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Effect of zinc and iron fertilization on yield of wheat

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ABSTRACT

To determine the impact of zinc (Zn) and iron (Fe) fertilization on wheat yield performance, a field experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, from November 2019 to March 2020. There were four zinc levels used in the experiment: 0 kg Zn ha^{-1} (Zn_0): No Zn fertilizer, 10 kg Zn ha^{-1} (Zn_1): Basal application of Zn, 10 kg Zn ha^{-1} (Zn_2): One foliar application (at tillering stage), 10 kg Zn ha^{-1} (Zn_3): Two foliar application (at tillering stage and flag leaf stage); and four levels of Fe viz., 0 kg Fe ha^{-1} (Fe_0): No Fe fertilizer, 12 kg Fe ha^{-1} (Fe_1): Basal application of Fe, 12 kg Fe ha^{-1} (Fe_2): One foliar application (at tillering stage), 12 kg Fe ha^{-1} (Fe_3): Two foliar application (at tillering stage and flag leaf stage). Three replications of the experiment were set up using a Randomized Complete Block Design (RCBD). The results showed that 10 kg Zn ha^{-1} at basal application (Zn_1) produced the highest grain yield (4.08 t ha^{-1}), straw yield (4.93 t ha^{-1}), biological yield (9.01 t ha^{-1}), and harvest index (45.13). Application of 0 kg Zn ha-1 (Zn_0) resulted in the lowest plant height (86.85 cm), number of fertile spikelets spike^{-1} (12.78), number of filled grains spike^{-1} (33.63), grain (3.08 t ha^{-1}), straw (4.53 t ha^{-1}), biological (7.61) yields, and harvest index. The highest total tillers plant^{-1} (2.96), grain yield (4.11 t ha^{-1}), straw (5.32 t ha^{-1}), and biological (9.43 t ha^{-1}) yields were obtained with the application of 12 kg Fe ha^{-1} (Fe_1) at basal application; in contrast, the control treatment (Fe_0) yielded the lowest grain (2.62 t ha^{-1}), straw (4.21 t ha^{-1}), biological (6.83 t ha^{-1}) yields, and harvest index (38.53 %). Out of all the interactions, 10 kg Zn ha^{-1} and 12 kg Fe ha^{-1} at both basal applications produced the highest grain yield (4.95 t ha^{-1}) and straw yield (5.89 t ha^{-1}). Results showed that the grain yield of wheat was increased with the treatment combination of Zn and Fe.

Key Words: *Wheat, Foliar application, Zinc fertilization, Iron fertilization and Yield performance.*

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I. Introduction

The world's most nutritious cereal, wheat (*Triticum aestivum* L.), ranks top among plants that feed people because of its significant nutritional value. In Pakistan, wheat is a staple crop grown on 43% of the cultivated land. Approximately 65% of the wheat crop is currently used for food, 17% for animal feed, and 12% for industrial purposes. One cup of whole wheat grain provides 33% protein, 29% carbohydrates, and 5% fat, according to USDA (2014). Although there are many crops grown and harvested worldwide, in 2018 the world's primary crop production was concentrated mainly in four crops: sugar cane (21 percent of total production, or 1.9 billion tons), maize (13 percent or 1.1 billion tons), rice (9 percent, or 0.8 billion tonnes), and wheat (8 percent, or 0.7 billion tons) (FAO, 2020). According to CIMMYT's prediction, the demand for wheat in developing nations is expected to rise by 60% by the year 2050 (CIMMYT, 2013). 3.34 lakh hectares of land yielded 10.23 lakh tons of wheat annually in 2019–20 (BBS, 2020).

Many enzymes metabolizing carbohydrates and auxin, protein synthesis, and membrane integrity contain zinc as a structural component (Cakmak, 2000; Rehman et al., 2018). As a metal component of enzymes or a functional, structural, or regulatory co-factor of numerous enzymes, zinc is widely recognized to have a significant role in biological processes (Hotz and Braun, 2004). A zinc deficiency is linked to stunted growth in children under five years old and is estimated to impact 155 million children worldwide (WHO, 2013).

Fe activates numerous enzymes and is a component of cytochrome and the electron transport chain (Soetan et al., 2010). Due to increased reports of human iron deficiency, iron (Fe) is becoming increasingly important as a micronutrient in biological systems (Welch and Graham, 2004). Iron deficiency, the most prevalent cause of anemia, impairs children's mental and psychomotor development and reduces adults' productivity (Neumann et al., 2002). Furthermore, soils with low organic matter absorb less iron (Havlin et al., 2005). Trace elements have been applied globally in several tests and the findings have demonstrated that doing so not only boosts yields in both quantitative and qualitative terms but also raises the amount of these elements in wheat grains (Malakouti and Tehrani, 2005).

II. Materials and Methods

Experimental site

The location of the experiment is 24.75°N latitude, 90.50°E longitude. The experimental area is located about 18 meters above sea level. The trial site falls under Agro Ecological Zone-09, known as the "Old Brahmaputra Floodplain" (UNDP and FAO, 1988).

Experimental treatments and design

Treatments included in the experiment included the following: Zinc dosage (Zn): 0 kg Zn ha^{-1} (Zn_0): No Zn fertilizer; 10 kg Zn ha^{-1} (Zn_1): Base Z application; 10 kg Zn ha^{-1} (Zn_2): One foliar application (at tillering stage); 10 kg Zn ha^{-1} (Zn_3): Two foliar applications (at tillering stage and flag leaf stage). The iron dose (Fe) is as follows: 0 kg Fe ha^{-1} (Fe_0): No Fe fertilizer; 12 kg Fe ha^{-1} (Fe_1): Basal application of Fe; 12 kg Fe ha^{-1} (Fe_2): One foliar application (at tillering stage); 12 kg Fe ha^{-1} (Fe_3): Two foliar applications (at tillering stage and flag leaf stage). Three replications, each representing a block, were used in the experiment's randomized full-block design. Each block was separated into 16 unit plots, each receiving a random allocation of 16 treatment combinations. Overall, there were 48 unit plots in the experiment. The dimensions of each plot were 5 m^2 (2 m x 2.5 m). Each inter-block and inter-plot distance was 1m.

