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Research Article

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THE FOLIAR APPLICATION OF NITROGEN AND ZINC APPLIED DURING TILLERING AND BOOTING STAGE ENHANCED THE GROWTH AND PRODUCTION OF WHEAT (*TRITICUM AESTIVUM* L.)

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ABSTRACT

Foliar application of nitrogen and zinc has proven beneficial to achieve high yield and growth of wheat. A field trial was conducted with Randomized Complete Block Design (RCBD) in three replications, at Student's Experiment Farm, Department of Agronomy, Sindh Agriculture University, Tandojam during spring 2022-2023. The study explored the effect of foliar application of nitrogen (N) and zinc (Zn) on wheat (*Triticum sativum* L.) variety TD-1 on different growth stages. The treatment comprised T_1 = Control, T_2 = 2.0% N (tillering), T_3 = 2.0% N (booting), T_4 = 0.1% Zn (tillering), T_5 = 0.1% Zn (booting), T_6 = 2.0% N + 0.1% Zn (tillering), and T_7 = 2.0% N + 0.1% Zn (booting). The results revealed that all the parameters were significantly affected ($p < 0.05$) by foliar applications of N and Zn at both tillering and booting stages. The highest growth and yield traits were recorded when the plants were treated with 2.0 % N + 0.1% Zn applied (foliar) at tillering stage. However, the plants grown under control conditions exhibited lower performance for all the traits recorded. In conclusion, the interaction of 2.0% N + 0.1% Zn with foliar spray demonstrated positive response towards wheat variety TD-1 at tillering stage as compared to other treatments. Hence, the combined strategy of applying foliar nitrogen and zinc at tillering stage is recommended to get higher grain yields and plant growth for chaff production.

Keywords: Wheat, Nitrogen, Zinc, Foliar Application, Growth and Yield

INTRODUCTION

Wheat (*Triticum sativum* L.) is an annual, self-pollinated, allohexaploid (Khan *et al.*, 2023) monocotyledon and an earliest planted cereal crop belonging to the family *Poaceae* (Saleem *et al.*, 2023). Due to its momentous longevity and nutritive quality, it is deemed the "king of cereals" (Khan *et al.*, 2023). It contains huge amounts of protein, carbohydrates, vital nutrients, and dietary fibers (Kumar *et al.*, 2022). Wheat is one of the most widely cultivated staple food grains across the globe including Pakistan and the second most important crop in the world after rice (Majeed *et al.*, 2023).

The annual production of wheat was recorded about 27.63 million tons cultivated on the area of about 9 million hectares in 2022-23. The production was increased about 5.4% as compared to the fiscal year 2021-22 (GoP, 2023). As Pakistan is included among the most populous countries, its population mostly depends on wheat, used as a staple food for meeting dietary needs (Ijaz *et al.*, 2023). It is estimated that by 2050, Pakistan is set to rank 6th in the world in terms of population thus leading to an increased demand for wheat production so as to ensure food security in the country (Islam *et al.*, 2021). So, there exists a dire need to accelerate wheat productivity for shrinking production-consumption gap.

Owing to the climatic conditions of Pakistan, many biotic and abiotic stresses contributed to the lower yield of cereal crops by affecting their enzymatic, physiological and, biochemical activities; one among the stresses is the unavailability and unawareness about the use of macro and micronutrients (Alotaibi *et al.*, 2023). Sustainable wheat production can be achieved by application of micro and macro nutrients (Alotaibi *et al.*, 2023). Inadequate provision of these nutrients is the prime cause beyond the suboptimal yield of wheat in Pakistan (Nadeem *et al.*, 2023).

Nitrogen, in particular, plays an energetic role in metabolic activities of wheat such as respiration and photosynthesis. It is effective for the morphogenesis of many molecules including Deoxyribonucleic acid (DNA), Ribonucleic acid (RNA), hormones, pigments, Adenosine triphosphate (ATP), etc. in plants. Deficiency of Nitrogen, therefore, results in premature aging and poor growth in plants. Balanced use of nitrogen increases the amount of protein in the grain, spikes and tillers thereby producing an improved quality grain (Rafiq *et al.*, 2023).

