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Effect of Foliar Application of Zinc and Boron on Growth, Yield and Quality Seed Production of Onion (*Allium cepa* L.) cv. Swat-1

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Abstract

Zinc and boron have a vital role in pollination, seed set processes and quality seed production. Foliar application of micronutrients enhances plant growth and yield. A research on quality onion (*Allium cepa* L.) seed production through investigating the effect of zinc and boron essential micronutrients at substation of Agriculture Research (MA), district Bajaur during the year 2024-25. Onion bulbs (cv. Swat-1) were sowed as planting material for seed production purposes. Zinc and boron were sprayed as foliar spray with a rate of 0, 0.2, 0.4, 0.6% and 0, 0.3, 0.6, 0.9% respectively. Randomized Complete Block Design with two factors was assigned for the experiment. Results depicted that application of both boron and zinc micronutrients positively affected all the studied attributes. Highest number of leaves per plant, leaf lengthplant⁻¹, number of umbels per plant⁻¹, number of seeds per umbel, weight of 1000 seeds (g), yield of seeds plant⁻¹ and yield of seeds ha⁻¹ (kg ha⁻¹) and less days to flowering were recorded in % zinc and % boron, respectively. However, non-significant interactions were recorded for the above mentioned parameters. It is concluded from the obtained results that maximum growth, yield characters and quality onion seeds ha⁻¹ (401.8, 400.3 kg ha⁻¹) were recorded at the rate of 0.6% zinc and 0.9% boron application in foliar spray under the agro climatic condition of Bajaur.

Keywords: *Allium cepa* L., Zinc, Plant growth, Boron, Onion, Umbel, Seed production, and Yield.

1. Introduction

Onion (*Allium cepa* L.) is one of the most essential spices as well as vegetable crops in the world including Pakistan which belongs to the Alliaceae family. With a global yield of dry bulbs production of 88 million tons, it is the third most important culti-

vated vegetable (FAO, 2014). Different essential biochemical constituents are present in it due to which it has many medicinal and functional properties (Lanzotti, 2006). It is a biennial in nature crop and for the production of onion seeds better selection of good quality bulbs are required. For the seed purposes bulbs

are obtained from known variety seed in first season and are used for replantation to get seed of same variety in another season. In the onion production better quality seed has a major and a vital role. Improved and quality seed contributes greatly to increase crop yield more than 30% (Shaikh *et al.*, 2002).

Conditions such as calcareous nature, alkaline reactions in soils, low organic matter content and absorption of zinc, boron are not conducive to the accessibility of micronutrients to crops. However, on such type of soils, applying these nutrients through foliar spraying proves to be a valuable method to combat micronutrient deficiencies (Silberbush, 2002).

Foliar application offers advantages over soil application, including effectiveness, a rapid response and the elimination of deficiency symptoms. Growth and yield of plant are enhanced by the existence of various micronutrients in foliar application. Nutrients are commonly more fastly absorbed by plants through foliar application compared to soil application. In fact, micronutrients applied in foliar can be six to twenty times more effective than when applied to the soil (Liew, 1988; Ullah *et al.*, 2023). Successful onion seed production relies on particular environmental conditions. Additionally, different cultivars of onion exhibit varying sensitivities to their growing environmental conditions, particularly concerning photoperiod and temperature (Rahim *et al.*, 1982; Mondal and Siddique, 1981). The growth and production of onion seeds are significantly affected by various factors, such as optimizing fertilizer application and conserving soil moisture (Singh *et al.*, 1996; Anez, 1996; Dubey and Khan, 1993). Zinc plays a crucial role in numerous physiological functions within plants. It is a constituent of several plant enzymes that regulate various metabolic processes in crops. Zinc is also essential for the development of plant auxin and plays an essential contribution during water absorption process (Sindhu, 1993). Insufficient zinc levels lead to various abnormalities and malformations in plants, resulting in less new vegetative growth as well as the development of narrower and smaller leaves (Singh and Pandey, 1995; Gardner, 1966; Hossain *et al.*, 2023).

