GROWTH AND YIELD PERFORMANCE OF CHICKPEA THROUGH FOLIAR APPLICATION OF ZINC AND BORON

SHABIHA SARKER

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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BY

SHABIHA SARKER

REGISTRATION NO. 19-10380
E-mail Id: shabihasarker@gmail.com
Phone No. 01796838049

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Approved by:

…………………………..	…………………………………….
Shimul Chandra Sarker	**Prof. Dr. H. M. M. Tariq Hossain**
Assistant Professor	**Co-Supervisor**
Supervisor	

…………………………………....
Prof. Dr. Md. Abdullahil Baque
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that thesis entitled, "**GROWTH AND YIELD PERFORMANCE OF CHICKPEA THROUGH FOLIAR APPLICATION OF ZINC AND BORON**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **SHABIHA SARKER,** Registration no.**19-10380** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Date:

Dhaka, Bangladesh

…………………………………..

Shimul Chandra Sarker

Assistant Professor

Department of Agronomy

Sher-e-Bangla Agricultural University,

Dhaka-1207

Dedicated to

My

Beloved Parents

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ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2020 to April 2021 in Rabi season, to study the growth and yield performance of chickpea through foliar application of zinc (Zn) and boron (B). The experiment consisted of two factors. Factor A. Different concentrations of Zn application: Zn_0= Control (Water spray), Zn_1= Basal application of Zn, Zn_2= 0.5 % foliar application at pre-flowering stage, Zn_3= 1 % foliar application at pre-flowering stage and Factor B. Different levels of B application: B_0= Control (Water spray), B_1= Basal application of B, B_2= 0.5 % foliar application at pre-flowering stage and B_3= 1 % foliar application at pre-flowering stage. Experimental result showed that foliar application of Zn and B were effective method for boost up of yield in chickpea compared to soil application and control treatment. In the case of different Zn levels, the lowest seed yield (1.02 t ha^{-1}) was recorded in the control treatment (Zn_0). The highest number of pods $plant^{-1}$ (27.79), seeds pod^{-1} (2.97), 1000-seed weight (109.06 g) and seed yield (1.75 t ha^{-1}) were recorded in Zn_3 (1 % foliar application at pre-flowering stage) treatment. In the case of different B treatments, the seed yield ranges between (1.19 -1.60 t ha^{-1}). The highest seed yield (1.60 t ha^{-1}) was recorded in B_3 (1 % foliar application at pre-flowering stage)treatment. Both Zn and B @ 1% solution sprayed at the pre-flowering stage (Zn_3B_3) effected chickpea plant growth and yield contributing characteristics, leading to the maximum seed yield (2.01 t ha^{-1}) than compared to other treatment combinations. Therefore, it could be suggested that application of Zn (1.0 %) and B (1.0 %) by foliar spray at pre-flowering stage is beneficial for better yield and quality production of chickpea crop.

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ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Boron	B
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Food and Agriculture Organization	FAO
Fresh weight	FW
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Ton	T
Gram	g
Percentage	%
Meter	M
Hectare	Ha
Kilogram	Kg

CHAPTER-I

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the second most important pulse crop globally, after common bean (*Phaseolus vulgaris*) (Singh *et al.*, 2021). It delivers benefits to farming systems that range from a smaller carbon footprint due to biological nitrogen fixation to improved soil health. Chickpea is a quality food source rich in proteins, minerals, vitamins, and fibres that benefit the health of domestic stock and humans (Madurapperumage *et al*., 2021). They can be an affordable source of staple grain for millions of the world's poorest and are a nutritious stock feed (Iriti and Varoni, 2017)). Chickpea is predominantly grown under rainfed conditions on stored soil water in arid and semiarid regions, and is an integral component of cereal-legume cropping systems in many countries. The global area of chickpea averages 13.0 million hectare with a total production of 12.4 million tons across 56 countries (FAOSTAT, 2020). The major chickpea producing countries are India, Australia, Pakistan, Turkey, Myanmar and Ethiopia account for about 90% of world chickpea production (Hoque, *et al*., 2021)

Chickpea is one of the major pulse corps in Bangladesh. In 2020-21, 2.30 % area was cultivated pulse crop in Bangladesh under the total cultivated area. Total production of chickpea in Bangladesh 8051 metric ton and the total cultivated area is about 18501 acres in (BBS, 2021).

The progress on increasing chickpea yields has stagnated in recent years and on average remains below 1.0 t ha^{-1}. The current yields of chickpea are insufficient for meeting the growing demand of plant-based foods, especially dietary protein (Sadras *et al*., 2021). Major constrains in increasing production of chickpea are poor soils, inadequate moisture, adverse climatic conditions, weeds and inadequate or even no fertilizer supply (Hoque *et al*., 2021).

Along with macronutrients micronutrients are essential elements required for plant growth and development at smaller amounts. Iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), molybdenum (Mo), and nickel (Ni) are metal micronutrients that participate in various reactions in plant cells or contribute to protein structure. (Moinudden *et al*., 2017). The nutrients can be applied to crop plants in variety of ways like seed treatment, soil and foliar application (Rehim *et al*., 2012). Foliar application of micronutrients is 6–20 times more useful than the soil application, which improves the nutrition (Dass *et al*., 2022).

Zn plays major role in many physiological processes *viz*., chlorophyll formation, pollen formation, fertilization, protein synthesis, cell elongation, nodule formation, regulatory cofactor for a variety of enzymatic functions (Sattar *et al*.,2022) and regulates the growth and development. Hence, Zn nutrition favourably influences the growth, yield, physiological parameters and nodule formation in pulses. Zn deficiency is the most common cause of yield reductions in numerous agronomic crops cultivated around the globe, and is prelevant in soils of major chickpea producing countries (e.g. India, Pakistan, Iran, Turkey) (Ullah *et al.,* 2019). Optimum dose of Zn helps maintains the water status, stomatal regulation and adjustment of guard cells in chickpea under water stress (Sattar *et al*., 2022). Furthermore, foliar applied Zn improves the crop growth which ultimately increases the yield because it has ability to regulate stomatal openings, improving photosynthetic efficiency, increases in the chlorophyll formation and also increase in the leaf area of plant (Karim *et al*., 2012).

B also plays important role in plant pollen tube growth, cell division, leaf expansion, formation of cell wall, cell elongation, membrane integrity, water relations of plant ionic absorption and all these processes might be affected due to shortage of B (Gupta and Solanki, 2013). Foliar application of B is the most productive when roots of plants are unable to absorb boron from soil due to the physical and chemical properties of soil such as soil pH, soil texture, cultivation, soiltemperature, microbial action, organic matter and leaching losses (Jalilian *et al*., 2016).B as a foliar spray at early stage can't give better result as better at booting stage of crop (Fakir *et al*., 2016). B as a foliar spray improved the grain size, number andyield (Ahmad *et al.,* 2021). It has been seen that the leaves of the plant were more efficient in nutrient uptake through leaves as compared to uptake by roots through soil(Fernandez and Brown, 2012).

Foliar sprays of micronutrients aid their rapid translocation, reducing plant stress, especially under late-sown conditions. Exogenous nutrition administration could be a useful strategy for reducing the adverse effects of heat (Waraich *et al.*, 2012). Zn is essential during the reproductive phase of crops. Rahman *et al.* (2017) reported that foliar application of micronutrients mixtures (Zn, Fe, Mg, Cu, B and Mn) in combination with nitrogen improved the plant growth, yield and yield components of chickpea. Kachave *et al.* (2018) indicated that foliar application by multi micronutrients gave the maximum seed yield and seed protein content of chickpea. Therefore, by considering the above facts, the research work was carried out with the following objectives: -

- ❖ To study the effect of foliar application of Zn or B on the growth and yield of chickpea.
- ❖ To assess and compare the combined effect of foliar application of Zn and B on the growth, yield and yield contributing characteristics of chickpea.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to investigate the growth and yield performance of chickpea through the foliar application of Zn and B, to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of zinc application

2.2 Plant height

Rathod *et al*. (2020) determined that plant height of chickpea significantly increased due to foliar application of Zn and B. The foliar application of Zn and B, which played a significant role in the synthesis of growth hormones such as tryptophan and auxin, which in turn increased chickpea growth parameters.

According to Jadhav *et al*. (2019), the role of foliar application in the synthesis of indole-3-acetic acid, auxin metabolism, biological activity, stimulating effect on enzyme activity, and photosynthetic pigments, which in turn encourage plant vegetative growth of plants.

Kayan *et al*. (2015) studied a comparative effect of 0, 0.6 and 0.8 percent Zn levels of Zn chelate (Zn-ethylene diamine tetraacetate: 8% Zn) and Zn sulphate (23% Zn) applied as foliar spray for Zn deficiency of chickpea. The results revealed that increased Zn doses resulted an increase in plant height of chickpea.