Land preparation

The experimental field was prepared for planting ten days in advance by opening it with a tractor-drawn disc harrow, then leveling and breaking up any clods on the ground with a ladder after four rounds of ploughing. A total of 180 kg ha^{-1} of Triple Super Phosphate (TSP), 50 kg ha^{-1} of Muriet of Potash (MoP), and 120 kg ha^{-1} of Gypsum were applied, except for Zinc and Iron fertilizers, by the directions provided by BARI (2010). Zinc sulphate (33%) and ferrous sulphate (36%), respectively, were used to apply zinc and iron by the experimental specifications. Before seeding, the entire amount of TSP, MOP, gypsum and one-third of the urea were applied during the last stages of land preparation. Twenty and fifty-five days after sowing (DAS) were used to top-dress the remaining two-thirds of urea in equal portions.

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Data recording

Ten randomly chosen sample plants in plot^{-1} were uprooted before harvesting to gather crop characteristics data. Plot-wise yields of grains and straw were measured in t ha^{-1} at a moisture level of 14%. From each plot, the following crop parameters' data were collected: Plant height, leaf area, total number of tillers plant^{-1}, spike length, number of fertile spikelets spike^{-1}, number of sterile spikelets spike^{-1}, number of filled grains spike^{-1}, number of unfilled grains spike^{-1}, Weight of 1000 grains (g), Harvest index (%), Grain yield (t ha^{-1}), Straw yield (t ha^{-1}), and Biological yield (t ha^{-1}).

Harvest index

The harvest index was calculated as follows:

Biological yield= Grain yield + Straw yield

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Statistical analysis

The analysis of variance (ANOVA) method was used to examine the obtained data statistically, and Duncan's New Multiple Range Test was used to determine the significance of mean differences (Zaman et al., 1982).

III. Results and Discussion

Effect of Zn level

Plant height: Different Zn levels were shown to have a substantial impact on plant height. The crop produced the tallest plants (90.56 cm) when fertilized with 10 kg Zn ha^{-1} during the tillering stage and the smallest plants (86.85 cm) when no Zn fertilizer was applied (Figure 01). According to the results above, applying zinc had a significant impact on plant height. According to several studies (Genc et al., 2006; Jain and Dahama, 2006), applying 6 kg Zn ha^{-1} to plants resulted in a considerable increase in height compared to other lower doses.

Leaf area: The amount of Zn applied at different levels did not appreciably change the leaf area. The control (Zn_0) had the largest leaf area (251.02 cm^2), while the tillering (10 kg Zn ha^{-1}) had the lowest (242.43 cm^2) (Figure 01). Ali Sher et al. (2018) reported a different outcome.

Number of total tillers plant^{-1}: The highest number of total tillers plant^{-1} (2.98) was found using 10 kg Zn ha^{-1} at the basal application and tillering and flag leaf stage (Zn_3), while the lowest number of total tillers plant^{-1} (2.78) was found using 10 kg Zn ha^{-1} during the tillering stage (Figure 01). Compared to other lower doses, the application of 6 kg Zn ha^{-1} resulted in a considerable increase in total tillers plant^{-1}, according to reports from other studies (Dewal and Pareek, 2004 and Singh, 2004).

Spike length: In the tillering stage (Zn_2), the longest spike length (15.82 cm) was produced from 10 kg Zn ha^{-1}, whereas the shortest figure (15.56 cm) was observed in the basal application (Zn_1) (Figure 01). In contrast to the control, spike length was considerably increased by foliar Zn applications of 0.02% and 0.006% (Sultana et al., 2016).

Number of fertile spikelets spike^{-1}: The application of zinc did not significantly increase the number of fertile spikelets spike^{-1}. The highest number of fertile spikelets spike^{-1} (12.97) was produced by zinc at a rate of 10 kg ha^{-1} (Zn_2), while the lowest number was produced by the control treatment (Figure 01). It is evident from this that Zn fertilization impacted the quantity of viable spikelets spike^{-1}. Zn treatment resulted in the greatest number of spikelets per spike, according to Seadh et al. (2009).

Number of sterile spikelets spike^{-1}: Fertilization with zinc did not significantly affect the amount of sterile spikelets spike^{-1}. The control (Zn_0) had the most sterile spikelets spike^{-1} (1.18), while 10 kg Zn ha^{-1} at the tillering and flag leaf stage (Zn_3) had the fewest (1.12) (Figure 01). According to Razvi et al. (2005), a substantial decrease in the number of sterile spikelets spike^{-1} of wheat was observed upon applying 10 kg ha^{-1} of ZnSO4 to the soil.

Number of filled grains spike^{-1}: Zn had a statistically insignificant effect on the number of grains spike^{-1}. The largest number of grains spike^{-1} (34.21) was observed at 10 kg Zn ha^{-1} during the tillering

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and flag leaf stage (Zn_3), while the lowest number (33.63) was observed at the control (Figure 01). Furthermore, Soleimani (2012) observed that the application of zinc increased the number of grains spike^{-1}.

