L₆: KRLI-4  | 8.60         | 9.48     | 9.63       | 0.88  | 1.03  |
| L₇: BL 1883 | 8.23         | 9.77     | 9.38       | 1.54  | 1.15  |
| Max         | 8.23         | 9.87     | 9.69       | 1.87  | 1.72  |
| Min         | 7.68         | 8.67     | 8.78       | 0.74  | 0.62  |
| Mean        | 7.91         | 9.14     | 9.02       | 1.23  | 1.10  |

Grain yield

Different varieties has different grain yield normally due to its difference of genetic potential. The varieties and advanced lines of wheat used in this study have produced different yield and there are variation of grain yield of wheat genotypes varied with varieties and breeding lines as well as fertilization.

Genotype effect

The grain yield of wheat generally varied with varieties and breeding lines which can be attributed to differences in genetic make-up. The grain yield does not have wide variation and ranged from 3.37 - 3.90 t ha⁻¹, the mean yield being 3.59 t ha⁻¹ (Table 5). The highest grain yield (3.90 t ha⁻¹) was obtained from variety BARI Gom 30 and very close yield was given by BARI Gom 26, Fery 60 and BL1883. Among the tested genotypes, BARI Gom 28 performed the lowest yield (3.37 t ha⁻¹) and similar yield was demonstrated by Prodip and Sufi. The average yield over the 17 genotypes was found 3.59 t ha⁻¹.

Fertilizer effect

The grain yield positively responded to Zn fertilization over the varieties (Table 5). The BARI Gom 30 obtained the maximum yield (4.65 t ha⁻¹) followed by BARI Gom 26 (4.57 t ha⁻¹). Regarding at the % yield increase, it ranged from 9.22 - 27.40% having the best response by advanced line Bijoy and least response by KRLI-4. The BARI Gom 30 exhibited the highest yield (4.65 t ha⁻¹) due to Zn fertilization. The mean yield across the genotypes
was 4.19 t ha\(^{-1}\) showing 0.6 t ha\(^{-1}\) higher over control yield. Virtually the yield remained unaffected by Fe fertilization.

**Table 5** Effects of Zn and Fe application on grain yield (t ha\(^{-1}\)) of wheat genotypes

| Genotypes    | T1 (Control) | T2 (Zn) | T3 (Zn+Fe) | % Increase of T2 | % Increase of T3 |
|--------------|--------------|---------|------------|------------------|------------------|
| V1: Shatabdi | 3.45         | 3.85    | 3.90       | 11.59            | 13.04            |
| V2: Sufi     | 3.39         | 4.06    | 3.85       | 19.76            | 13.57            |
| V3: Bijoy    | 3.54         | 4.51    | 4.17       | 27.40            | 17.80            |
| V4: Prodig   | 3.38         | 4.08    | 3.99       | 20.71            | 18.05            |
| V5: BARI Gom 25 | 3.51      | 3.94    | 3.66       | 12.25            | 4.27             |
| V6: BARI Gom 26 | 3.82      | 4.57    | 4.40       | 19.63            | 15.18            |
| V7: BARI Gom 27 | 3.62      | 4.11    | 3.98       | 13.54            | 9.94             |
| V8: BARI Gom 28 | 3.37      | 4.17    | 3.71       | 23.74            | 10.09            |
| V9: BARI Gom 29 | 3.51      | 3.91    | 4.03       | 11.40            | 14.81            |
| V10: BARI Gom 30 | 3.90      | 4.65    | 4.68       | 19.23            | 20.00            |
| L1: Rawal 87 | 3.63         | 4.12    | 4.22       | 13.50            | 16.25            |
| L2: Vijay   | 3.59         | 4.22    | 4.35       | 17.55            | 21.17            |
| L3: BAW 917 | 3.59         | 4.06    | 4.12       | 13.09            | 14.76            |
| L4: Fery 60 | 3.83         | 4.44    | 3.92       | 15.93            | 2.35             |
| L5: BL 1040 | 3.59         | 4.27    | 4.22       | 18.94            | 17.55            |
| L6: KRLI-4  | 3.58         | 3.91    | 4.11       | 9.22             | 14.80            |
| L7: BL 1883 | 3.80         | 4.31    | 4.40       | 13.42            | 15.79            |
| Max         | 3.90         | 4.65    | 4.68       | 27.40            | 21.17            |
| Min         | 3.37         | 3.85    | 3.66       | 9.22             | 2.35             |
| Mean        | 3.59         | 4.19    | 4.10       | 16.52            | 14.08            |

Genotypes V1 - V10 represent varieties and L1 - L7 represent advanced breeding lines. Lettering was not done since the treatment effects were not significant.
IV. DISCUSSIONS

The existing wheat cultivars are not able to fulfill the Zn requirement for people in Bangladesh. Agronomic biofortification can solve this problem immediately which will be sustainable and easy adoptable to decipher Zn insufficiency in cereals (Qamar et al. 2017). The Zn concentration of wheat grain markedly increased due to Zn fertilization showing an increment of 3.5 - 11.7 µg g⁻¹ Zn across the 17 genotypes used. Similarly, the grain Fe concentration had increased (5.5 - 11.4 µg g⁻¹) for the use of Fe fertilizer despite the fact that crop yield did not increase and further the experimental fields were not Fe deficient.