Boron holds a crucial role as a micronutrient with diverse functions in plants. Despite being required in small quantities; it is one of the most commonly used micro-elements. Its deficiency in soil can significantly hinder crop yield. Boron plays numerous essential roles in plant metabolism, including facilitating the proper development of meristematic tissues. It is necessary for vital processes like salt absorption, nitrogen and carbohydrate metabolism, cell division, and maintaining water relations within the plant (Rao, 1971). Boron contribute plays an important role in the translocation of starches, sugars, phosphorus and nitrogen as well as in the synthesis of proteins and amino acids (Varma *et al.*, 2005; Tisdale *et al.*, 1984). Extensive studies conducted across various regions of the world have demonstrated the remarkable impact of different doses of boron on several aspects of onion production, including germination percentage, plant height, leaf production, weight of 1000 seeds, seed yield and seed quality (Bhonde *et al.*, 1999; Maury *et al.*, 1975). Zinc and boron play crucial roles in fertilization as well as seed set processes, their insufficiency can lead to reduced seed formation and consequent yield reduction. The survey of soil fertility has revealed that the physic-chemical conditions of KPK soils are not favorable to providing sufficient micro-nutrients (Munir *et al.*, 2006; Ullah *et al.*, 2023).

Zinc serves a protective function against the toxic effects of high boron concentration in the root zone (Graham *et al.*, 1987; Singh *et al.*, 1990). Applying micronutrients in a foliar form proves to be a valuable method to combat micronutrient deficiency and enhance crop growth. This approach offers advantages over soil application, including rapid response, greater effectiveness, and the elimination of deficiency symptoms. In certain regions of Pakistan, the bulb to seed method is employed for producing seeds of this particular variety. The local variety of onion, known as Swat-1, is widely cultivated throughout the country. The existing data regarding the impact of plant nutrients, specifically boron and zinc on onion seed production in Pakistan, is inconclusive. There is a limited amount of research conducted on the impact of boron and zinc on seed production in Pakistan. This research study has been focused on establishing a quality onion seed production through investigating

the effect of zinc and boron on seed production of onion to enhance local production of high-quality onion seeds, reducing dependency on imported seeds and ensuring the availability of seeds suitable for local agro-climatic conditions keeping in view the role of micronutrients.

2. Materials and Methods

The research study was performed at Experimental Farm of Agriculture Research Merged Areas, Bajaur. The experiment was performed to study the efficacy of zinc and boron application on the quality seed production of onion. Four different levels of zinc with concentration (0%, 0.2 %, 0.4 %, and 0.6 %) and boron having concentration (0%, 0.3%, 0.6% and 0.9%) were given in a foliar spray in RCBD with three replications.

Swat-1 was cultivated in the experiment, which is a popular variety at KP with better qualities. The experimental beds were prepared from a good soil media a month before planting the bulbs. Soil analysis was conducted before field preparation. Field was well prepared and all the suggested cultural practices were done during the period of experiment. Based on soil analysis report the required amount of NPK fertilizer was added to the beds before sowing. Half dose of the nitrogen was given at sowing time and remaining half was given at stage of heartening up. Based on the color, shape, size of the bulb and confirming to varietal characters were selected and planted on dated 20th October, 2024. Before planting, the one third top portion of the bulb were cut and removed. Then the bulbs were cured with fungicide like copper oxychloride of 0.2 percent solution for 5-10 minutes before sowing. Treated bulbs were planted on ridges at 30 cm bulb to bulb and 60 cm row to row spacing.

The fields were maintained free of weeds and off types plants were removed. Percent zinc and boron solution was prepared while zinc sulphate and boric acid were used as a source material. Both zinc and boron solution sprayed with hand held atomizer directly on the plants at proper stages. The spraying was done at early within the morning to avoid its drying because of transpiration. During the period of flowering formation stage the application was avoided. Seeds were collected individually from each plot based on the maturity of the umbels. This involved cutting off the umbels when approximately 15-20% of them had opened. The harvested umbels were cut at proper stage and dried under shade. Following the harvest, the seeds were carefully dried in the sun before proceeding to the threshing stage. Threshing of umbels, cleaning of seeds, and weighing were carried out manually on a plot wise basis.