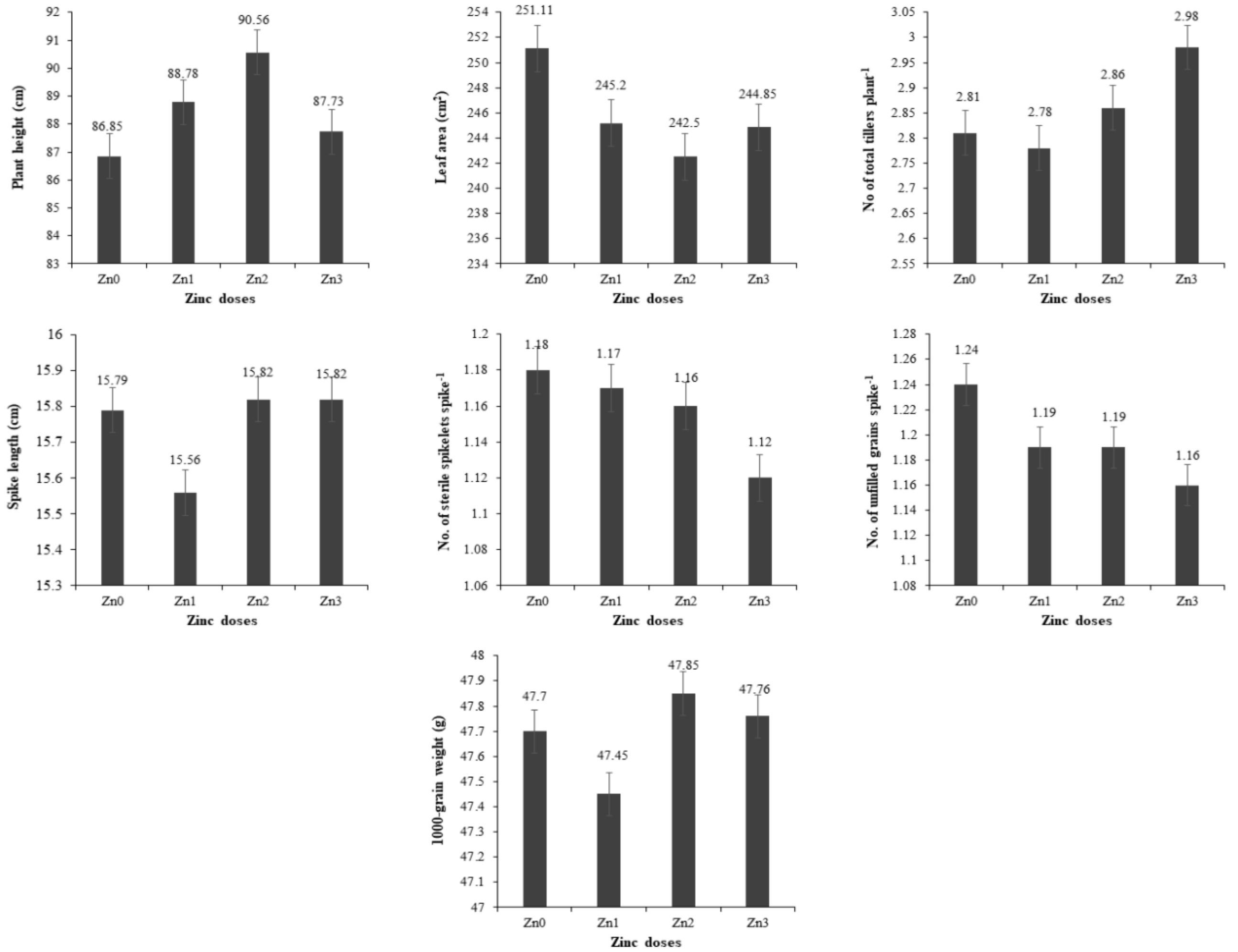

Figure 01. Zn's impact on plant height, leaf area, number of total tillers plant^{-1}, spike length, number of fertile spikelets spike^{-1}, number of sterile spikelets spike^{-1}, number of filled grains spike^{-1}

Zn0= 0 kg Zn ha^{-1}: No Zn fertilizer, Zn1= 10 kg Zn ha^{-1}: Basal application of Z, Zn2= 10 kg Zn ha^{-1}: One foliar application (at tillering stage), Zn3= 10 kg Zn ha^{-1}: Two foliar application (at tillering stage and flag leaf stage)

Number of unfilled grains spike^{-1}: Zn had a statistically non-significant impact on the number of unfilled grains spike^{-1}. As shown in Figure 02, the number of empty grains spike^{-1} was lowest (1.16) at 10 kg Zn ha^{-1} at the tillering flag leaf stage (Zn_3) and greatest (1.24) at the control treatment (Zn_0).

1000-grain weight: The application of zinc did not significantly alter the weight of one thousand grains. Zn was applied at a rate of 10 kg Zn ha^{-1} at the tillering stage (Zn_2) to yield the greatest 1000-grain weight (47.85 g), while 10 kg Zn ha^{-1} at the tillering and flag leaf stage (Zn_3) produced the second-highest 1000-grain weight (47.76 g) (Figure 02). According to Hussain et al. (2005), 1000 grains' weight rises during the tillering, boot, and milk stages when a micronutrient spray is applied.

Grain yield: The treatment with the highest grain yield (4.08 t ha^{-1}) was 10 kg Zn ha^{-1} (Zn_1), while the control had the lowest grain yield (3.08 t ha^{-1}). At the tillering stage, 10 kg Zn ha^{-1} produced the second-highest result (Zn_2) (Figure 02). Numerous writers have also demonstrated that grain output rose dramatically as Zn levels rose (El-Majid et al., 2000 and Seilsepour, 2007). According to Wang et al. (2012), Zn was shown to be more abundant in wheat grains when applied topically rather than through soil.

Straw yield: The maximum straw yield (4.93 t ha^{-1}) was produced in 10 kg Zn ha^{-1} at basal application

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(Zn_1); this may be because Zn predominantly promotes vegetative growth. On the other hand, zinc is a crucial component found in plant enzymatic systems. Thus, zinc has a noticeable impact on plant growth as well. The control treatment (Zn_0) produced the lowest straw yield (4.53 t ha^{-1}) (Figure 02). The results for this character are consistent with the outcome of Genc et al. (2006).