Some of the wheat varieties and breeding lines had potential of higher Zn accumulation and the Zn fertilization had an additive effect. The EDTA extractable Zn (0.78 mg kg⁻¹) was found low in the study location. The critical limit of Zn in Bangladesh soil is 0.60 mg kg⁻¹ (FRG-2018). Yilmaz (1997) observed that Zn fertilization produced higher grain yield and increase the Zn concentration in grain as well in wheat and very crucial in soil where Zn is deficient (Cakmak, 2010). Duxbury et al. (2005) reported an elevated level of Zn, Cu and Mo in rice and wheat grains from their supplementary application.

The present study has screened out several varieties of wheat which have greater ability to uptake and accumulate Zn and Fe in grain, with a further possibility to enhance grain Zn concentration of wheat through Zn and Fe fertilization. Rawal 87, BL 1040, Vijoy & BAW 917 have been identified as Zn enriched breeding lines (>28.1 µg g⁻¹) grain Zn. Virtually Fe fertilization did not influenced on Zn concentration in grain. Increment of grain Zn concentration due to Zn application is similar between varieties and lines tested. Findings from Cakmak (2010) showed that Zn concentration increased 11.7 (control) to 26.9 µg g⁻¹ by Zn application.

Zinc fertilization depending on the varieties increased wheat yield by 9.2 - 27.4%. The grain yield differed with genotypes which can be attributed to differences in genetic make-up. Response of wheat yield to Zn application is much evidenced in Bangladesh and India (Khan et al., 2009, Prasad et al., 2010; Singh et al., 2012). Numerous studies have shown pronounced increase in grain yield (9-256%) and grain Zn concentration (9-912%) of wheat with Zn application to Zn deficient soils (Rafique et al., 2006; IZA, 2009).

The results showed that Fe concentration of wheat grain generally increased for Fe fertilization, the increment being on an average 6-12 µg g⁻¹. The grain Fe concentrations of different varieties have been divided into four groups with an interval of 4 µg g⁻¹ Fe: <20 µg g⁻¹ Fe, 20.1 - 24 µg g⁻¹ Fe, 24.1 - 28 µg g⁻¹ Fe and >28 µg g⁻¹ Fe. Similar to classification of grain Zn concentration, not all the grain Fe concentration of the same genotypes fell into the same class between two locations. This variation could be due to varied soil and climatic conditions.

Genetic biofortification together with agronomic approach extends a good possibility of development of new cultivars more efficient in accumulating minerals in the edible part (Mingotte et al., 2018). Agronomic biofortification with Zn can provide a practical and cost-effective option to tackle the global Zn malnutrition problem (Cakmak and Kutman, 2018).

V. CONCLUSION

Some varieties and breeding lines of wheat have genetically greater ability to uptake and accumulate Zn and Fe in grain. It is possible to enhance further Zn and Fe level by their fertilization. Varieties BARI GOM 25, 27, 28 & 29 are identified as Zn enriched varieties, having 24 - 30 µg g⁻¹ Zn in grain. Concerning Fe biofortification, Shatabdi, Prodip, BARI GOM 25 & 28 and Sufi are identified as Fe enriched varieties (24 - 30 µg g⁻¹). These genotypes would serve as breeding materials for biofortification of Zn & Fe in wheat, without compromising crop yield. Genetic biofortification coupled with agronomic approach (fertilization) would help develop of new cultivars of wheat that would have ability to accumulate Zn and Fe in grain.

REFERENCES

[1] Alloway BJ 2008: Micronutrient Deficiencies and Global Crop Production. Springer, Netherlands, 353 pp.
[2] BBS 2018: Year Book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics. Ministry of Planning, Government of the Peoples Republic of Bangladesh, Dhaka.
[3] Bouis HE 2013: Biofortification: A new tool to reduce micronutrient malnutrition. In Proc.: XVII. International Plant Nutrition Colloquium, pp. 67-68.
[4] Brooks WA, Santosham M, Naheed A, Goswami D, Wahed MA, Diener-West M, Faruque ASG, Black RE 2005: Effect of weekly zinc supplements on incidence of pneumonia and diarrhoea in children younger than 2 years in an urban, low-income population in Bangladesh: randomised controlled trial. The Lancet366 999-1004
[5] Cakmak I, Kutman UB, 2018: Agronomic Biofortification of Cereals with Zinc: A Review. European Journal of Soil Science 69 172-180.
[6] Cakmak I 2010: Biofortification of cereals with zinc and iron through fertilization strategy. 19th World Congress of Soil Science, 1-6 August, Brisbane, Australia, Proceeding: pp. 4-6.
Cakmak I 2008: Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? Plant and Soil 302: 1–17.