Similarly, Zinc is known as a vital nutrient for the survival of all living organisms and essential micronutrients for plants. The insufficiency of micronutrients has created dilemma of hidden hunger and malnutrition, by affecting 3 million of world's population (Saquee *et al.*, 2023). It acts as a key element in numerous metabolic processes of plants such as enzymes regulation, chlorophyll production and, protein synthesis; its deficiency leads to poor development and growth of plants. Since Pakistan's soil is calcareous in nature, zinc deficiency is observed in its soil (Kamran *et al.*, 2023). Hence, a wheat crop grown under Zn deficient soil will exhibit the symptoms of Zn deficiency in plants and their products. Therefore, in the light of the aforementioned studies, the present study assessed the foliar application of nutrients namely nitrogen and zinc for improved yield and growth of wheat crop in the area of Sindh, Pakistan. The main focus encompasses determining the impact of both, isolated and mixed foliar application of N and Zn during various stages of TD-1 variety of wheat. The study will create awareness among research and farming communities for the judicious use of foliar application of nitrogen and zinc at different growth stages of wheat crop to get maximum yield benefits.

MATERIALS AND METHODS

Site Selection and Plant Material: The field experiment was carried out at the student experimental farm, located at latitude 68.33° and longitude 25.25°, in the Department of Agronomy, Sindh Agriculture University, Tandojam, Sindh, Pakistan. The wheat variety TD-1 was compared to various foliar spray levels of N and Zn at both the tillering and booting stage. The entire study was set up using Randomized Complete Block Design (RCBD) and was duplicated three times. The size of the net plot was handled as 12 m^2. The Agriculture Research Institute's Agronomy Section in Tandojam, Sindh, Pakistan, provided the seeds of wheat variety TD-1. Using a single coulter hand drill, the seeds were drilled in the experimental field. Following the instructions of Sindh's Agriculture Research Wing, 125 kg of seed was utilized as seed rate per hectare. On the other hand, rows and plants were separated by 30 and 75 cm spacings, respectively. November 2022 was the month of seed sowing, while March 2023 was the month of harvesting.

Land Preparation and Agronomic Management: Two dry ploughings were applied to the site to break up the hard pan of soil and get rid of weeds. However, dry ploughing was followed by soft ploughing, which included clod crushing and leveling the field, before seedbed preparation. The aim was to provide a well-distributed seedbed and consistent application of water, fertilizer, and seed throughout field. During the whole growth season, the crop was kept free of weeds. Thirty days after seeding, as well as after the second and fourth irrigations, weeding and intercultural practices were performed. At the onset of crown root development, the first irrigation was given. From the sprouting of seedlings to crop maturity, a total of four irrigations were applied. Every morning, the crop was inspected for disease and insect pests, and appropriate action was taken if any issues were reported. When the crop reached its maturity, the harvesting process was carried out manually with the use of a sickle. Threshing of seeds of all plots was carried out by thresher except for seed index for which the seeds were obtained manually.

Foliar applications of N and Zn and Nutrition Management: The wheat crop was subjected to seven foliar applications of N and Zn during tillering and booting stages. The treatments included T_1 = Control, T_2 = 2.0% N (tillering), T_3 = 2.0% N (booting), T_4 = 0.1% Zn (tillering), T_5 = 0.1% Zn (booting), T_6 = 2.0% N + 0.1% Zn (tillering), and T_7 = 2.0% N + 0.1% Zn (booting). There was no treatment applied to the control plots. Nitrogen, Phosphorus and Potassium were applied in the form of Urea, Diammonium Phosphate (DAP), and Muriate of Potash (MOP) at the rate of 168-84-60 kg ha^{-1}, respectively. At the time of sowing, all DAP, MOP, and one-third of the urea were applied. The remaining urea was divided equally into two halves for the first and second irrigations.