Ehsanullah *et al*. (2015) reported that the highest plant height was obtained in the treatment of foliar application of $ZnSO_4$ at flowering which might be attributed to the role of Zn to synthesize the plant growth regulator such as auxins, which takes active role in enlargement and elongation of plant cell.

Hussain *et al.* (2022) reported that significant plant height obtained with foliar the application of Zn and B. Zn (0.5%) foliar treatment along with B (0.5%) gave maximum plant height.

Number of branches plant^{-1}

Doddamani *et al*. (2020) conducted a field bean experiment to determine the influence of foliar Zn and B administration on vegetative development, fruiting order, and yield. The results of the experimental trial indicated that the vegetative growth like number of branches plant^{-1} was significantly influenced by Zn and B foliar application treatments.

Sangolli*et al*. (2018) took an investigation with the aim of knowing the effects of Zn nutrition on morphological characters in chickpea. Results revealed significant differences with respect to number of branches as influenced by Zn nutrition.

Drostkar*et al*. (2016) performed a field experiment to find out the effects of foliar application of Zn, Iron and NPK as nano-fertilizers on chickpea at rainfed conditions. Number of branches plant^{-1} was significantly increased as compared to plants grown in normal (No fertilizer) condition.

According to results of Shivay *et al*. (2014) it was observed that all the treatments in which $ZnSO_4$ was applied as soil application, foliar spray or in combination of both noticed significantly higher number of primary branches in comparison to control.

Dry matter weight plant^{-1}

Brijnandan *et al.* (2018) carried out an investigation to study the influence of Zn and Fe on growth, yield and quality of chickpea (*Cicer arietinum* L.) under rainfed subtropics. Among the Zn and Fe treatment, the treatment RDF followed by foliar application of Zn (0.5%) and Fe (0.05%) at pre-flowering and pod formation stage given to chickpeavarieties recorded significantly dry matter accumulation at 90 DAS and at harvest.

Valenciano (2010) observed that the applications of Zn, B and Mo with natural conditions and acidic soils and their experimental results showed that both soil Zn and B applications at high moisture availability, increases the total dry matter and grain yield.

Number of pods plant^{-1}

Nandan *et al*. (2018) found that Zn and Fe treatments through foliar application as well as soil treatments resulted in significantly higher number of pods plant^{-1}.

Shivay *et al*. (2014) found that pod number plant^{-1} increased when Zn was applied.

Number of seeds pod^{-1}

Kayan *et al.* (2015) conducted a field experiment to determine the optimum Zn source and dose for seed yield and seed mineral contents of chickpea under dryland condition during summer season of 2012 and 2013 in Turkey. The comparative effect of 0, 0.2, 0.4, 0.6 and 0.8% Zn levels of zinc chelate (Zn-EDTA; 8% Zn) and zinc sulfate (23% Zn) applied as foliar sprays for assuaging Zn deficiency of chickpea was evaluated under field condition. The result showed that number of seed pod^{-1} increased by the application of Zn.

1000-seed weight

Yashona (2018) found that in terms of increasing plant development, yield, and production of pulse crops, combining Zn with organic manures and foliar sprays showed to be more helpful than any single way of application. The treatments of application of $ZnSO_4$ at sowing, foliar spray or combination of both recorded significantly higher 100 seed weight than control except that only Zn foliar spray at flowering stage.

A field experiment was conducted by Singh *et al*. (2015), to see the effect of foliar fertilization on various growth parameters of chickpea. They observed that 1,000 grain weight was significantly higher in foliar treated plants rather than their control.

Pathak *et al*. (2012) stated that seed weight of chickpea increased as Zn doses was increased.

Kakiuchi and Kobata (2008) reported that Zn application also had a pivotal role on crop growth, involving in photosynthesis, respiration and nitrogen metabolism-protein synthesis. The assimilated photosynthates are translocated from vegetative plant parts to the seed, thus, considerably enhance seed weight.

Seed yield

Afsahi *et al*. (2020) reported that Zn as a microelement plays a salient role in thevital processes of plants such as metabolism and nutrition. The application of Zn significantly increased the chlorophyll content as compared to control treatment. The highest chlorophyll content was observed in foliar spraying of 3.5 and 5 g L^{-1} Zn in Okapi cultivar. While, the highest value of RWC content resulted only with spraying 5 g L^{-1} of Zn. The result showed that zinc foliar of 5 g L^{-1} obtained the highest oil and seed yields and seed yield components. In addition, the highest qualitative seed traits (oil, protein content and Zn content in seed and plant) resulted with spraying 5g L^{-1} of Zn.

Hidoto *et al*. (2017) conducted an experiment to study the effects of Zn application strategy on Zn content and productivity of chickpea grown under Zn deficient soils and determine that in grain and straw Zn concentrations significantly influenced by Zn application strategy. Zn foliar application resulted in the highest grain and straw Zn content as compared to both soil application. Foliar application of Zn had benefitted 21and 22 percent grains over soil application and seed priming. Grain Zn yield content of chickpea also varied significantly among application strategies with foliar application having the highest grain Zn yield of 85 g ha^{-1}.

Liu *et al*. (2016) observed that Zn applied as both basal and foliar spray in summer maize enhanced the grain yield with varying their application rates.

Melash *et al*. (2016) concluded that foliar spray, soil application and seed treatment are the most effective application strategies for some micronutrients.

El Habbasha *et al*. (2013) reported that when Zn is applied as foliar spray at flowering and grain filling stages, it increased grain yield in chickpea.

Hadi*et al*. (2013) conducted an experiment in loamy clay soil at Iran. They reported that foliar application of Zn had positive effects on plant height, number of branches $plant^{-1}$ and seed yield. Zn application could decrease negative effects of water stress on yield and yield components of chickpea. The Zn foliar application manipulates the growth of chickpea, resulting in beneficial changes in yield and yield components. The highest seed yield was obtained by using normal irrigation and Zn spraying.

Nawaz *et al*. (2012) reported that the deficiencies of any one of the micronutrients adversely affect plant growth, development and ultimately yield thus declining the usefulness of other agricultural inputs including recommended dose of fertilizers containing N, K and P.

Pathak *et al*. (2012) observed that Zn deficiency is responsible for low productivity of the crops with low Zn concentration in seeds, leads to poor dietary Zn uptake and also application of micronutrients improved the concentration in seeds and in various pulses. They also reported that foliar application of Zn enhanced the chickpea seed yield.

Mousavi (2011) indicated that foliar application of micronutrients was better than soil application due to the rapid availability, ease of use and reduced toxicity that could be caused by accumulation and element stabilization in the soil.

Stover yield

Kumar *et al.* (2017) conducted a field experiment during winter season of 2012-13 and 2013-14 at Narendra Deva University of Agriculture and Technology, Faizabad, to study the effect of foliar and soil application of micro nutrients and use of PSB on productivity and water use efficiency of chickpea under rainfed condition. The result revealed that basal application of 100 kg DAP ha^{-1} and two foliar sprays of 2 % $ZnSO_4$ (25 and 45 DAS) resulted in highest stover yield, consumptive use and water use efficiency.

Biological yield

Kobraee (2019) explored the effects of Zn and Mn foliar fertilization on yield, dry matter accumulation, Zn and Mn concentrations in leaf and seed of chickpea varieties. The results specified that the spraying treatments had a significant effect on dry weight of stems, leaves, seeds, pods and total plant. They noticed that Zn spraying had the greatest effect on biological yield, dry weight of leaves, seeds, pod dry weight, grain yield and protein content.

Harvest index

Abid *et al.* (2019) conducted a field experiment entitled "Effect of foliar application of Zn and B on growth and yield components of wheat. Experiment result revealed that the maximum HI (39.06 %) was recorded with zinc spray while minimum HI (29.72 %) was observed with B application. This might be due to better starch utilization resulting in more seed set and developing grains which increases the grain size.

Nandan *et al*. (2018) observed that Zn and Fe treatments through foliar application as well as soil treatments resulted in significantly highest harvest index (34.00 %) with T_4 treatment (RDF + Zn (0.5%) and Fe (0.05%) foliar spray) over rest of treatments including control treatment.

2.3 Effect of boron application

2.4 Plant height

Hoque *et al.* (2021) conducted an experiment to study the effect of micronutrients on the growth and yield performance of chickpea. The experiment was consisted using two factors- variety and treatments. Two local cultivars viz. BARI Chola-5 and BARI Chola-9 and five treatments e.g., T_0 = control, T_1 = 2 kg B ha^{-1}, T_2 = 2 kg Mo ha^{-1}, T_3= seed priming with Mo (1 g L^{-1} water), T_4 = foliar spray of B (0.5 g L^{-1} water) + seed priming with Mo (1 g L^{-1} water), and T_5 = 2 kg B ha^{-1} + seed priming with Mo (1 g L^{-1} water) were considered for this study. Treatment showed significant effect on the yield attributes and yield of chickpea. The highest plant height was observed at T_4 = foliar spray of B (0.5 g L^{-1} water) treatment.