Experimental data of onion crop were recorded for no. of leaves per plant, leaf length plant^{-1} , days to flowering, number of flowers umbel $^{-1}$, number of umbels per plant $^{-1}$, number of seeds umbel $^{-1}$, weight of 1000 seeds (g), yield of seeds plant $^{-1}$ and yield of seeds ha $^{-1}$ (kg ha $^{-1}$). The growth parameters were recorded at proper stages during growing season. All the umbels were harvested, sundried, threshed, and cleaned manually and the remaining parameters were recorded.

Soil analysis of experimental site

Before sowing, a composite soil sample was obtained from the research field with a depth of 0-15 cm. This sample analysis was done to determine various physico-chemical properties, including soil texture, electrical conductivity (EC), lime content, and soil pH, organic matter and NPK at Soil and Water Testing Laboratory Agriculture Research (MA), district Bajaur.

Table 1: Physico-chemical properties of experimental soil used during research.

| Determinants | Obtained results |
|------------------------------|------------------|
| Soil texture | Silt-Loam |
| pH (1:5) | 7.6 |
| Organic matter(%) | 0.96 |
| EC (dS/m) | 0.27 |
| Nitrogen(%) | 0.62 |
| Lime (%) | 0.6 |
| Phosphorous (AB-DTPA)(mg/kg) | 5.09 |
| Potassium (mg kg $^{-1}$) | 98 |

3. Results and Discussion

Plant height (cm)

Plant height (cm) is significantly influenced by the foliar application of zinc and boron. The application of 0.6% zinc resulted in the highest plant height recorded (71.5cm), while the minimum height (67.8cm) was observed under control treatment (Table 01). However, highest plant height (70.4cm) obtained at the rate of 0.9% boron application and less plant height (66.9cm) was recorded in the control treatment. Non-significant interaction was found in foliar application of zinc and boron. In their study, Chattopadhyay and Mukhopadhyay, (2004) found that the application of higher doses of boron resulted in an increase in plant height. The favorable influence of micro-nutrients, particularly zinc on growth of plants can be attributed to its contribution in numerous physiological, enzymatic processes and cellular essential functions within the plants. Additionally, they play a crucial role in enhancing plant growth by facilitating the synthesis of vital endogenous plant hormones accountable for enhancement of growth (Hansch and Mendel, 2009). Similar findings were also noted by Ballabh *et al.* (2013). Boron plays an essential role in many vital processes within plants, including cell division, carbohydrate metabolism and nitrogen, as well as water and salt absorption relations. It is also involved in the translocation of starches, sugars, phosphorus nitrogen and plays a fundamental role in the formation of proteins and amino acids (Varma *et al.*, 2005; Tisdale *et al.*, 1984). These effects include influencing germination percentage, leaf production, plant height, 1000 seeds weight, seed yield and overall seed quality (Bhonde *et al.*, 1999; Uddin *et al.*, 2022).

Number of leaves plant⁻¹

Zinc and boron foliar application had a significant effect on number of leaves per onion plant. Greater number of leaves per plant (22.3) was observed when 0.6% zinc was applied, while less number (16.9) was recorded in the control application (Table 2). While in case of boron application maximum number of leaves (21.1) was obtained at the rate of 0.9% boron and minimum number of leaves per plant (18.5) was recorded in the control. However, non-significant interaction effect was recorded. Zinc plays a crucial

role in various fundamental carbon metabolism and cellular mechanisms, ultimately influencing the development and growth of vegetable crops. Moreover, zinc is a vital constituent of many enzymes, including superoxide dismutase and catalase, which help protect plant cells from oxidative stress. Additionally, zinc is involved in the production of tryptophan, a precursor of auxin a critical growth hormone essential for plant growth. These findings align with the results observed by Gamili *et al.* (2000). Boron is considered one of the essential elements for almost higher plants and its involvement extends to various essential biological processes. It contributes a vital role in photosynthesis, nitrogen fixation, the growth of meristematic tissues, transpiration, respiration and other essential biochemical processes (Pinho *et al.*, 2015).