Biological yield: The crop fertilized with 10 kg Zn ha^{-1} at the tillering stage (Zn_1) produced the maximum biological yield (9.01 t ha^{-1}), while the control group produced the lowest (7.61 t ha^{-1}). These findings showed that raising Zn concentrations from 0 to 10 kg Zn ha^{-1} (Figure 02). The findings make it clear that zinc had a significant impact on biological yield. Zinc is an essential element found in the enzyme systems of plants. According to some writers, the rate at which zinc was applied to wheat boosted its biological production (Ali et al., 2009; Grewal et al., 1997).

Harvest index: Significant variations in the effects of zinc on the harvest index are shown in Figure 02. 10 kg Zn ha^{-1} at basal application (Zn_1) produced the maximum harvest index (45.13 %), while 40.38 was the lowest harvest index under control (Figure 02). According to Khan et al. (2008), Zinc treatments reduced harvest index.

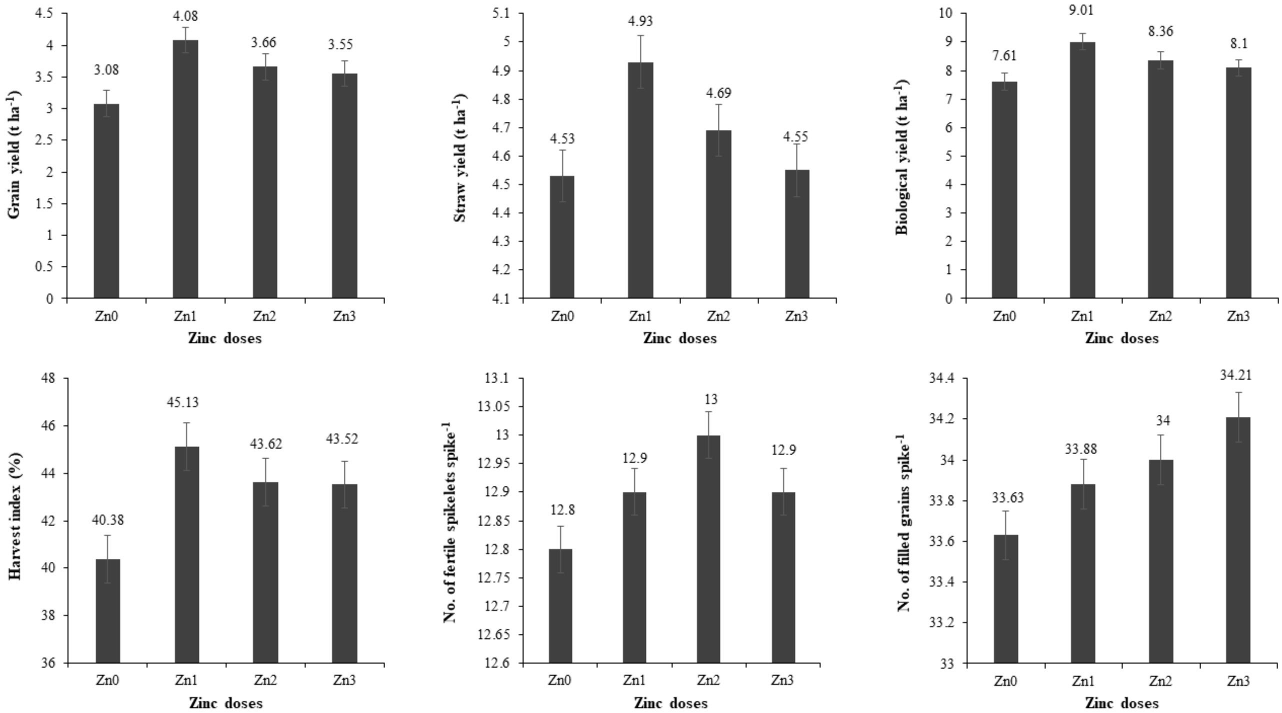

Figure 02. Zn's impact on number of unfilled grains spike^{-1}, 1000-grain weight, grain yield, straw yield, biological yield, harvest index

Effect of Fe level

Plant height: Plant height was significantly impacted by the amount of iron applied. When the crop received 0 kg Fe ha^{-1}, the maximum plant height (90.80 cm) was observed. When the crop was fertilized with 12 kg Fe ha^{-1} at the tillering stage, the smallest plant height (86.73 cm) was observed (Figure 03). These findings coincide with those of Ferrarezi et al. (2007), who found that citrus had considerable growth in all the examined growth characteristics.

Leaf area: The outcome additionally demonstrated that Fe fertilization had no discernible effect on leaf area. The treatment of 12 kg Fe ha^{-1} at the tillering stage (Fe_2) produced the maximum leaf area (248.01cm^2), while the treatment of 12 kg Fe ha^{-1} at the tillering and flag leaf stage (Fe_3) produced the lowest (243.18cm^2). (Figure 03). According to Hemantaranjan and Garg (1988), foliar application of Fe in wheat resulted in a higher leaf area index when compared to the control treatment.

Number of total tillers plant^{-1}: Different levels of Fe application did not significantly affect the total number of tillers plant^{-1}. The treatment of 12 kg Fe ha^{-1} at basal application yielded the largest number of total tillers plant-1 (2.96), whereas the treatment of 12 kg Fe ha-1 at tillering and flag leaf stage (Fe_3) gave the lowest value (2.78) (Figure 03). According to Nadim et al. (2012), applying iron alone or in conjunction with other nutrients greatly boosts the number of tillers compared to control.

Spike length: The effect of varying Fe levels on the wheat spike length was statistically significant. The control treatment (Fe_0) showed the longest spike length (15.83 cm). Treatment Fe_2 produced the shortest outcomes, at 15.67 (Figure 03).