Trait Measurement: Five plants were chosen at random from each treatment in each replication, and were tagged. The data collection focused on plant height (cm), tillers (m^2), spike length (cm), grains $spike^{-1}$, grain weight (g $plant^{-1}$) and seed index (1000-seed weight) from those randomly selected plants; the average of five plants was obtained for each treatment. After attaining the plants' average, each treatment's average from all three replications was acquired and thereby utilized for statistical purpose. Manual threshing of seeds and weighing was carried out to get seed index. After determining the grain yield (kg $plot^{-1}$) for each treatment, the following formula was used to convert the grain yield (kg ha^{-1} from kg $plot^{-1}$):

$$Grain\ yield\ (kg\ per\ ha) = \frac{Grain\ yield\ per\ plot\ (kg)}{Plot\ Size\ (m^2)} \times 10000$$

Data analysis: The STATISTIX-8.1 (www.statistix.com) program was used to analyze the replication-wise data that had been gathered. Tukey's Honestly Significant Difference (HSD) and Analysis of Variance (ANOVA) were programed to determine whether there were significant differences between treatments at the probability level ($p \leq 0.05$).

RESULTS AND DISCUSSION

Plant height (cm): The data in relation to plant height (cm) of wheat variety TD-1 as affected by various combinations of foliar applied nitrogen and zinc are presented in Table 1. The results showed that all the treatments of nitrogen and zinc applied through foliar spray affected significantly ($p \leq 0.05$) (Supplementary Table. 1) plant height as compared to Control. The highest plant height 65.0 and 63.2 cm was recorded under T_6 and T_7, respectively. The diminishing trend in plant height of wheat was noted in T_5 (60.3 cm), T_4 (58.5 cm), T_3 (55.7 cm) and T_2 (55.5 cm). The statistical analysis shows no significant difference between T_7 and T_6, T_5 and T_4. The lowest plant height (51.3 cm) was recorded under control conditions. Our results confirm the findings of Farooqi *et al.*, (2019) where they stated that 8% nitrogen supplied to foliage parts of wheat crop as liquid solution can significantly maximize the height of plants. A very recent study published by Kamran *et al.*, (2023) concludes that foliar applied $ZnSO_4$ has the ability to produce taller wheat plants in comparison with control and zinc amino acid chelates (ZnAACH)
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Table 1. Plant height (cm) of wheat variety TD-1 as affected by foliar applied nitrogen and zinc at various growth stages

Treatments	R-I	R-II	R-III	Mean
T_1 = Control (No foliar application)	50.2	50.6	53.2	51.3 D
T_2 = 2.0 % nitrogen (tillering)	52.6	55.2	52.6	53.5 CD
T_3 = 2.0% nitrogen (booting)	57.2	54.8	55.0	55.7 C
T_4 = 0.1% zinc (tillering)	58.4	59.6	57.4	58.5 B
T_5 = 0.1% zinc (booting)	61.6	59.0	60.2	60.3 B
T_6 = 2.0% nitrogen + 0.1% zinc (tillering)	64.0	65.0	66.0	65.0 A
T_7 = 2.0% nitrogen + 0.1% zinc (booting)	62.2	62.0	65.4	63.2 A

Tillers (m^{-2}): The results in Table 2 showed that maximum tillers 298.3 m^{-2} were recorded under T6, followed by T_7, T_5 and T_4 with 288.3, 285.7 and 281.7 tillers m^{-2}. The T_4 and T_5 were statistically similar in terms of tillers m^{-2}. The minimum tillers 256.7 m^{-2} were observed in the plots where no foliar application was applied. Tillers (m^{-2}) have a direct significant effect on wheat grain yield. The number of tillers (m^{-2}) were significantly increased when all N, K and Zn were applied as foliar spray (Gull *et al.*, 2011). Awwad *et al.*, (2018) tested the efficiency of wheat crop against different planting methods and varying N levels applied as soil and foliar spray. The maximum number of tillers (456 and 467 m^{-2}) were produced when wheat field was supplemented with 60 kg N as soil + foliar application of urea in flat and terrace planting methods, respectively