According to Howlader *et al.* (2010), the higher no. of leaves per plant observed might be attributed to the role of boron in enhancing nutrient availability, which in turn promotes more extensive vegetative growth. In addition to its role in nutrient availability, boron also serves as a crucial structural component of cell wall ingredients. Its deficiency can lead to disruptions in cell wall structure and function, as well as reduced expression of various enzymes located in the cell wall that are involved in cell enlargement. As a result, boron stimulates cell division and expansion, particularly in meristematic tissues, leading to increased plant growth (Al-Tameemi and Al-Juboori, 2020). The progressive increase in the application of boron is associated with a corresponding increase in the growth parameters of onion. This effect is likely due to the role of boron in promoting cell division, enhancing meristematic activity in plant tissues, and facilitating cell expansion (Patil *et al.*, 2009).

Leaf length plant⁻¹

The application of zinc and boron had a highly significant effect on leaf length per plant (Table 1). The maximum leaf length per plant recorded was 28.1 cm was observed from the application @ 0.6% zinc and minimum seed yield plant⁻¹ (22.3 cm) was recorded in the control. Similarly, maximum seed yield per plant (26.3 cm) were obtained at the rate of 0.9% boron while minimum leaf length plant⁻¹ (24.2

cm) in the control. Significant interaction was not observed in zinc and boron application. The application of zinc has been associated with an increase in growth parameters, which can be attributed to its role in various physiological processes like cell division, photosynthesis, and nitrogen metabolism. Zinc also plays a critical role in the biosynthesis of cytochrome and maintains the integrity of the plasma membrane. Moreover, zinc influences the activity of carbonic anhydrase, an enzyme involved for carbo-hydrate fixation in plants in converting carbon dioxide to reactive bicarbonate species. It is also a component of enzymes such as catalase and superoxide dismutase, which help protect plant cells from oxidative stress. Additionally, zinc's involvement in the production and synthesis of tryptophan, a precursor for auxin, contributes to its role as an essential growth hormone for plant development. These findings align with previous studies by Jitendra *et al.* (1989) and Lal and Maurya, (1981). Similarly, the application of boron leads to an increase in growth parameters in onion plants, because of its role in cell expansion, cell elongation, cell division and meristematic activity. Furthermore, boron's favorable effects on plant growth are linked to its involvement in physiological processes such as metabolism of carbohydrate and protein, as well as cellular functions within the physiology of plants. Boron primarily influences development of hormone and the inhibition or stimulation of specific metabolic pathways, contributing to its beneficial effects on plant growth (Waqar *et al.*, 2009).

Days to flowering

The foliar spray of boron and zinc had significant effects on the days to flowering of the onion crop, as given in Table 01. The longest time (185.2) were observed when zinc was given at the rate 0.6% and shortest time (171.2) was reported in the lowest level of application. According to Khan *et al.* (2007), the application of zinc resulted in a reduction in the no. of days to flowering in the onion crop in lower level as zinc is essential micronutrient which acts as an enhancer on other plant growth regulators due to days to flowering may get enhanced. The results also indicated a significant impact of boron on the days required to flowering. The application of 0.9% boron led to the minimum time (180.4 days) from planting to flowering, while the control treatment recorded the maximum time (176.3 days) for days to flowering. Non-significant interaction was observed. Mishra *et al.* (1990) reported a decrease in the number of days needed for flowering with the use of higher doses of boron. Similarly, Jana and Mukhopadhaya, (2002) also found that the days to flowering reduced with the use of higher doses of both zinc and boron. The improvement in the number of flowers per plant can be accredited to the role of micronutrients, such as zinc and boron in meristematic activity, promoting cell division in plant tissues, and expansion of cells, ultimately leading to an increased number of flowers (Patil *et al.*, 2009; Ullah *et al.*, 2022).