Cakmak I 2004: Identification and correction of widespread zinc deficiency in Turkey, A success story. IFS Proceedings No. 552, International Fertiliser Society, York, UK, pp 1–28.

Cakmak I 2002: Plant nutrition research: Priorities to meet human needs for food in sustainable ways. Plant and Soil 247: 3–24.

Duxbury JM, Bodruzaman MD, Johnson S, Mayer ABM, Lauren J G, Meisner CA, Welch RM 2005: Impacts of increased mineral micronutrient content of rice and wheat seed/grain on crop productivity and human nutrition in Bangladesh. Li CJ, Zhang FS, Dobermann A, Hinsinger P, Lambers Marschner L, Maene L, Mcgrath S, Oenema O, Peng SB, Rengel Z, Shen QR, Welch R, Von Wiren N, Yan XL, Zhu YZ (Editor), Plant Nutrition for Food Security, Human Health and Environment Protection pp. 30-31.

FRG (2018). Fertilizer Recommendation Guide-2018. Bangladesh Agricultural Research council (BARC), Farmgate, Dhaka, Bangladesh

Gibson RS, Bailey KB, Gibbs M 2010: A review of phytate, iron, zinc, and calcium concentrations in plant-based complementary foods used in low-income countries and implications for bioavailability. Food and Nutrition Bulletin 31: 34–46.

Gomez KA, Gomez AA 1984: Statistical procedures for agricultural research (second edition). An International Rice Research Institute Book. John Wiley & Sons, Inc., USA, pp. 139-240.

Hotz C, Brown KH (2004) Assessment of the risk of zinc deficiency in populations and options for its control. Food Nutr Bull 25:S91–S204

Islam MR, Jahiruddin M, Islam MR, Alim MA, Akhtaratuzzaman M 2013: Consumption of unsafe foods: evidence from heavy metal, mineral and trace element contamination. FAO Project Completion Report.

IZA 2009: Zinc in Fertilizers: Essential for Crops, Essential for Life/ International Zinc Association, Brussels, Belgium.

Jahiruddin M, Bhuity ZH, Hoque MS, Rahman L 1981: Effect of rates and methods of zinc application on rice. Madras Agricultural Journal 68: 211–216.

Jahiruddin M, Islam MR 2014: Project Report (2011-2014). Requirement of Micronutrients for Crops and Croping patterns. PIU-BARC (NATP Phase-I) project. Project ID No. 339. Bangladesh Agricultural Research Council, Dhaka.

Khan A, Gurmani AR, Khan MS, Gurmani MH 2009: Residual, direct and cumulative effect of zinc application on wheat and rice yield under rice-wheat system. Soil and Environment 28(1) 24-28.

McDonald GK, Genc Y, Graham RD 2008: A simple method to evaluate genetic variation in zinc grain concentration by correcting for differences in grain yield. Plant and Soil 306: 49–55.

Mingotte FLC, Revolli LTM, Unêda-Trevisoli SH, Lemos LB, Filho DF 2018: Rice (Oryza sativa) breeding strategies for grain biofortification. African Journal of Biotechnology 17(14) 466-477.

Prasad RK, Kumar V, Prasad B, Singh AP 2010: Long term effect of crop residue and zinc fertilizer on crop yield, nutrient uptake and fertility built-up under rice wheat cropping system in calcareous soil. Journal of Indian Society of Soil Science 58(2) 205-211.

Qamar uz Zaman, Aslam Z, Yaseen M, Zahid Ihsan M, Khaliq A, Fahad S, Bashir S, P. M. A. Ramzani, Naeem M 2017: Zinc biofortification in rice: leveraging agriculture to moderate hidden hunger in developing countries. Archives of Agronomy and Soil Science 64: 147-161.

Rafique E, Rashid A, Ryan J, Bhatti AU 2006: Zinc deficiency in rainfed wheat in Pakistan: magnitude, spatial variability, management, and plant analysis diagnostic norms. Communications in Soil Science and Plant Analysis 37: 181-197.

Singh O, Kumar S, Awanish 2012: Productivity and profitability of rice as influence by high fertility levels and their residual effect on wheat. Indian Journal of Agronomy 57(2) 143-147.

Stein AJ 2010: Global impacts of human mineral malnutrition. Plant and Soil 335: 133–154.

Welch RM (2008) Linkages between trace elements in food crops and human health. In: Alloway BJ (ed) Micronutrient deficiencies in global crop production. Springer, Netherlands, pp 287–309

WHO (World Health Organization) 2007: World Health Report 2007: Reducing Risks, Promoting Healthy Life, Geneva.

Yilmaz A, Ekiz H, Torun B, Gultekin I, Karanlik S, Bagci SA, Cakmak I 1997: Effect of different zinc application methods on grain yield and zinc concentration in wheat grown on zinc-deficient calcareous soils in Central Anatolia. Journal of Plant Nutrition 20: 461–471.