Table 2. Tillers (m^{-2}) of wheat variety TD-1 as affected by foliar applied nitrogen and zinc at various growth stages

Treatments	R-I	R-II	R-III	Mean
T_1 = Control (No foliar application)	265	254	251	256.7 E
T_2 = 2.0 % nitrogen (tillering)	265	270	258	264.3 ED
T_3 = 2.0% nitrogen (booting)	262	280	283	275.0 CD
T_4 = 0.1% zinc (tillering)	288	278	279	281.7 BC
T_5 = 0.1% zinc (booting)	288	289	280	285.7 BC
T_6 = 2.0% nitrogen + 0.1% zinc (tillering)	306	298	291	298.3 A
T_7 = 2.0% nitrogen + 0.1% zinc (booting)	291	294	280	288.3 AB

Spike Length (cm): The results showed in Table 3 reveals that the maximum spike length (9.2 cm) was perceived under T_6 = 2.0% nitrogen + 0.1% zinc (tillering), followed by T_7 = 2.0% nitrogen + 0.1% zinc (booting) and T_3 = 2.0% nitrogen (booting) with 8.7 and 8.2 cm spike length, respectively. The diminishing trend in wheat spike length was noted when fertilized with 0.1% zinc at tillering stage, 0.1% zinc at booting stage and 2.0% nitrogen at tillering stage resulting in 7.8, 7.6 and 7.4 cm spike length. However, the plots where no foliar fertilization was applied remained lowest in spike length (7.0 cm). A recent study showed that 180 kg N, 18 kg Zn ha^{-1} combined with the application of 10 Kg humic acid gave a positive response in increasing the length of spikes of wheat crop (Iqbal *et al.,* 2022). Farooqi *et al.*, (2019) observed the highest 17.15 cm spike length when they treated their wheat crop with 8% N and 2% B foliar application. Zn along with other micronutrients such as Fe, Cu and B proved to be responsible for accumulating highest spike length in wheat crop (Ijaz *et al.*, 2023).

Table 3. Spike length (cm) of wheat variety TD-1 as affected by foliar applied nitrogen and zinc at various growth stages

Treatments	R-I	R-II	R-III	Mean
T_1 = Control (No foliar application)	7.0	6.6	7.4	7.0 E
T_2 = 2.0 % nitrogen (tillering)	7.4	6.9	7.9	7.4 DE
T_3 = 2.0% nitrogen (booting)	8.5	7.9	8.2	8.2 BC
T_4 = 0.1% zinc (tillering)	8.1	7.8	7.5	7.8 C
T_5 = 0.1% zinc (booting)	7.1	7.9	7.7	7.6 CDE
T_6 = 2.0% nitrogen + 0.1% zinc (tillering)	9.2	9.4	9.0	9.2 A
T_7 = 2.0% nitrogen + 0.1% zinc (booting)	8.9	8.5	8.7	8.7 AB

Grains Spike^{-1}: The data shown in Table 4 exhibited that the maximum grain spike^{-1} 56.5 and 54.2 were recorded under T_6 and T_7, respectively and have no significant difference. The T_5 and T_4 produced 51.1 and 48.4 grain spike^{-1}, respectively and were statistically alike. The minimum grain spike^{-1} 40.9 and 38.0 were recorded in T_2 and T_1, respectively and exhibited no significant difference between each other. Our results are in agreement with Bhutto *et al.*, (2016); they investigated the performance of wheat against various foliar concentrations of zinc and concluded that 2.0% Zn was responsible in the increment of number of grain spike^{-1}. Similarly, Farooqi *et al.*, (2019) also concluded that foliar spray consisting of 8% N significantly maximizes the quantity of grains per spike in the plants of wheat crop.