Table 2: Impact of application of zinc and boron in foliar form on plant height at harvest (cm), leaf length plant⁻¹, number of leaves plant⁻¹ and days required to flowering.

| Foliar Application | Plant height (cm) | Number of leaves plant ⁻¹ | Leaf length plant ⁻¹ | Days to flowering |
|----------------------|-------------------|--------------------------------------|---------------------------------|-------------------|
| Zinc Levels (%) | | | | |
| 0 | 67.8 | 16.9 | 22.3 | 185.2 |
| 0.2 | 63.2 | 19.2 | 24.9 | 178.8 |
| 0.4 | 67.4 | 20.4 | 26.5 | 175.4 |
| 0.6 | 71.5 | 22.3 | 28.1 | 171.2 |
| LSD at α 0.05 | 2.578 | 1.238 | 1.099 | 1.652 |
| Significance Level | *** | *** | *** | *** |
| Boron Levels (%) | | | | |
| 0 | 66.9 | 18.5 | 24.2 | 180.4 |
| 0.3 | 64.6 | 18.8 | 25.8 | 177.4 |
| 0.6 | 68.0 | 20.3 | 25.6 | 176.5 |
| 0.9 | 70.4 | 21.1 | 26.3 | 176.3 |

| | | | | |
|-------------------------------|-------|-------|-------|-------|
| LSD _{0.05} | 2.578 | 1.238 | 1.099 | 1.652 |
| Significance Level | * | *** | ** | *** |
| CV% | 4.52 | 7.54 | 5.18 | 1.12 |
| LSD for (ZxB) _{0.05} | N.S | N.S | N.S | N.S |

Number of umbels plant⁻¹

Data presented in the table 02 for the number of umbels plant⁻¹ were analyzed. Statistical analysis shown that both boron and zinc had a significant influence on the number of umbels per plant. Specifically, the plants that received 0.6% zinc gave the maximum number of umbels plant⁻¹ (14.2). In contrast, minimum number of umbels plant⁻¹ (9.0) were produced in the control. In case of boron application highest numbers of umbels plant⁻¹ (12.7) were observed at the rate of 0.9% boron and less number of umbels (10.4) plant⁻¹ were recorded in the control. However, non-significant interaction was observed. According to Mishra *et al.* (1990), the days required for the first bolting in plants reduced with the use of maximum doses of zinc. With the application of higher doses of zinc, the number of flowers per plant increased (Mukesh *et al.*, 2000; Ullah *et al.*, 2023). Similarly, Rashid *et al.* (2007) described that a high dose of boron also led to an increase in the number of umbels per plant. Furthermore, the interaction impact of boron and zinc on the number of flowers per plant were statistically non-significant. This indicates that the combined application of boron and zinc had a significant impact on the number of flowers produced by each plant. Indeed, both zinc and boron are crucial micronutrients that play essential roles in various aspects of plant growth. They are necessary for important processes such as cell division, carbohydrate metabolism, nitrogen and water relations within the plants (Brady, 1990). Proper availability and application of these micronutrients are vital to ensure healthy and robust growth of onion crops.

Number of seeds umbel⁻¹

Data presented in Table 02 demonstrate that the number of seeds per umbel in onion has significantly influenced by both boron and zinc. The highest number of seeds per umbel (609.9) was recorded when zinc was given at a rate of 0.6%, whereas the lowest number (480.4) was obtained with no zinc application (control). Similarly, Khan *et al.* (2007) also found a maximum no. of seeds per umbel while zinc was

applied @ of 5 kg ha⁻¹. Regarding boron, significant effect was observed in the no. of seeds per umbel. The highest number of seeds per umbel (583.8) was obtained with the foliar application of 0.9% boron, while the minimum number (506.3) was recorded in the control group. Statistical analysis showed non-significant interaction. Chattopadhyay and Mukhopadhyay, (2004) also reported that application of higher doses of boron increased the number of seeds per umbel. Moreover, non-significant interaction was observed. Jana and Mukhopadhyay, (2002) found that the number of seeds per umbel improved with the use of higher doses of both zinc and boron.