Der *et al.* (2015) conducted the experiment to know the effect of micronutrients on growth and yield of groundnut. Application of B foliar spray @ 0.2 % at 40 DAS recorded the highest plant height of (33.9 cm) which was on par with the K @ 0.5 % + Fe @ 0.5 % + Zn @ 0.5 % + B 0.2 % foliar spray at 40 DAS.

Gowthami and Rao (2014) studied the effect of foliar application of K, B and Zn on growth and seed yield in soybean. The foliar application of potassium nitrate @ 2% + boric acid @ 50 ppm with $ZnSO_4$ @ 1 % at 30 and 60 DAS was found to be superior in increasing the plant growth characteristics of soybean.

Number of branches plant^{-1}

Praveena *et al.* (2018) in an experiment to study the effect of foliar spray of B and different Zn levels on growth and yield of green gram (var. PDM-139). Foliar spray (0.2 %) of four B levels at different days of intervals (control, 0.2 %, foliar spray at 20 and 35 DAS and 0.2 % foliar spray of borax at both stage (20 and 35 DAS) with basal application of three Zn levels (control, 2.5kg ha^{-1}, 5kg ha^{-1}). Results revealed that growth parameters viz. no. of branches per plant (7.80) was recorded significantly higher under treatment T_{12} at 20 and 35 DAS (0.2 % foliar spray) of B +5.0 kg ha^{-1} of Zn.

Ravichandra *et al.* (2015) conducted the experiment to know the effect of foliar spray of B to groundnut at pod formation and flowering stage. Application of 1 ppm of B recorded the highest number of branches per plant (17.95) compared to other treatments and control.

Udhav (2013) at jobner (Jaipur) reported that foliar spray of borax at pre flowering being at per with foliar spray of borax at both stages (branching and flowering), significantly increased number of branches plant^{-1} over control treatment.

Moghazy *et al*. (2014) studied the influence of foliar application with B and its combinations with compost manure and mineral nitrogen fertilizer with their interaction and found that number of branches increased with spray of B @ 50 ppm in pea.

Dry matter weight plant^{-1}

Mondal *et al.* (2012) reported that among the various levels of B, foliar spray of 0.2 % borax at flowering stage consistently influenced all growth parameters.

Ali and Mishra (2001) reported that highest amount of total dry matter accumulation observed with B application might be due its role in translocation of photosynthetic assimilates which reflected towards the total dry matter production.

Number of pods plant^{-1}

Chatterjee and Bandyopadhyay (2015) conducted an experiment to study effect of B, Mo and bio-fertilizers on growth and yield of cowpea and result revealed that combined use of seed treatment with Mo (0.5 g kg^{-1} seed) and bio-fertilizers along with foliar spray of B at 4 weeks of planting registered and increased of 42 % and 54% in number of pods and pod yield plant^{-1}, respectively, over control.

Pandey and Gupta (2012) at Lucknow reported that foliar application of B at 0.1 % increase the yield attributing parameter like number of pod plant^{-1} in blackgram. Foliar application of micronutrients in small amount was served as beneficial factor. Foliar application of B was more prefer than soil application.

Number of seeds pod^{-1}

Islam *et al*. (2018) reported that agronomic bio-fortification through foliar B application might have enhanced the seed setting that resulted in an increasing number of seeds per pod.

Dragan *et al.* (2008) conducted pot experiment to study the effect of B on alfalfa and reported that foliar application of B influenced of the number of pods in all the years with an average increase in the number of pods per plant of around 7 % compared to control. Foliar application of B with 0.5% boric acid yielded higher number of seeds per pod in all the years over control.

1000-seed weight

Santosh *et al*. (2020) was conducted a field experiment to study the effect of soil and foliar application of Zn and B on growth, yield and micro nutrient uptake of chickpea. Results revealed that significantly higher 100 seed weight (25.62 g) was recorded with POP + foliar application of Zn as ZnSO4 @ 0.5% + B as Soluble @ 0.2 % (T_{11}) and the lowest 100 seed weight found in control treatment.

Latif and Haggan (2014) concluded from field experiments that Fe, Zn, Mn and B had positive effect on yield and quality of soybean. They further reported that foliar application of Fe + Zn + Mn + B in combination resulted in significant increased 100-seed weight, as compared to control treatment.

Raza *et al.* (2014) founded significant increase in 1000-grain weight in wheat with B spray. This increase in grains weight is primarily owing to role of B in grain setting and sugar translocation. B may have played its role in translocation and that is why grains gained more weight.

Shaker and Mohammed (2011) reported that in sunflower application of B as foliar spray during budding stage on different genotypes recorded the significant increase in 1000 seed weight both in *spring* and *autumn* season.

Seed yield

Paul *et al*. (2021) conducted an experiment to study the response of lentil to irrigation levels and different methods of B application in relation to yield and yield contributing characters. Three levels of irrigation viz., I_0: control (No irrigation), I_1: one irrigation at 25 days after sowing (DAS), I_2: two irrigations at 25 DAS and 40 DAS, and four levels of B viz., B_0: control (No boron), B_1: 80% recommended dose as basal + rest 20% as a foliar spray at pre-flowering , B_2: 60% RD as basal + rest 40% as FS at PF, B_3: 40% RFD as basal + rest 60% as FS at PF as treatment variables. Experimental result revealed that B application had a significant effect on the yield and yield contributing characters of lentil and the highest yield 583.51 kg ha^{-1} was observed in B_3 treatment.

Alam *et al*. (2017) found that application of B significantly improved yield and yield attributes of chickpea.

Fakir *et al*. (2016) evaluated the effect of foliar application of B on seed yield of wheat and concluded that significantly higher yield could be obtained by soil application of B at the rate of 1.5 kg B ha^{-1} or foliar application of 0.4 % boric acid solution at primordial or booting stage of the crop.

Tomic *et al*. (2015) conducted a field trial in order to evaluate the effect of foliar application B on seed yield and found significant increase in B-treatedplants compared with control and revealed that sufficient level of B supply to red clover plants for seed production has a remarkably positive effect under conditions hampering pollination and fertilization.

Kallol *et al.* (2015) conducted the experiment to know the effect of B fertilizationon sunflower in soils of West Bengal. Foliar spray of B @ 0.2 % and 0.3 % was done at 30, 40 and 50 DAS. Higher seed yield (2.27 t ha^{-1}) and stalk yield (9.37 t ha^{-1}) was seen at 0.3 % foliar spray of B.

Mogazhy *et al*. (2014) observed that foliar spray with B @ 50 ppm + application of nitrogen fertilizer in compost form at 2.5-ton fed^{-1} and inorganic N- fertilizer @ 60 kg fed^{-1} in pea were the most effective treatment for improving quality and increasing dry seed yield.

Padbhushan *et al.* (2014) was conducted an experiment on B deficient soil to study the influence of soil and foliar application of boron on green gram, showed that soil applied B has more influenced on mean dry matter yield while foliar applied B has on mean grain yield. Among all soil applied B 0.5 mg kg^{-1} is best treatment while 0.1 % is best foliar treatment.

Mohammad *et al.* (2012) conducted the experiment to study the effect of B foliar application on yield of safflower. Treatments consist of three concentrations of B (0, 0.5 and 1 %). Foliar application of B had a positive effect on yield parameters of safflower. Foliar spray @ 1 % B produced higher seed yield(2,291.89 kg ha^{-1}) than B applied @ 0.5 % (2,139.89 kg ha^{-1}).

Mondal *et al.* (2012) reported treatment combination involving three irrigations at branching, pre-flowering and pod filling stages along with foliar application of 0.2 %

borax at flowering stage recorded maximum mung bean seed yield (898 kg ha^{-1}) which was comparatively higher over other treatment combinations.

Bozoglu *et al.* (2008) determining the effect of B fertilization was on some agronomic characteristics of chickpea. This study designed with randomized completed blocks design with 3 replications. Boron (B_0:0, B_1:0.25 ppm, B_2:0.50 ppm) doses were applied through foliar application when the plants were in vegetative period. The effect of years was found to be statistically significant on characteristics expect for seed yield and ratio of seed above 9 mm sieve. The highest seed yields were found for B_2 dose (1462.2 kg ha^{-1}).

Stover yield

Muhmood *et al.* (2014) conducted a study to evaluate the effect of B application on seed germination, seedling vigour and yield of wheat and found that stover yield increased with application of B.