Table 4. Grains spike^{-1} of wheat variety TD-1 as affected by foliar applied nitrogen and zinc at various growth stages

Treatments	R-I	R-II	R-III	Mean
T_1 = Control (No foliar application)	36.5	41.0	36.6	38.0 D
T_2 = 2.0 % nitrogen (tillering)	41.6	40.0	41.0	40.9 D
T_3 = 2.0% nitrogen (booting)	48.0	45.0	41.6	44.9 C
T_4 = 0.1% zinc (tillering)	50.6	49.3	45.3	48.4 B
T_5 = 0.1% zinc (booting)	51.9	51.5	49.8	51.1 B
T_6 = 2.0% nitrogen + 0.1% zinc (tillering)	57.2	56.8	55.5	56.5 A
T_7 = 2.0% nitrogen + 0.1% zinc (booting)	53.0	55.6	54.0	54.2 A

Grain weight (g plant^{-1}): The results shown in Table 5 displayed that the maximum grain weight 24.7 g plant^{-1} was recorded under T_6 = 2.0 % nitrogen + 0.1 % zinc at tillering stage, followed by T_7 = 2.0 % nitrogen + 0.1 % zinc at booting stage and T_5 = 0.1 % zinc at booting stage with 22.0 and 20.1 g grain weight plant^{-1}. The diminishing trend in wheat grain weight g plant^{-1} was noted when fertilized with 0.1% zinc at tillering stage (T_4), 2.0 % nitrogen at booting stage (T_3) and 2.0 % nitrogen at tillering stage (T_2) resulting in 17.5, 14.6 and 12.0 g grain weight plant^{-1}. However, minimum grain weight 10.1 g plant^{-1} was recorded under control conditions. Our results are in line with a recent study conducted by Lyu *et al.*, (2022); documented that foliar application of urea significantly improved the weight of grains (mg) in comparison to foliar applied NO^{-}_3 and NH^{+}_4.

Table 5. Grain weight (g plant^{-1}) of wheat variety TD-1 as affected by foliar applied nitrogen and zinc at various growth stages

Treatments	R-I	R-II	R-III	Mean
T_1 = Control (No foliar application)	9.8	10.5	10.0	10.1 E
T_2 = 2.0 % nitrogen (tillering)	11.0	12.0	13.0	12.0 ED
T_3 = 2.0% nitrogen (booting)	13.2	15.7	14.8	14.6 D
T_4 = 0.1% zinc (tillering)	18.0	18.0	16.4	17.5 C
T_5 = 0.1% zinc (booting)	19.4	22.0	18.8	20.1 BC
T_6 = 2.0% nitrogen + 0.1% zinc (tillering)	25.9	21.5	26.7	24.7 A
T_7 = 2.0% nitrogen + 0.1% zinc (booting)	20.1	23.3	22.6	22.0 AB

Seed Index (1000-seed weight, g): The results in relation to seed index of wheat as affected by various combinations of liquid applied nitrogen and Zn are presented in Table 6. Results showed that maximum seed index 53.3, 51.5 g was recorded under T_6 = 2.0 % nitrogen + 0.1 % zinc (tillering) and T_7 = 2.0 % nitrogen + 0.1 % zinc (booting) and were statistically similar to each other. The seed index of T_5 (48.3 g) and

T_4 (45.8 g) was on 2nd and also statistically alike. The diminishing trend in wheat seed index was observed in rest of the treatments. However, the minimum seed index 38.0 g was observed in control treatment where no liquid N or Zn was applied. Iqbal *et al.,* (2022) conducted an experiment to evaluate the morphological traits, yield and yield components of wheat against numerous applications of nitrogen, zinc and humic acid. They concluded that a combined application of 160 kg N, 18 kg Zn and 15 kg humic acid proved to be responsible for increased 1000-weight grain (g). This shows that N and Zn have the ability to increase grain yield by enhancing 1000-grain weight (g). The highest the concentration of Fe and Zn in foliar application the highest is 1000 grain weight (Akhter *et al.,* 2022).