Weight of 1000 seeds

Boron and zinc combined application had significant impact on the 1000 seeds weight, while their interaction was non-significant. In case of zinc greater 1000 seeds weight (4.0g) was recorded from the foliar application of 0.6% Zinc and the lower weight (2.5g) was obtained from the treatments of control. In term of boron application highest weight of 1000 seeds (3.6g) were recorded at 0.9% dose of boron while less weight of 1000 seeds (2.8g) was obtained in the control treatment. Interactions was non-significant. Khan *et al.* (2007) expressed a similar viewpoint, reporting that the use of zinc @ 4 kg ha⁻¹ led to an increase in the seed yield per plot. The observed rise in seed yield could possibly be attributed to the beneficial impact of boron. Regarding boron's potential role in growth of pollen tube, it may involve processes like fusion, vesicle production, transport, or the subsequent formation of the pollen cell wall. Notably, precursors for pollen tube cell wall are abundant in polypeptides, mainly glycoproteins, and polysaccharides (Li and Liskens, 1983). Furthermore, the application of micronutrients to facilitate the mobilization to the developing seeds of photosynthates could potentially account to enhance in seed weight (Sivaiah *et al.*, 2013).

Seeds yield (kg ha⁻¹)

Data regarding the seeds yield (kg ha⁻¹) were evaluated and given in Table 02. Obtained results revealed that

both B and Zn have positively influenced the seeds yield (kg/ha). The greater seed yield (401.8 kg/ha) was obtained with the foliar application of 0.6% Zinc and minimum seed yield (358.8kg/ha) was observed in the control. Similarly seed yield (kg ha⁻¹) was also significantly affected with application of boron. Highest seeds yield (400.3 kg ha⁻¹) was obtained from the foliar application of 0.9% boron and less seeds yield (365.7 kg/ha) was noted in the control. Significant interaction was recorded. Accumulation of Zn in the plant leads to increased rate of photo-

synthesis and improved production of plant hormones like IAA, gibberellins and cytokinins (Rehman *et al.*, 2018). Maintaining a consistent supply of Zn throughout the plant's development could potentially enhance seed yield due to improved plant growth. The current research focused on applying Zn through foliar application, which resulted in positive effects on seed traits, including improved seed germination, increased 1000-seed weight and higher seed yield.

Table 3: Influence of zinc and boron foliar application on number of umbels per plant, number of seeds umbel⁻¹, weight of 1000 seeds (g) and yield of seeds (kg ha⁻¹).

| Foliar Application | Number of umbels plant ⁻¹ | Number of seeds per umbel | Weight of 1000 seeds (g) | Yield of seeds (kg ha ⁻¹) |
|-------------------------------|--------------------------------------|---------------------------|--------------------------|---------------------------------------|
| Zinc Levels (%) | | | | |
| 0 | 9.0 | 480.4 | 2.5 | 358.8 |
| 0.2 | 10.6 | 536.7 | 2.9 | 376.5 |
| 0.4 | 11.9 | 591.3 | 3.3 | 385.3 |
| 0.6 | 14.2 | 609.9 | 4.0 | 401.8 |
| LSD _{0.05} | 0.943 | 42.321 | 0.315 | 4.584 |
| Significance Level | *** | *** | *** | *** |
| Boron Levels (%) | | | | |
| 0 | 10.4 | 506.3 | 2.8 | 365.7 |
| 0.3 | 10.9 | 559.2 | 3.2 | 370.4 |
| 0.6 | 11.7 | 569.2 | 3.3 | 386.0 |
| 0.9 | 12.7 | 583.8 | 3.6 | 400.3 |
| LSD _{0.05} | 0.943 | 42.321 | 0.315 | 4.584 |
| Significance Level | *** | ** | *** | *** |
| CV% | 9.91 | 9.15 | 11.81 | 1.44 |
| LSD for (ZxB) _{0.05} | Non-Sig. | Non-Sig. | Non-Sig. | 9.168 (***) |