Biological yield

Zahoor *et al*. (2011) reported that application of B increases the biological yield due to its possible positive correlation present between boron and other micronutrientsand enzymatic activity. Hence stem diameter, head diameter and plant height increasedand ultimately biological yield of sunflower was also increased. The increase in biological yield might be due to role of B in cell elongation, cell division and biomass accumulation.

Harvest index

Saleem *et al*. (2020) was carried out a field trial at Agronomy Research Farm, University of Agriculture Faisalabad for analysing the effectiveness of different levels of B spray on wheat. Treatments included were eight levels of B (0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%) along with water spray and control (without any treatment). B solution of different concentrations was prepared by dissolving required quantity of boric acid in water. HI is the measurement of efficiency of crop to translate assimilates into grain yield. B sprayat booting stage functioned significantly in improving HI of the wheat crop. Foliar application of B showed significant results as compared with control and water spray. Data (Table 2) revealed that significantly higher HI (47.88 %) was calculated in treatment with 1.5 % B spray at booting stage comparable to other treatments.

Ahmad *et al.* (2012) investigated the effect of foliar application of B on yield of rice. The results showed that application of 1 % B solution significantly effected harvest index of rice.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to investigate the growth and yield performance of chickpea through the foliar application of Zn and B. This chapter includes materials and methods that were used in conducting the experiment are present below under the following headings.

3.1 Experimental period

The experiment was conducted during the period from November-2020 to April 2021 in Rabi season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar Agargong, Dhaka,1207. The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level).

3.2.2 Agro-Ecological Zone

The experimental site belongs to the Argo-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain.

3.2.3 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4–5.6 (Anon., 1989). The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0–15 cm depths were collected from the Sher-e-Bangla Agricultural University (SAU) Farm, field. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological and physiochemical properties of the soil are presented in Appendix-I.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-II.

3.3 Experimental materials

BARI Chola-5 (Pabnai) and different doses of Zn and B application methods wereused as experimental materials for this experiment. The important characteristics of BARI Chola-5 variety was mentioned below:

BARI Chola-5 (Pabnai)

BARI Chola-5 (Pabnai) variety was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh. It was originated from the International Crops Research Institute for the Semi-Arid Tropics and released in the year in 1996. Main identifying character of this variety is spreading stature and light green colour, no pigmentation observed at seedling stage but light grey pigmentation observed in the matured stem, small seed size is small and seed coat is grey brown colour, hilum is prominent, both side of the seed is somewhat flattery, smooth, plant slightly bushy, plant height 45-50 cm,1000 seed weight 110-120 g, cooking time 35-40 min. Rabi, 20th November to 10th December for barind area last week of October to first week of November was the planting season of this variety. Ripening time 125-130 days. Yield 1.8-2.0 t ha^{-1} and contain protein 20-22%.

3.4 Experimental design and layout

The experiment was laid out in split-plot design having 3 replications. In main plot there was Zn treatment and in sub plot there was different B fertilization application method treatment. There are 16 treatment combinations and 48-unit plots. The unit plot size was 4 m^2 (2 m × 2 m). The blocks and unit plots were separated by 0.7 m and 0.50 m spacing, respectively. Row to row and plant to plant distances were 45 and 15 cm respectively. The layout of the experimental field was shown in Appendix-III.

3.5 Experimental treatment

There were two factors in the experiment namely different method of zinc and boron application as mentioned below:

Factor A. Different levels of zinc application

Zn_0= control (Water spray)

Zn_1= basal application of Zn

Zn_2= 0.5 % foliar application of Zn at pre-flowering stage

Zn_3= 1 % foliar application of Zn at pre-flowering stage

Factor B. Different levels of boron application

B_0= control (Water spray)

B_1= basal application of B

B_2= 0.5 % foliar application of B at pre-flowering stage

B_3= 1 % foliar application of B at pre-flowering stage

3.6 Land preparation

Initially the field was prepared with the help of tractor drawn implement. After giving one deep ploughing the experimental field was cross harrowed and levelled properly to break the clods and bring the soil to the desired tilth. The final land preparation was done on 20^{th}, November, 2020. Experimental land was divided into plots following the design of the experiment. The plots were prepared manually for sowing the subsequentcrops of the experimental study.

3.7 Seed collection

For conducting the present experiment, the seeds of the test crop *i.e.*, BARI Chola-5 was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.8 Fertilizer requirement

The application of the nutrients was done on the basis of the nutrient recommendations of chickpea crops. The recommended dose of 15 kg ha^{-1} of nitrogen, 40 kg ha^{-1} of phosphorus and 20 kg ha^{-1} of potash for chickpea crop was applied through Triple super phosphate and murate of potash as basal application at the time of sowing in lines below the seed. The application of Zn and B through zinc sulphate heptahydrate ($ZnSO_4.7H_2O$) and Borax heptahydrate was given at per treatment requirement.

3.9 Seed sowing

Before sowing seeds were treated with Autostin to control the seed borne disease. The seeds of chickpea were sown on November 20, 2020 in solid rows in the furrows having a depth of 2-3 cm maintaining 30 cm × 10 cm row to row and plant to plant distance. Water was supplied every line before sowing of chickpea seeds. 90% of seeds were germinated on the 5th day after sowing.

3.10 Application of supplementary treatment

Foliar spray of water, 0.5 and 1 % Zn and 0.5 and 1 % B were applied in selected plots just after flowering (55 DAS).

3.11 Intercultural operations

3.11.1 Thinning and weeding

Seeds started germination of five days after sowing (DAS). Thinning was done two times; at 12 DAS and at 18 DAS to maintain optimum plant population in each plot. First weeding was done at 30 DAS and then weeded as per necessary of the experimental plots.

3.11.2 Irrigation and mulching

The irrigation was done as per requirement. First irrigation was done at 12 DAS. Irrigation was continued till soil saturation.

3.11.3 Protection against insect and pest

The experimental crop was infected with Sclerotium *rolfsi* at early stage of growth. So, Autostin @ 2% was applied 3 times at 5 days interval and infected plants were pulled out. At later stage of growth pod borer (*Marucat estulalis*) attacked the plant. Ripcord 10 EC was sprayed @ 1 mm per litre water for two times at 7 days interval to control the insects.

3.12 Harvesting and threshing

Harvesting of the crop was done after 120 DAS for data collection when about 80% of the pods attained maturity. At 1 m^2 pre-marked area from middle portion of each plot was harvested at maturity. The harvested plants of each treatment were brought to the cleaned threshing floor and sun dried for three days and separated pods from plants by hand.

3.13 Drying, cleaning and weighing

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.14 Recording of data

The data were recorded from 30 DAS and continued until the end of recording of yield contributing characters of the characters of the crop after harvest. Dry weights of plant were collected from the inner rows leaving border rows by destructive sampling of 5 plants at different dates. The following data were recorded during the experiment.

i. Plant height (cm)
ii. Primary branches plant^{-1} (no.)
iii. Secondary branches plant^{-1} (no.)
iv. Above ground dry matter plant^{-1} (g)
v. Pods plant^{-1} (no.)
vi. Seeds pod^{-1} (no.)
vii. 1000 seed weight (g)
viii. Seed yield (t ha^{-1})
ix. Stover yield (t ha^{-1})
x. Biological yield (t ha^{-1})
xi. Harvest index (%)

3.15 Detailed procedures of recording data

i. Plant height

Five plants were selected randomly from the inner row of each plot. The height of the plants was measured from the ground level to the tip of the plant at 30, 50, 70, 90 DAS and harvest (120 DAS). The mean value of plant height was recorded in cm.

ii. Primary branches plant^{-1}

The primary branches plant^{-1} was counted from five randomly sampled plants. It was done by counting total number of branches of all sampled plants at 30, 50, 70, 90 DAS and harvest (120 DAS) and then the average data were recorded.

iii. Secondary branches plant^{-1}

The secondary branches plant^{-1} was counted from five randomly sampled plants. It was done by counting total number of branches of all sampled plants at harvest (120 DAS) and then the average data were recorded.

iv. Above ground dry matter plant^{-1}

Five plants were collected randomly from each plot at harvest (120 DAS). Then the leaves were separated from each plant put into envelop and placed in oven maintaining 700C for 72 hours for oven dry until attained a constant weight and the mean of dry weight of leaves plant^{-1}, stem plant^{-1} and pods plant^{-1} was determined. The calculated value of leaf dry weight, stem dry weight and pods dry weight was added to determine the value of above ground dry matter weight and it was expressed in gram (g).

v. Pods plant^{-1}

The number of total pods of 5 plants from each plot were counted and the mean numbers were expressed as plant^{-1} basis.

vi. Seeds pod^{-1}

The number of seeds pod^{-1} was counted randomly from selected pods at the time of harvest. Data were recorded as the average of 10 pods from each plot.

vii. Weight of 1000 seeds

One thousand cleaned, dried seeds were counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

viii. Seed yield

Seed yield was recorded from 1 m^2 area of each plot were sun dried properly. The weight of seeds was taken and converted the yield in t ha^{-1}.

ix. Stover yield

After separation of seeds from plant, the straw and shell from harvested area was sun dried and the weight was recorded and then converted into t ha^{-1}.

x. Biological yield (t ha^{-1})

Seed yield and Stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Seed yield + Stover yield.

xi. Harvest index

Harvest index was calculated from the seed yield and Stover yield of chickpea for each plot and expressed in percentage.