Number of fertile spikelets spike^{-1}: Fertilizer levels also had a negligible effect on the number of fertile spikelets spike^{-1} in wheat. While 12 kg Fe ha^{-1} at the tillering stage (Fe_2) had the lowest number of fertile spikelets spike^{-1} (12.74), 12 kg Zn ha^{-1} at the tillering and flag leaf stage (Fe_3) had the highest number of fertile spikelets spike^{-1} (12.98) (Figure 03). A comparable outcome at 15 kg Fe ha^{-1} under control treatment was reported by Vicek and Mehta (2020).

Number of sterile spikelets spike^{-1}: The results demonstrated that Fe fertilization had no discernible effect on the quantity of sterile spikelets spike^{-1}. The control group had the greatest number of sterile spikelets spike^{-1} (1.2), while the group receiving 12 Kg Fe ha^{-1} at basal application had the lowest number (1.13) (Figure 03). This could help to explain why sterile spikelets spike^{-1} are caused by a Fe deficit.

Number of filled grains spike^{-1}: Different Fe levels also had non-significant effects on the number of filled grains spike^{-1}. When 12 kg Fe ha^{-1} was sprayed at the tillering and flag leaf stage (Fe_3), the greatest number of filled grains spike^{-1} was discovered (34.25). The application of 12 kg Fe ha^{-1} at the tillering stage resulted in the lowest (33.49) number of grains spike^{-1} (Figure 03).

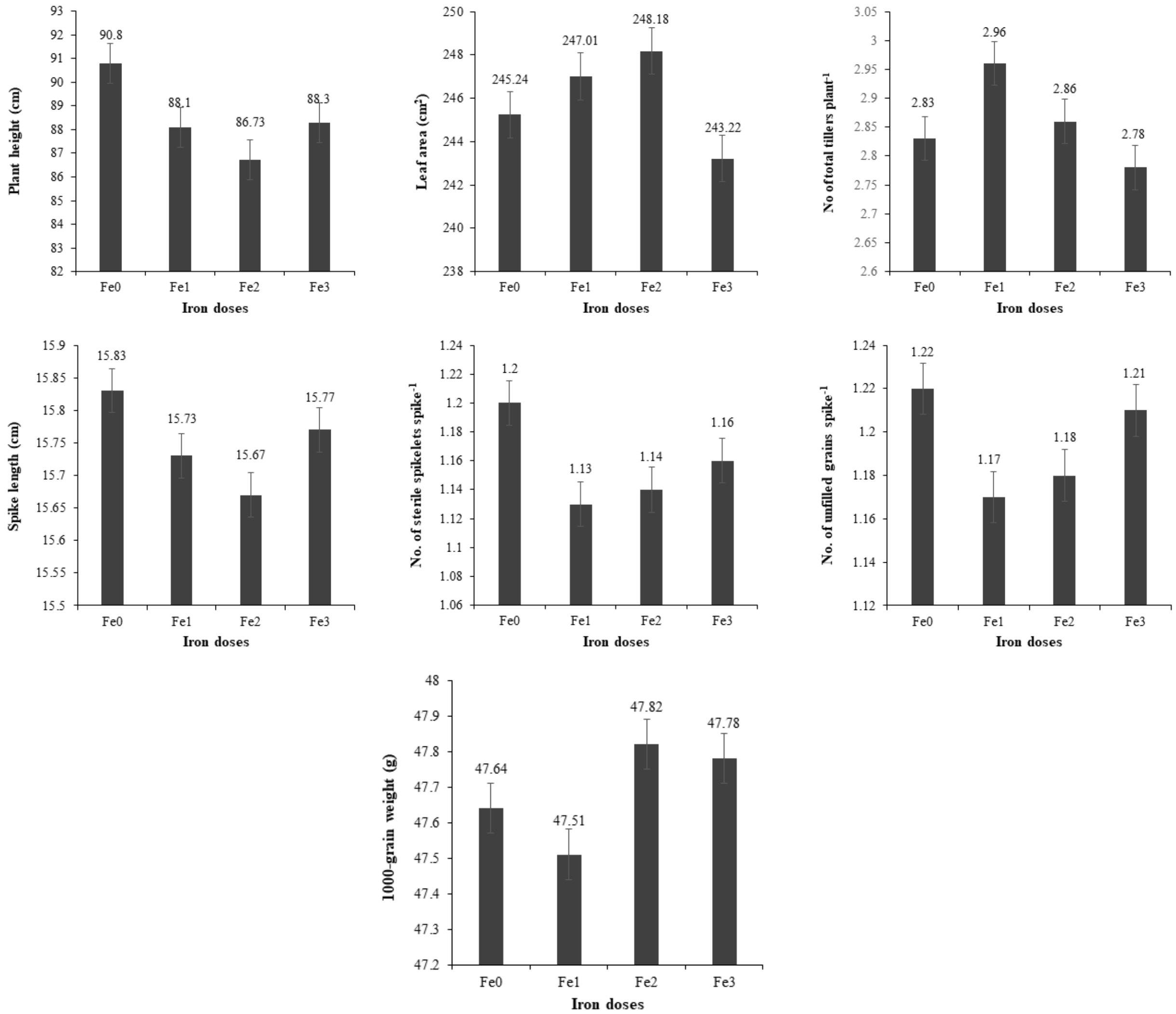

Figure 03. Fe's impact on plant height, leaf area, number of total tillers plant^{-1}, spike length, number of fertile spikelets spike^{-1}, number of sterile spikelets spike^{-1}, number of filled grains spike^{-1}

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Number of unfilled grains spike^{-1}: The number of unfilled grains spike^{-1} was not significantly affected by varying Fe levels. Under supervision, it was discovered that the maximum number of unfilled grains spike^{-1} was 1.22. Applying 12 kg Fe ha^{-1} during basal treatment resulted in the lowest (1.17) number of unfilled grains spike^{-1} (Figure 04).