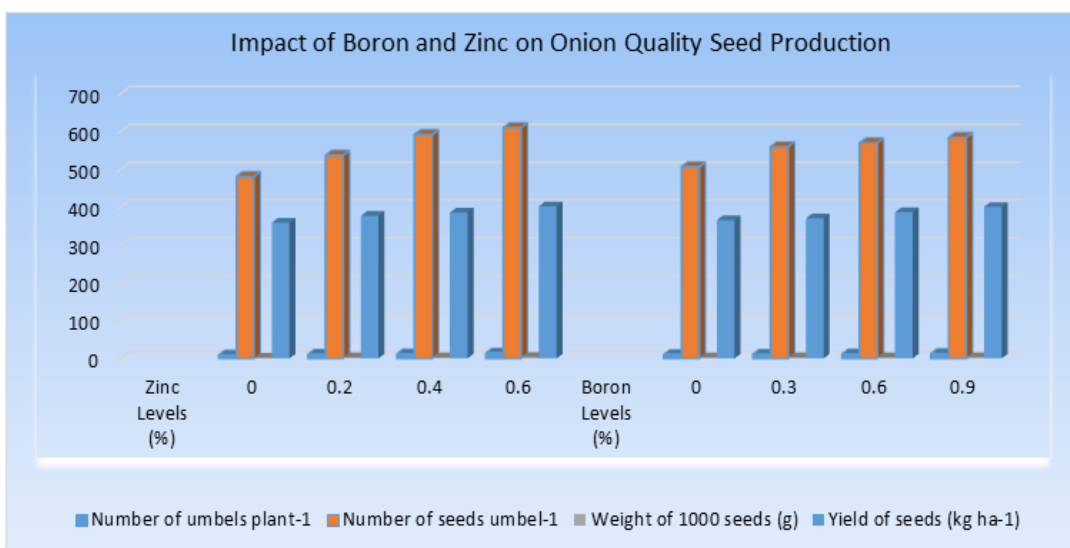


Fig. 1: Graphical representation of onion production due to effect of Boron and Zinc.

Our findings indicate that Boron (B) also played a crucial role in enhancing seed characteristics, such as seed germination, 1000-seed weight, and enhance seed size. Boron is vital for various physiological vital processes in crop plants, such as maintaining membrane integrity, cell elongation, promoting cell maturation, activating dehydrogenase enzymes, facilitating leaf expansion, supporting meristematic tissue development, aiding translocation of sugar, and promoting synthesis of protein. Moreover, Boron's importance extends to plant reproductive growth, influencing crucial aspects like pollen tube elongation, pollen grain germination, seed, fruit set, and overall yield (Christensen *et al.*, 2006). Chowdhury *et al.* (2004) recorded a significant increase in seed yield when higher doses of boron were applied. Similarly, Robinowitch *et al.* (2002) demonstrated that foliar application of boron led to an improvement in onion seed yield. Moreover, both boron and zinc are vital for enhancing growth and seed production of a crop, as they contribute to the biosynthesis of plant endogenous hormones responsible for stimulating seed production in plants (Hansch *et al.*, 2009).

4. Conclusion

Foliar application of both zinc and boron shows significant result towards the growth, quality seed production of onion. Growth parameters such as plant height at harvest (cm), leaf length plant⁻¹, number of leaves per plant, were enhanced and significantly affected by foliar application of boron and zinc. Numerous studies conducted across different regions of the world have established the remarkable effects of boron at varying doses on various aspects of onion seed production. As micronutrients, they have a positive impact on the growth characteristics of onion plants and can markedly influence their overall development and productivity. The beneficial impact of zinc on plant growth is attributed to its involvement in various physiological processes and cellular functions within plants. Yield parameters were also highly responded to zinc as well as boron, so high application dose of boron and zinc may have depicted maximum yield.

5. Author Contributions

A.U.: conceived and designed the experiments. A.U.; and Z.J.: performed the experiments. H.; F.K.; and

B.R.: analyzed the data. M.A.; and S.H.: contributed reagents, materials, and analysis tools. A.U.; and Z.S.: wrote the manuscript.

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7. Conflicts of Interest

The authors declare that they have no competing interests.

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