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

3.16 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistic 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

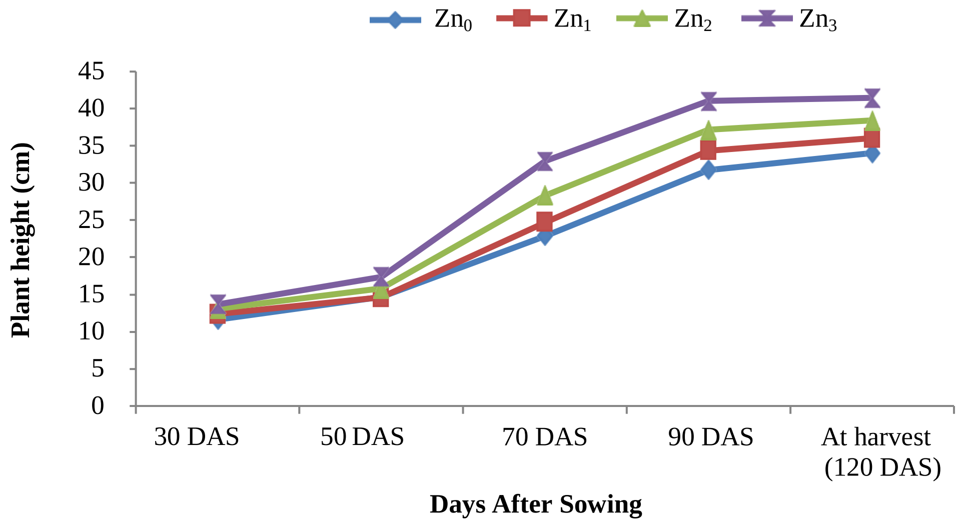
Results obtained from the present study have been presented and discussed in this chapter with a view to study the growth and yield performance of chickpea through foliar application of Zn and B. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Plant growth parameters

4.1.1 Plant height

Effect of zinc application

Plant height is an essential character of the vegetative stage of the crop plant and indirectly impacts on yield of crop plants. Different concentration of Zn application significantly influenced on plant height of chickpea at different days after sowing (DAS). It was seen that height increased more and more with the age of the crop up to harvest. The plant height reached the highest value at maturity (Figure 1). Experimental result revealed that the highest plant height at 30, 50, 70, 90 DAS and at harvest respectively (120 DAS) was observed in Zn_3 treatment (1 % foliar application at pre-flowering stage). Whereas the lowest plant at 30, 50, 70, 90 DAS and at harvest respectively (120 DAS) was observed in Zn_0 (Control) treatment which was statistically similar with (14.60 cm) Zn_1 (basal application of zinc) treatment at 50 DAS. The result obtained from the present study was similar with the findings of Ehsanullah *et al*. (2015) who reported that the highest plant height was obtained in the treatment of foliar application of $ZnSO_4$ at flowering which might be attributed to the role of Zn to synthesize the plant growth regulator such as auxins, which takes active role in enlargement and elongation of plant cell. Hussain *et al.*(2022) reported that significant increase in plant height observed with foliar the application of Zn and B. Zn (0.5%) foliar treatment along with boron gave maximum plant height, increase in plant length might be due to the role of Zn foliar application in the synthesis of IAA, metabolism of auxins, biological activity, stimulation of an enzyme activity and photosynthetic pigments because of that, encourage vegetative growth of plants.

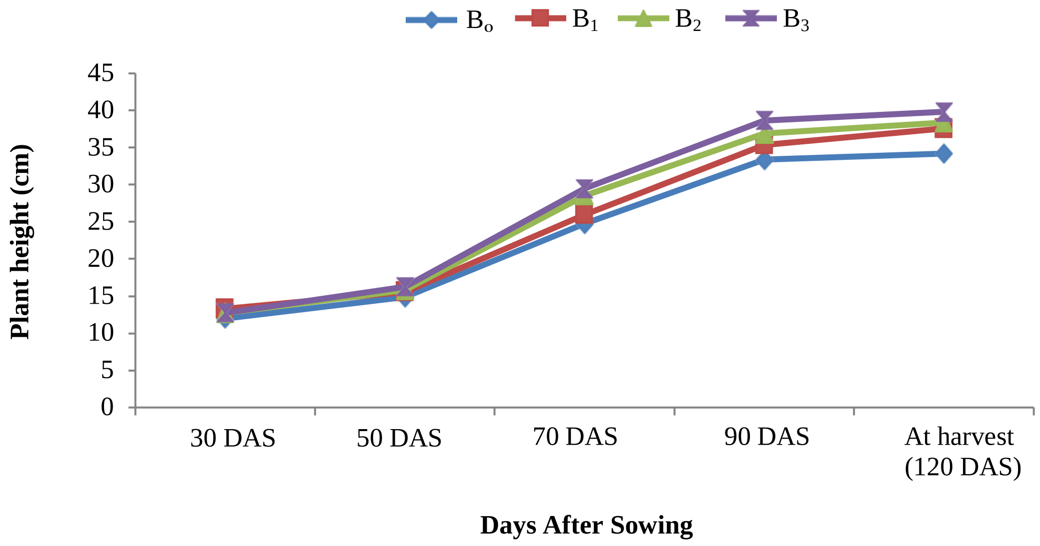


Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage.

Figure 1. Effect of different zinc application methods and concentrations onPlant height of chickpea at different DAS [$LSD_{(0.05)}$= 0 .03, 0.054, 0.94 and 0.50 at 30, 50, 70, 90 and 120 DAS respectively]

Effect of boron application

Plant height of chickpea showed significant variation due to the effect of different methods and concentrations of B application at different DAS (Figure 2). Experimental result showed that the highest plant height at 30 DAS was observed in B_1 (Basal application of boron) treatment. At 50, 70, 90 DAS and at harvestrespectively (120 DAS) the highest plant height was observed in B_3 (1 % foliar application at pre-flowering stage) treatment. While thelowest plant height at 30, 50, 70, 90 DAS and at harvest respectively (120 DAS) was observed in B_0 (Control) treatment. B is a micronutrient required for plant growth. Plants may seem healthy without enough B in the soil, but they won't bloom or bear fruit. In plants, B aids in regulating sugar transport. Cell division and seed development also depend on it. Der *et al.* (2015) reported that application of B through foliar spray influenced the plant height of groundnut at different DAS comparable to the basal application of B. Hoque *et al.* (2021) reported that The highest plant height (56.10 cm) at harvest was obtained from T_4 (0.5 % foliar spray of B) treatment. This might due to B plays vital role in cell division, cell wall development and growth of plants



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 2. Effect of different boron application methods and concentrations onPlant height of chickpea at different DAS [$LSD_{(0.05)}$= 0 .34, 0.40, 0.86, 1.28 and 1.43 at 30, 50, 70, 90 and 120 DAS respectively]

Combined effect of zinc and boron application

Different methods of Zn application along with B application significantly influenced on plant height of chickpea at different DAS (Table 1). Experimental result revealed that the highest plant height (13.96 cm) was observe in Zn_3B_1 treatment combination at 30 DAS which was statistically similar with Zn_3B_3 (13.89 cm), Zn_3B_2, (13.62 cm), Zn_2B_3 (13.44 cm), Zn_2B_2 (13.44 cm) and Zn_2B_1 (13.47 cm) treatment combination. At 50, 70, 90 DAS and at harvest respectively (120 DAS) the highest plant height (17.95, 35.72, 45.60 and 46.60 cm) was observed in Zn_3B_3 treatment combination which was statistically similar with Zn_3B_1 (17.95 cm) and Zn_3B_2 (17.43 cm) treatment combination at 50 DAS; with Zn_3B_2 (34.77 cm) treatment combination at 70 DAS. While the lowest plant height (10.98, 13.49, 18.82, 27.06 and 29.33 cm) at 30, 50, 70, 90 DAS and at harvest respectively (120 DAS) was observed in Zn_0B_0 (Control) treatment combination, which was statistically similar with Zn_0B_3 (11.16 cm) at 30 DAS and with Zn_1B_0 (13.74 cm) and Zn_1B_1 (14.25 cm) at 50 DAS. Rathod *et al.* (2020) reported that plant height of chickpea significantly increased due to foliar application of Zn and B. The foliar application of Zn and B, which played a significant role in the synthesis of growth hormones such as tryptophan and auxin, which in turn increased chickpea growth parameters.