Table 6. Seed index (1000-grian weight, g) of wheat variety TD-1 as affected by foliar applied nitrogen and zinc at various growth stages.

Treatments	R-I	R-II	R-III	Mean
T_1 = Control (No foliar application)	37	39	38	38.0 D
T_2 = 2.0 % nitrogen (tillering)	39	40	42	40.3 CD
T_3 = 2.0% nitrogen (booting)	43	43	41	42.3 C
T_4 = 0.1% zinc (tillering)	44	44	49.5	45.8 B
T_5 = 0.1% zinc (booting)	47	48	50	48.3 B
T_6 = 2.0% nitrogen + 0.1% zinc (tillering)	55	53	52	53.3 A
T_7 = 2.0% nitrogen + 0.1% zinc (booting)	51.9	49.5	53.2	51.5 A

Grain yield (kg ha^{-1}): The data shown in Table 7 exhibited that the maximum grain yield 5907.0 and 5758.0 kg ha^{-1} was recorded under T_6 and T_7 and exhibited no significant difference. While producing 5374.0 and 5167.7 grain yields (kg ha^{-1}), T5 and T4 respectively, were also comparable to one another. The diminishing trend was observed in T_3 and T_2 where both these treatments produce 4753.0 and 4493.0 grain yield (kg ha^{-1}), respectively. The minimum grain yield 4111.7 kg ha^{-1} was measured in T_1. A two years experiment was conducted by Lyu *et al.,* (2022) where they stated that grain yield of Xinong-20 and Xiaoyan-22 was enhanced when urea fertilizer applied as foliar spray along with other nitrogen forms. The highest grain yield in various wheat cultivars was achieved when Zn and N were applied combine with foliar and soil application methods (Coronado *et al.,* 2017). Our results are also in agreement with Akram *et al***.,** (2017); concluded that grain yield of three wheat genotypes namely NIA-Amber, BWQ-4 and SD-998 was enriched when nitrogen and zinc were applied as 180 kg N and 10 kg Zn per hectare. Supplying nitrogen as 4% urea at tillering + heading stage of wheat can significantly improve the grain quantity of wheat crop (Shah ***et al*.,** 2003).

Table 7. Grain yield (kg ha^{-1}) of wheat variety TD-1 as affected by foliar applied nitrogen and zinc at various growth stages

Treatments	R-I	R-II	R-III	Mean
T_1 = Control (No foliar application)	4013	4367	3955	4111.7 E
T_2 = 2.0 % nitrogen (tillering)	4530	4393	4556	4493.0 D
T_3 = 2.0% nitrogen (booting)	4534	4936	4789	4753.0 C
T_4 = 0.1% zinc (tillering)	5067	5276	5160	5167.7 B
T_5 = 0.1% zinc (booting)	5437	5396	5289	5374.0 B
T_6 = 2.0% nitrogen + 0.1% zinc (tillering)	5870	6063	5789	5907.3 A
T_7 = 2.0% nitrogen + 0.1% zinc (booting)	5750	5882	5642	5758.0 A

CONCLUSION

It is concluded from the result that all the treatments of foliar applied nitrogen and zinc caused significant ($p \leq 0.5$) positive effect on growth and yield traits of wheat variety TD-1 as compared to control. Application of 2.0 % nitrogen + 0.1 % zinc was found most effective in producing morphological traits of wheat and maximizing yield and its components under agro-ecological conditions of Tandojam. It is recommended that farmers and growers can use 2.0 % nitrogen + 0.1 % zinc at tillering stage of wheat to get maximum grain yield (kg ha^{-1}).

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