1000-grain weight: The application of Fe fertilizer did not significantly affect the weight of 1000 grains. When wheat was treated with Fe_2 (12 kg Fe ha^{-1} at the tillering stage), the highest 1000 grain weight (47.82 g) was discovered. At basal application (Fe_1) treatment, the lowest 1000 grain weight (47.51 g) of wheat was reported at 12 kg Fe ha^{-1} (Figure 04). Yaseen et al. (2010) found that plants treated with urea and iron foliar spray significantly increased their 1000-grain weight compared to the control.

Grain yield: The highest grain yield (4.11 t ha^{-1}) was obtained with the 12 kg Fe ha^{-1} at basal application (Fe_1) treatment, whereas the lowest grain yield (2.62 t ha^{-1}) was noted with the control treatment (Fe_0) (Figure 04). The highest amounts of Fe were recorded by Khan et al. (2014) during the Fe treatment and by Yassen et al. (2010) during the micronutrient combo therapy.

Straw yield: A noteworthy impact on straw yield was also demonstrated by the various Fe dosages. As shown in Figure 04, the Fe_1 treatment produced the maximum straw yield of 5.32 t ha^{-1}, while the control (Fe_0) treatment produced the lowest straw yield of 4.21 t ha^{-1}. The findings were corroborated by Shahrokhi et al. (2012), who found that applying iron at several doses significantly increased the amount of straw produced compared to the control.

Biological yield: Fertilization with Fe has a considerable impact on biological yield. In comparison to the lowest biological output (6.83 t ha^{-1}) from the control, treatment Fe_1 (12 kg Fe ha^{-1} at basal application) demonstrated the maximum biological yield (9.43 t ha^{-1}). (Figure 04). It is evident from the aforementioned data that there was a rise in the biological yield due to elevated Fe levels. This could be because Fe has a major impact on wheat's vegetative and reproductive growth in all stages.

Harvest index: The Fe_2 treatment yielded the highest harvest index (45.71%), while the control treatment with Fe_0 produced the lowest harvest index (38.35%) (Figure 04). Rawashdeh (2013) supported the results, demonstrating that foliar iron application considerably increased the harvest index.

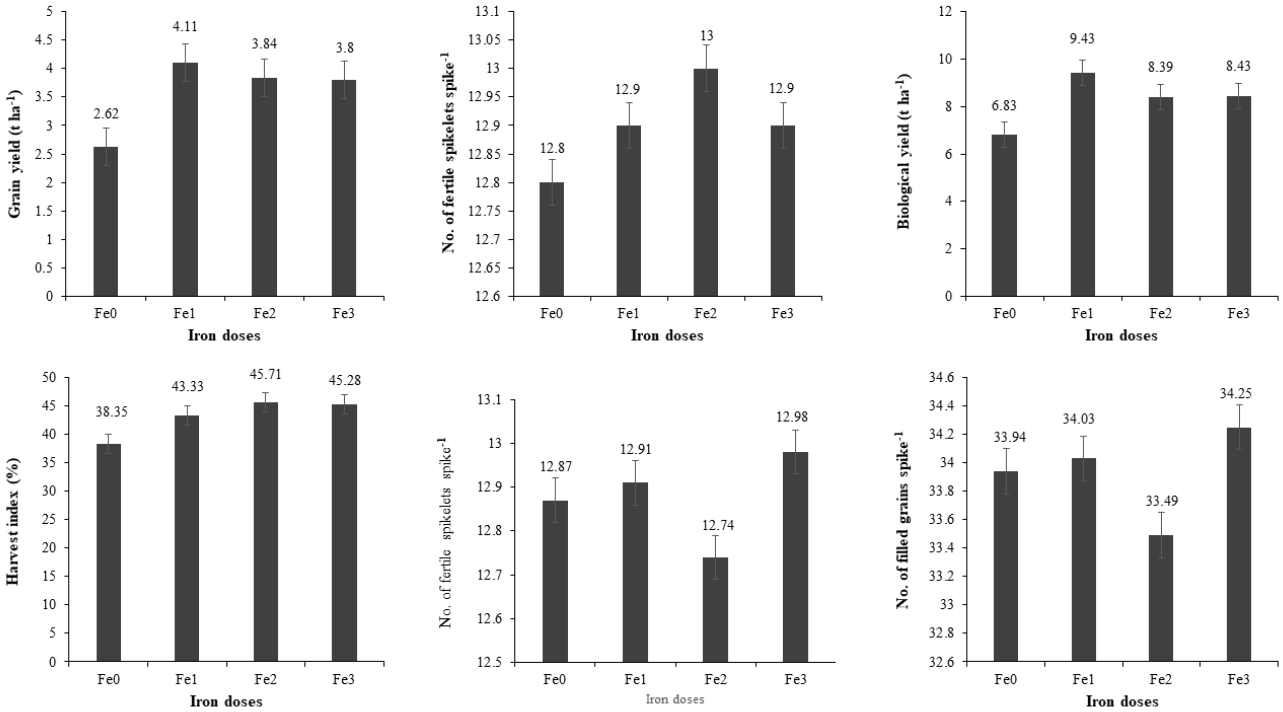

Figure 04. Fe's impact on number of unfilled grains spike^{-1}, 1000-grain weight, grain yield, straw yield, biological yield, harvest index

Interaction effect of Zn and Fe level

Plant height: The interaction effects of Zn and Fe levels had a substantial impact on plant height. The treatment combination of 10 kg Zn ha^{-1} × 0 kg Fe ha^{-1} resulted in the greatest plant height of 93.20 cm, while the lowest plant height of 84.73 cm was obtained from 0 kg Zn ha^{-1} and basal dose of 12 kg Fe ha^{-1} (Table 01). According to the results, plants that received no Fe fertilization (Zn_2Fe_0) and 10 kg Zn ha^{-1} during the tillering stage grew taller. A comparable outcome was obtained by Khan et al. (2008) through the application of zinc sulfate to wheat soil.