Table 1. Combined effect of zinc and boron application methods and concentrations on plant height of chickpea at different DAS

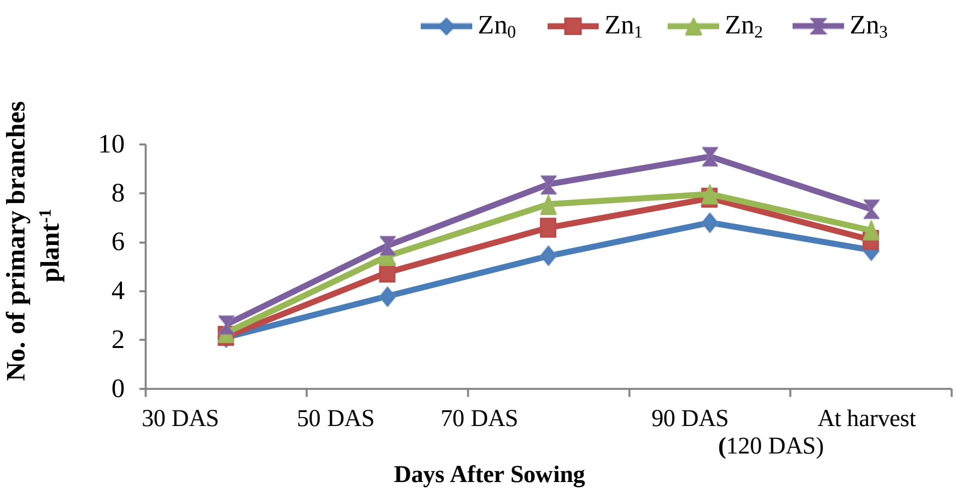
Treatment combinations	Plant height (cm)				
	30 DAS	50 DAS	70 DAS	90 DAS	At harvest (120 DAS)
Zn_0B_0	10.98 j	13.49 h	18.82 h	27.06 i	29.33 g
Zn_0B_1	12.66 d-f	15.08 d-g	22.61 g	31.78 h	35.02 ef
Zn_0B_2	11.80 hi	15.03 d-g	24.82 ef	33.24 gh	35.83 e
Zn_0B_3	11.16 ij	15.26 c-f	25.38 de	35.01 e-g	36.03 e
Zn_1B_0	11.84 gh	13.74 h	23.14 fg	31.25 h	32.98 f
Zn_1B_1	13.11 c-e	14.25 gh	23.44 fg	34.88 fg	36.80 de
Zn_1B_2	12.11 f-h	14.74 fg	25.68 c-e	35.06 e-g	36.91 de
Zn_1B_3	12.43 e-g	15.66 b-e	26.58 c-e	36.23 d-f	37.50 c-e
Zn_2B_0	11.92 gh	15.90 b-d	26.66 cd	35.63 d-f	37.22 de
Zn_2B_1	13.47 a-c	15.03 e-g	27.18 c	37.62 cd	38.66 cd
Zn_2B_2	13.44 a-c	16.09 bc	29.11 b	37.64 cd	38.66 cd
Zn_2B_3	13.44 a-c	16.22 b	30.27 b	37.75 cd	39.18 cd
Zn_3B_0	13.21 b-d	16.23 b	30.38 b	39.57 bc	37.26 c-e
Zn_3B_1	13.96 a	17.95 a	30.81 b	37.23 c-e	39.89 bc
Zn_3B_2	13.62 a-c	17.43 a	34.77 a	41.67 b	42.14 b
Zn_3B_3	13.89 ab	17.95 a	35.72 a	45.60 a	46.60 a
LSD (0.05)	0.60	0.89	1.77	2.30	2.54
CV (%)	3.22	3.11	3.79	4.23	4.55

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

4.1.2 Number of primary branches plant^{-1}

Effect of zinc application

Due to different methods and concentrations of Zn application number of primary branches plant^{-1} of chickpea varied significantly at different DAS (Figure 3). Experimental result showed that the highest number of primary branches plant^{-1} (2.63, 5.86, 8.36, 9.50 and 7.36) at 30, 50, 70, 90 DAS and at harvest respectively (120 DAS) was observed in Zn_3 treatment (1 % foliar application at pre-flowering stage).While the lowest number of primary branches plant^{-1} (2.11, 3.78, 5.44, 6.80 and 5.66)at 30, 50, 70, 90 DAS and at harvest respectively (120 DAS) was observed in Zn_0 (Control) treatment which was statistically similar with Zn_1 (2.14 and 6.08) at 30 DAS and at harvest respectively (120 DAS). Spraying of Zn fertilizer ensured favorable condition for the growth of chickpea plant with maximum branches plant^{-1}. Increase in number of branches may be due to more nutrient uptake during vegetative growth. While at later stage nutrients were diverted towards reproductive parts of plants. Sangolli *et al*. (2018) reported significant differences with respect to number of branches as influenced by Zn nutrition. Shivay *et al*. (2014) also reported that all the treatments in which $ZnSO_4$ was applied as soil application, foliar spray or in combination of both noticed significantly higher number of primary branches incomparison to control.

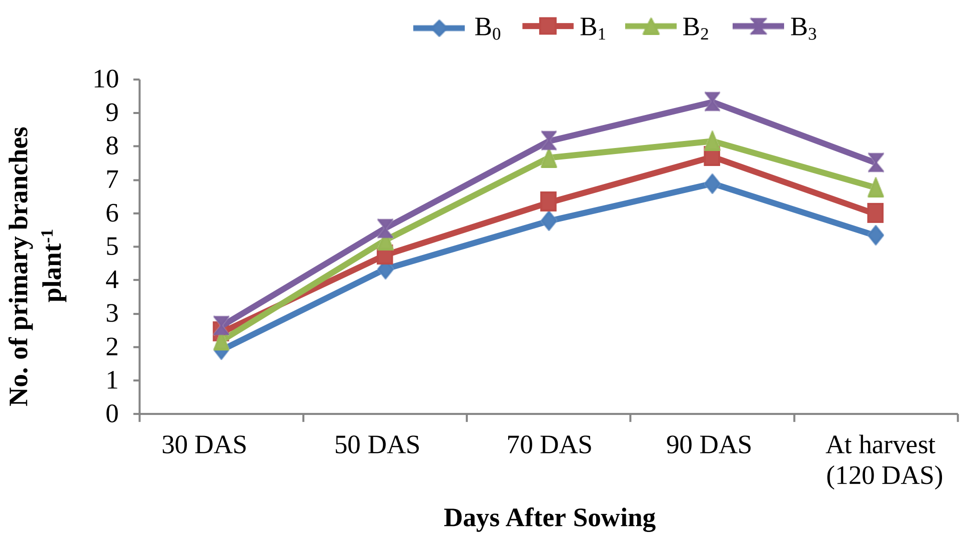


Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage

Figure 3. Effect of different zinc application methods and concentrations on number of primary branches plant^{-1} of chickpea at different DAS [$LSD_{(0.05)}$= 0 .17, 0.28, 0.46, 0.61 and 0.50 at 30, 50, 70, 90 and 120 DAS respectively]

Effect of boron application

The number of primary branches plant^{-1} of the chickpea was significantly influenced by various B application methods and concentrations at different DAS (Figure 4). Experimental result showed that the highest the highest number of primary branches plant^{-1} (2.63, 5.55, 8.16, 9.33 and 7.51) at 30, 50, 70, 90 DAS and at harvest respectively (120 DAS) was observed in B_3 treatment (1 % foliar application at pre-flowering stage). While the lowest number of primary branches plant^{-1} (1.91, 4.33, 5.77, 6.89 and 5.33) at 30, 50, 70, 90 DAS and at harvest respectively (120 DAS) was observed in B_0 (Control) treatment. B is linked with the development of plant cell wall and differentiation of cells and results in improved shoot growth and thus increased plant height, branches per plant and leaves per plant. Ravichandra reported that application of 1 ppm of B recorded the highest number of branches per plant (17.95) compared to other treatments and control.



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 4. Effect of different boron application methods and concentrations onnumber of primary branches plant^{-1} of chickpea at different DAS [$LSD_{(0.05)}$= 0 .86, 0.26, 0.45, 0.32 and 0.24 at 30, 50, 70, 90 and 120 DAS respectively]

Combined effect of zinc and boron application

The combined effect of Zn and B application had shown significant effect on number of primary branches plant^{-1} of the chickpea at different DAS (Table 2). Experimental result showed that the highest number of primary branches plant^{-1} (2.99, 6.22, 9.44, 11.22 and 8.67) at 30, 50, 70, 90 DAS and at harvest respectively (120 DAS) was observed in Zn_3B_3 treatment combination which was similar with Zn_2B_3 (2.77, 6.89 and 9.33) at 30, 50, 70 DAS. While the lowest number of primary branches plant^{-1} (1.33,3.00, 4.00, 4.77 and 4.33) at 30, 50, 70, 90 DAS and at harvest, respectively (120 DAS)was observed in Zn_0B_0 treatment combination. Doddamani *et al*. (2020) reported that the vegetative growth like number of branches plant^{-1} was significantly influenced by Zn and B foliarapplication treatments.

Table 2.Combined effect of zinc and boron application methods and concentrations on number of primary branches plant^{-1} of chickpea atdifferent DAS

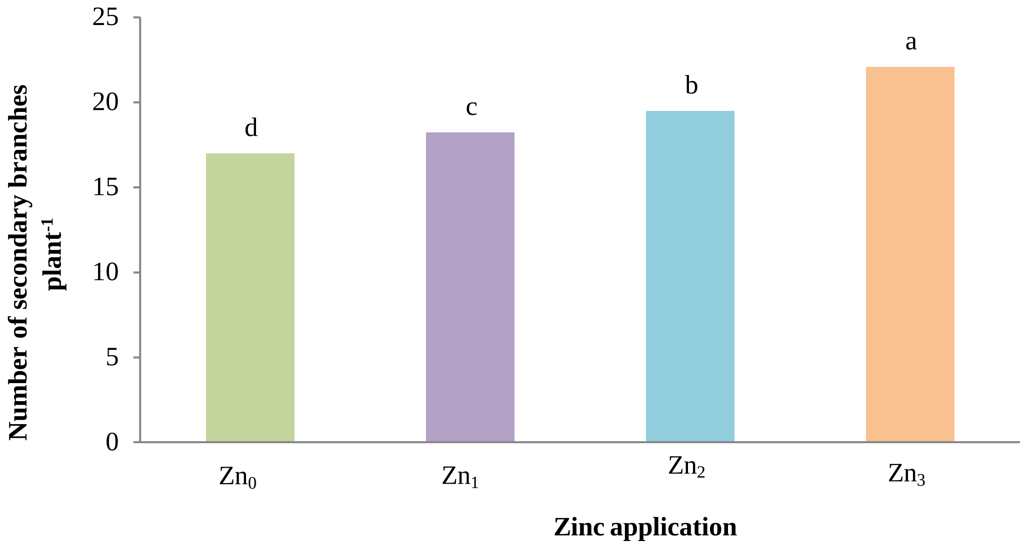
Treatment combinations	No. of primary branches plant^{-1}				
	30 DAS	**50 DAS**	**70 DAS**	**90 DAS**	**At harvest (120 DAS)**
Zn_0B_0	1.33 h	3.00 g	4.00 h	4.77 f	4.33 j
Zn_0B_1	2.44 c-e	3.89 f	5.11 g	6.66 e	5.83 gh
Zn_0B_2	2.33 de	3.99 f	6.33 de	7.22 de	5.99 f-h
Zn_0B_3	2.44 c-e	4.22 ef	6.33 de	8.55 bc	6.50 ef
Zn_1B_0	1.99 f	4.55 de	5.66 fg	6.88 e	4.99 i
Zn_1B_1	2.33 de	4.66 de	5.89 ef	7.77 cd	5.55 h
Zn_1B_2	1.77 g	4.89 d	7.22 c	7.77 cd	6.55 ef
Zn_1B_3	2.33 de	4.88 d	7.55 c	8.78 b	7.22 b-d
Zn_2B_0	2.00 f	4.22 ef	5.77 ef	7.22 de	5.55 hi
Zn_2B_1	2.44 c-e	4.78 d	6.55 d	7.44 de	5.77 h
Zn_2B_2	2.00 f	5.89 bc	8.55 b	8.44 bc	6.99 c-e
Zn_2B_3	2.77 ab	6.89 a	9.33 a	8.78 b	7.66 b
Zn_3B_0	2.33 e	5.55 c	7.66 c	8.67 b	6.44 e-g
Zn_3B_1	2.55 b-d	5.66 c	7.77 c	8.89 b	6.78 de
Zn_3B_2	2.66 bc	5.99 bc	8.55 b	9.22 b	7.55 bc
Zn_3B_3	2.99 a	6.22 b	9.44 a	11.22 a	8.67 a
$LSD_{(0.05)}$	0.23	0.54	0.64	0.83	0.65
CV (%)	4.49	6.34	4.43	4.84	4.51

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

4.1.3 Number of secondary branches plant^{-1}

Effect of zinc application

The experimental results showed that number of secondary branches plant^{-1} was significantly influenced by different methods and concentrations Zn application at harvest respectively (Figure 5). The highest number of secondary branches plant^{-1} (22.08) was observed in Zn_3 treatment. Whereas the lowest number of secondary branches plant^{-1} (16.99) was observed in Zn_0 treatment. Drostkar *et al*. (2016) reported that number of branches plant^{-1} was significantly increased due to the application of Zn, Iron and NPK as nano-fertilizers on chickpea as compared to plants grown in normal (no fertilizer) condition. Foliar application of Zn, Fe and NPK, through the action as a growth promoter, can increase in the plant growth in chickpea.

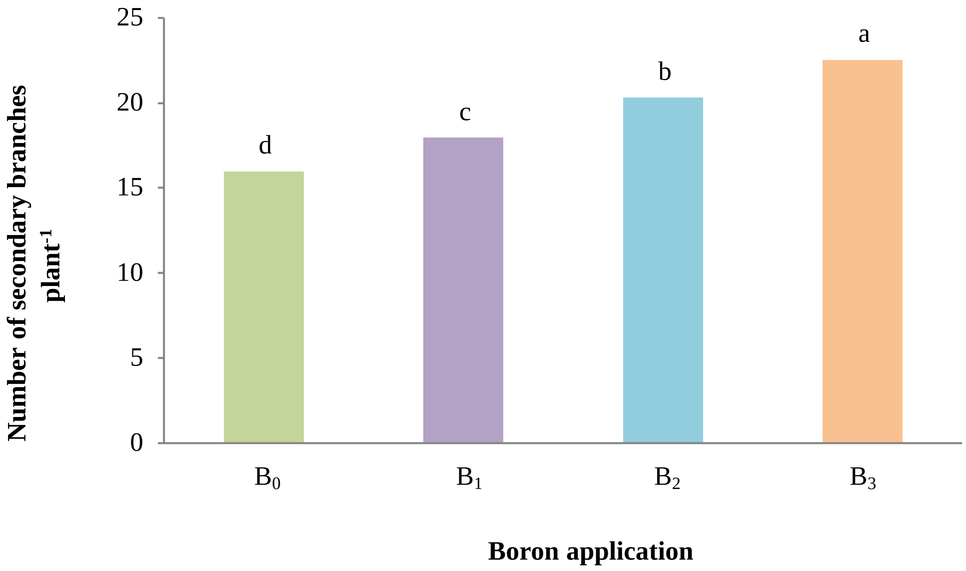


Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage.

Figure 5. Effect of different zinc application methods and concentrations onnumber of secondary branches plant^{-1} of chickpea at harvest [$LSD_{(0.05)}$=0.07]

Effect of boron application

The outcomes of the experiment explained that different concentrations of applyingB fertilizer had a significant impact on the number of secondary branches plant^{-1} at harvest (Figure 6). The highest number of secondary branches plant^{-1} (22.54) was observed in B_3 treatment. Whereas the lowest number of secondary branches plant^{-1} (15.98) was observed in B_0 treatment. Udhav (2013) reported that foliar spray of borax at both stages (branching and flowering), significantly increased number of branches plant^{-1} over control treatment.