Leaf area: The results provided indicated that there was no significant interaction between Zn and Fe in leaf area. The treatments with the largest leaf area (257.90 cm^2) were Zn_0Fe_2, which was equal to 0 kg Zn ha^{-1} + 12 kg Fe ha^{-1} at the tillering stage; Zn_1Fe_3, on the other hand, had the lowest leaf area (237.69 cm^2) (Table 01).

Number of total tillers $plant^{-1}$: The interaction between Zn and Fe on the total number of tillers $plant^{-1}$ was not significant, according to the results. The treatment that produced the greatest number of total tillers $plant^{-1}$ (3.13) was 10 kg Zn ha^{-1} at flag leaf stage + 12 kg Fe ha^{-1} at basal application (Zn_3Fe_1), whereas the treatment that produced the lowest number (2.53) was Zn_1Fe_3) (Table 01). Current findings demonstrated that the Zn_3Fe_1 treatment combination contributes to an increase in the total number of tillers $plant^{-1}$.

Spike length: Regarding spike length, the Zn and Fe interaction effect was not significant. The maximum spike length (16.11 cm) was observed in 10 kg Zn ha^{-1} + 12 kg Fe ha^{-1} at both flag leaf stage (Zn_3Fe_3), and the smallest (14.92 cm) was in Zn_1Fe_2 treatments combination (Table 01), even though Zn and Fe interaction did not significantly affect spike length. It can be inferred from the results above that both Zn and Fe increase spike length. Hemantaranjan and Grey (1988) noted that applying Fe and Zn to the soil lengthened the spikes.

Number of fertile spikelets $spike^{-1}$: The treatment combination of Zn and Fe levels caused a considerable variation in the number of viable spikelets $spike^{-1}$ of wheat. In the basal stage (Zn_0Fe_1), 0 kg Zn ha^{-1} + 12 kg Fe ha^{-1} produced the greatest number of fertile spikelets $spike^{-1}$ (13.30), whereas, in the tillering stage (Zn_1Fe_2), 10 kg Zn ha^{-1} + 12 kg Fe ha^{-1} produced the lowest number (12.25) (Table 01).

Number of sterile spikelets $spike^{-1}$: There was a noticeable difference in the number of sterile spikelets $spike^{-1}$. The crop fertilized with 10 kg Zn ha^{-1} at basal application and 12 kg Fe ha^{-1} at tillering stage (Zn_1Fe_2) (Table 01) showed the lowest number of sterile spikelets $spike^{-1}$ (1.09) and the highest number of sterile spikelets $spike^{-1}$ (1.27) when combined with 12 kg Fe ha^{-1} at tillering stage.

Number of filled grains $spike^{-1}$: Significant fluctuation was seen in the number of filled grains $spike^{-1}$ due to the interaction effects of Zn and Fe. The range of $spike^{-1}$ grain count was 31.81 to 35.04, contingent on the different treatments applied. Treatment Zn_1Fe_3 yielded the most $spike^{-1}$ grains (35.04), while treatment Zn_1Fe_2 produced the fewest (31.81) (Table 01).

Number of unfilled grains $spike^{-1}$: The number of unfilled grains $spike^{-1}$ did not significantly vary in response to Zn and Fe interaction effects. Depending on the different treatments applied, the number of unfilled grains $spike^{-1}$ ranged from 1.08 to 1.38. The treatment Zn_1Fe_3 yielded the greatest number of unfilled grains $spike^{-1}$ (1.38) compared to the control treatment Zn_0Fe_0, and the treatment Zn_2Fe_2 produced the least amount (1.08) (Table 01).

1000-grain weight: Zn and Fe's interaction effect was not statistically significant for grain weight of 1000. At the tillering stage, however, 0 kg Zn ha^{-1} + 12 kg Fe ha^{-1} produced the maximum 1000-grain weight (48.32 g) (Zn_0Fe_2). The treatment with (Zn_0Fe_3) had the lowest 1000-grain weight (46.94 g) (Table 01).

Grain yield: Grain yield was significantly impacted by the interplay between varying Zn and Fe fertilizer amounts. Out of all the treatments, the combination of 10 kg Zn ha^{-1} at tillering and flag leaf stage + 0 kg Fe ha^{-1} (Zn_3Fe_0) produced the lowest grain yield (2.47 t ha^{-1}), while the combination of 10 kg Zn ha^{-1} × 12 kg Fe ha^{-1} (Zn_1Fe_1) produced the greatest (4.95 t ha^{-1}) (Table 01). Higher grain yields

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were obtained by combining Zn and Fe at both basal applications, as the trial has shown. The application of Zn and Fe together raised grain Zn concentration, according to Ravi et al. (2008).

Straw yield: Significant effects were seen in the interaction between Zn and Fe and straw yield. Significantly, 10 kg Zn ha^{-1} + 12 kg Fe ha^{-1} (Zn_1Fe_1) provided the highest (5.89) straw yield, according to the interaction treatments. The Zn_0Fe_0 treatment demonstrated the lowest straw yield performance (Table 01). Fe and Zn spraying on the leaves boosted wheat grain and straw yields, according to Ziaeian and Malakouti (2001).

Biological yield: The interplay between zinc and iron had a major impact on wheat's biological output. According to Table 01, the treatment with Zn_2Fe_0 provided the lowest biological output (6.55 t ha^{-1}), while the control treatment (Zn_0Fe_0) produced the maximum biological yield (10.84 t ha^{-1}).

Harvest index: The interaction between varying levels of Zn and Fe greatly impacted the harvest index. The findings show that the maximum harvest index (48.59%) was achieved by 10 kg Zn ha^{-1} at basal application × 12 kg Fe ha^{-1} at flag leaf stage (Zn_1Fe_3), as opposed to (Zn_3Fe_0) treatments (37.35%) (Table 01). The combination of zinc and iron, along with higher grain and biological yields, could be the cause.

Table 01. Interaction effects of Zn and Fe on the yield and yield contributing characters of wheat cv. BARI Gom-25.

Interaction	Plant height (cm)	Leaf area (cm^2)	No of total tillers plant^{-1}	Spike length (cm)	No. of fertile spikelets spike^{-1}	No. of sterile spikelets spike^{-1}	No. of filled grains spike^{-1}	No. of unfilled grains spike^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Zn_0Fe_0	89.26abc	256.11ab	2.8	15.59	12.52ab	1.26	32.81ab	1.38	48.25	2.65hi	4.26cd	10.84	38.30fg
Zn_0Fe_1	84.73c	246.91abc	3.06	16.02	13.30a	1.15	34.36ab	1.2	47.28	2.94g	4.31cd	6.92h	40.53defg
Zn_0Fe_2	87.93abc	258.01a	2.8	15.96	12.82ab	1.13	34.18ab	1.21	48.32	3.27f	4.77bc	7.25gh	40.66defg
Zn_0Fe_3	85.46bc	243.42abc	2.6	15.59	12.47ab	1.18	33.16ab	1.19	46.94	3.46ef	4.77bc	8.04f	42.03cdef
Zn_1Fe_0	92.20ab	246.44abc	3	16.01	13.02ab	1.25	34.29ab	1.11	47.19	2.82gh	4.41cd	8.24ef	39.02efg
Zn_1Fe_1	90.86abc	255.11ab	2.73	15.54	12.94ab	1.12	34.38ab	1.18	47.03	4.95a	5.89a	7.24gh	45.69abc
Zn_1Fe_2	85.33bc	241.44bc	2.86	14.92	12.25b	1.09	31.81b	1.25	47.54	4.28b	4.79bc	9.08cd	47.23ab
Zn_1Fe_3	86.73abc	237.81c	2.53	15.78	13.23ab	1.24	35.04a	1.24	48.05	4.25b	4.64cd	8.90de	48.59a
Zn_2Fe_0	93.20a	238.20c	2.66	15.83	12.93ab	1.13	34.20ab	1.28	47.66	2.53i	4.01d	6.55h	38.72fg
Zn_2Fe_1	91.13abc	247.35abc	2.93	15.92	12.97ab	1.12	34.29ab	1.17	47.68	4.32b	5.64a	9.97b	43.33bcde
Zn_2Fe_2	86.80abc	241.63abc	2.8	15.96	12.85ab	1.27	33.57ab	1.08	48.05	3.95c	4.35cd	8.31ef	47.62ab
Zn_2Fe_3	91.13abc	242.80abc	3.06	15.59	13.13ab	1.14	33.92ab	1.24	48.02	3.86cd	4.75bc	8.61def	44.81abcd
Zn_3Fe_0	88.53abc	240.23bc	2.86	15.9	13.02ab	1.17	34.45ab	1.13	47.45	2.47i	4.14cd	6.62h	37.35g
Zn_3Fe_1	85.66bc	238.66c	3.13	15.44	12.42ab	1.13	33.08ab	1.16	48.07	4.23b	5.44ab	9.67bc	43.75bcd
Zn_3Fe_2	86.86abc	251.66abc	3	15.86	13.07ab	1.1	34.42ab	1.18	47.4	3.85cd	4.29cd	8.14f	47.31ab
Zn_3Fe_3	89.86abc	248.85abc	2.93	16.11	13.10ab	1.06	34.89a	1.18	48.13	3.64de	4.33cd	7.98fg	45.67abc
$LSD_{(0.05)}$	**7.00**	**16.41**	**0.54**	**0.89**	**1.02**	**0.24**	**3.07**	**0.21**	**1.39**	**0.27**	**0.71**	**0.73**	**4.43**
Level of sig.	**	**	NS	NS	*	NS	*	NS	NS	**	**	**	**
CV (%)	**4.75**	**4.00**	**11.52**	**3.41**	**4.77**	**12.32**	**5.43**	**10.78**	**1.76**	**4.61**	**9.11**	**5.34**	**6.16**

In column, figures with same letter(s) or without letter do not differ significantly as per (DMRT). ** = Significant at 1% level of probability, *= Significant at 5% level of probability and NS = Non-significant. Zn_0 = 0 kg Zn ha^{-1}, Zn_1 = 10 kg Zn ha^{-1}: at basal application, Zn_2 = 10 kg Zn ha^{-1}: at tillering stage, Zn_3 = 10 kg Zn ha^{-1}: at tillering and flag leaf stage. Fe_0 = 0 kg Fe ha^{-1}, Fe_1 = 12 kg Fe ha^{-1}: at basal application, Fe_2 = 12 kg Fe ha^{-1}: at tillering stage, Fe_3 = 12 kg Fe ha^{-1}: at tillering and flag leaf stage.

IV. Conclusion

Breeding and agronomic management can increase the zinc and iron content of cereals. But, obtaining wheat genotypes with increased Fe and Zn content is laborious and time-consuming. However, agronomic management makes increasing the zinc and iron content in grains simple and quick. Production of wheat could partially replace the need for food grains to meet zinc and iron required to support an expanding population. As a result, the current study proposal aims to assess how zinc and iron affect wheat. The study showed that wheat may be grown successfully to produce the highest possible yield by applying 10 kg Zn ha^{-1} × 12 kg Fe ha^{-1} at both basal applications (Zn_1Fe_1). To provide a useful nationwide suggestion, more research in additional Bangladeshi agroecological zones (AEZs) is necessary before determining the proper dosage of zinc and iron.

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