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 6. Effect of different boron application methods and concentrations onnumber of secondary branches plant^{-1} of chickpea at harvest [$LSD_{(0.05)}$=0.69]

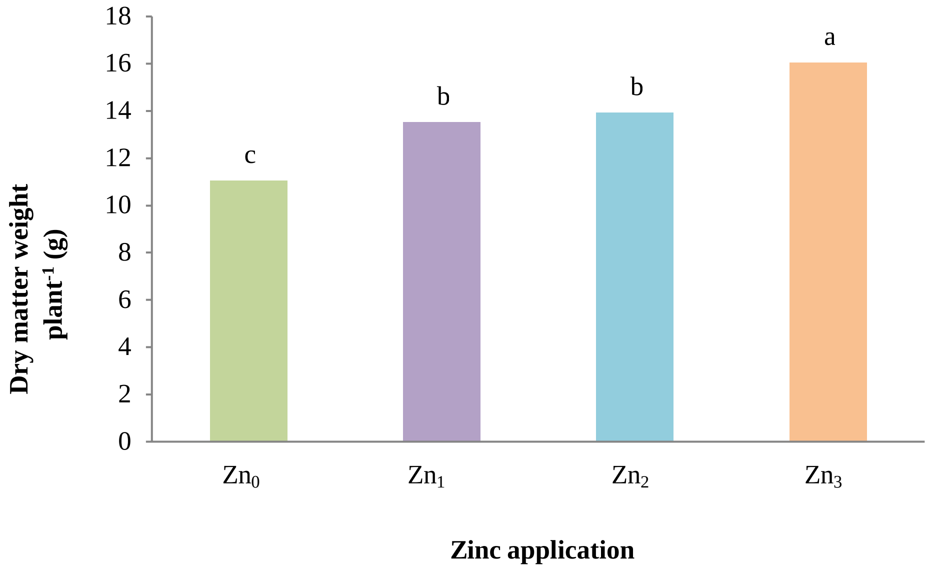
Combined effect of zinc and boron application

The combined effect of Zn and B application had significant effect on number of secondary branches plant^{-1} of chickpea at harvest (Table 3). Experimental result showedthat the highest number of secondary branches plant^{-1} (26.01) was observed in Zn_3B_3 treatment combination. Whereas the lowest number of secondary branches plant^{-1} (12.99) was observed in Zn_0B_0 treatment combination.

4.1.4 Dry matter weight plant^{-1}

Effect of zinc application

The experimental findings demonstrated that different methods and concentration of Zn application had a significant effect on dry weight plant^{-1} of chickpea at harvest respectively (Figure 7). Experimental result revealed that the Zn_3 treatment had the highest dry matter weight plant^{-1} (16.05 g). While Zn_0 treatment showed the lowest dry matter weight plant^{-1} (11.06 g) at harvest respectively. Zn stimulates the processes of biomass accumulation through increasing the effectiveness of other nutrients. Brijnandan *et al.* (2018) reported the treatment RDF followed by foliar application of Zn (0.5%) and Fe (0.05%) at pre-flowering and pod formation stage given to chickpea varieties recorded significantly higher dry matter accumulation at 90 DAS and at harvest.

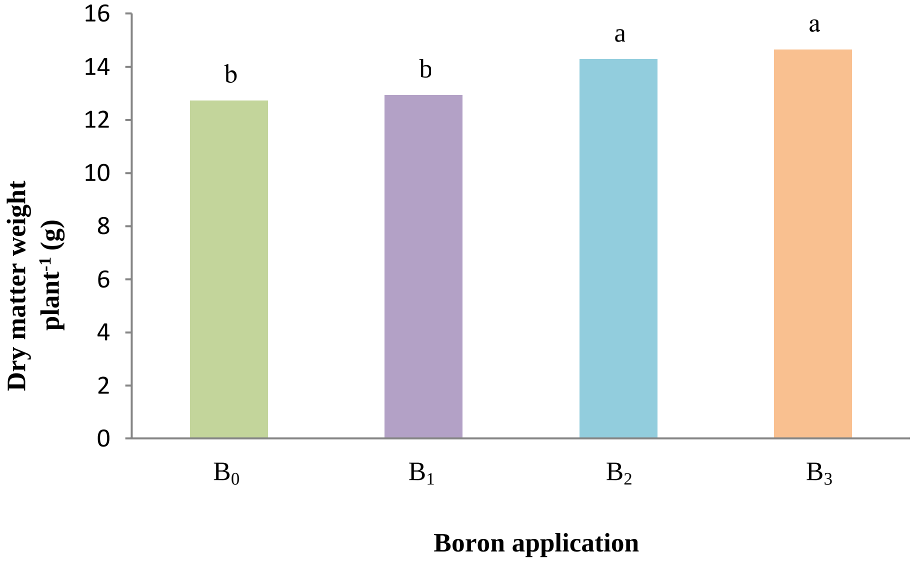


Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage.

Figure 7. Effect of different zinc application methods and concentrations on drymatter weight plant^{-1} of chickpea at harvest [$LSD_{(0.05)}$=0.63]

Effect of boron application

The experimental results showed with B_0 treatment had the lowest dry matter weight plant^{-1} (12.72 g) at harvest that various B application methods and concentrations significantly affected the dry weight plant^{-1} of chickpea at harvest (Figure 8). According to experimental result B_3 treatment had the highest (14.64 g) dry matter weight plant^{-1} which was similar with B_2 (14.27 g) treatment. While plot which was similar with B_1 (12.92 g) treatment. Ali and Mishra (2001) reported that highest amount of total dry matter accumulation observed with B application might be due its role in translocation of photosynthetic assimilates which reflected towards the total dry matter production.



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 8. Effect of different boron application methods and concentrations on drymatter weight plant^{-1} of chickpea at harvest [$LSD_{(0.05)}$=0.47]

Combined effect of zinc and boron application

The dry matter weight plant^{-1} of the chickpea at harvest was significantly affected by the combined effects of Zn and B application (Table 3). The results of the experiment revealed that the Zn_3B_3 (18.07 g) treatment combination, which was similar to Zn_3B_2 (17.83 g) treatment combination, had the highest dry weight plant^{-1} of chickpea at harvest. The Zn_0B_0 (9.97 g) treatment combination had the lowest dry weight plant^{-1} of chickpea at harvest which was similar to the Zn_1B_1 (10.73 g) treatment combination.

Table 3.Combined effect of zinc and boron application methods and concentrations on number of secondary branches and dry matter weightplant^{-1} of chickpea at harvest respectively

Treatment combinations	No. of secondary branches plant^{-1}	Dry matter weight plant^{-1} (g)
Zn_0B_0	12.99 j	9.97 e
Zn_0B_1	17.49 gh	11.30 d
Zn_0B_2	17.97 g	11.30 d
Zn_0B_3	19.50 f	11.67 d
Zn_1B_0	14.97 i	14.63 b
Zn_1B_1	16.65 h	10.73 de
Zn_1B_2	19.65 f	14.63 b
Zn_1B_3	21.66 cd	14.07 bc
Zn_2B_0	16.65 h	13.20 c
Zn_2B_1	17.31 gh	14.40 b
Zn_2B_2	20.97 de	13.33 c
Zn_2B_3	22.98 b	14.77 b
Zn_3B_0	19.32 f	13.87 bc
Zn_3B_1	20.34 ef	14.43 b
Zn_3B_2	22.65 bc	17.83 a
Zn_3B_3	26.01 a	18.07 a
LSD (0.05)	1.20	1.03
CV (%)	4.27	4.10

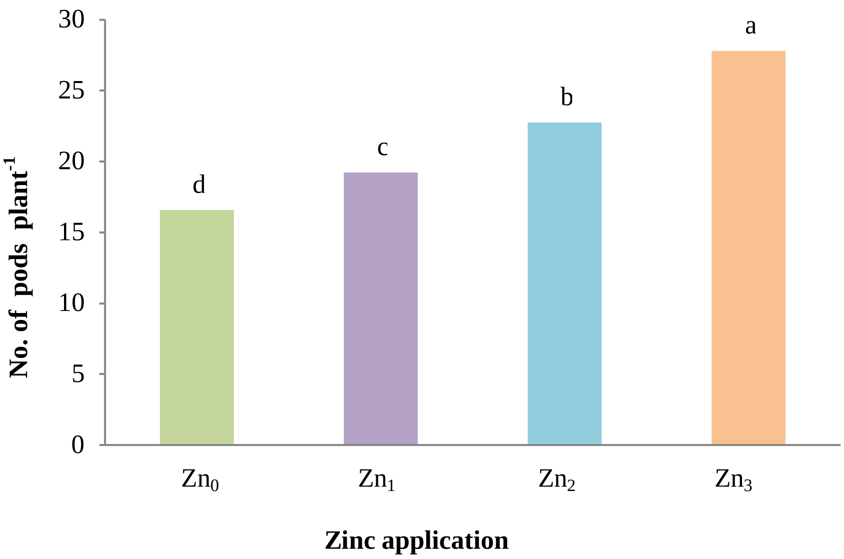
Here,in a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

4.2 Yield contributing characters

4.2.1 No. of pods plant^{-1}

Effect of zinc application

The different concentrations of Zn application significantly affected the number of pods plant^{-1} of chickpea (Figure 9). Experimental result revealed that the highest number of pods plant^{-1} (27.79) was found in Zn_3 treatment. Whereas the lowest number of pods plant^{-1} (16.79) was found in Zn_0 treatment. The variation in pods number due to the different method of Zn application. Nandan *et al*. (2018) found that Zn and Fe treatments through foliar as well as soil treatments resulted in significantly higher number of pods plant^{-1}. Shivay *et al*. (2014) found that pod number plant^{-1} increased when Zn was applied.

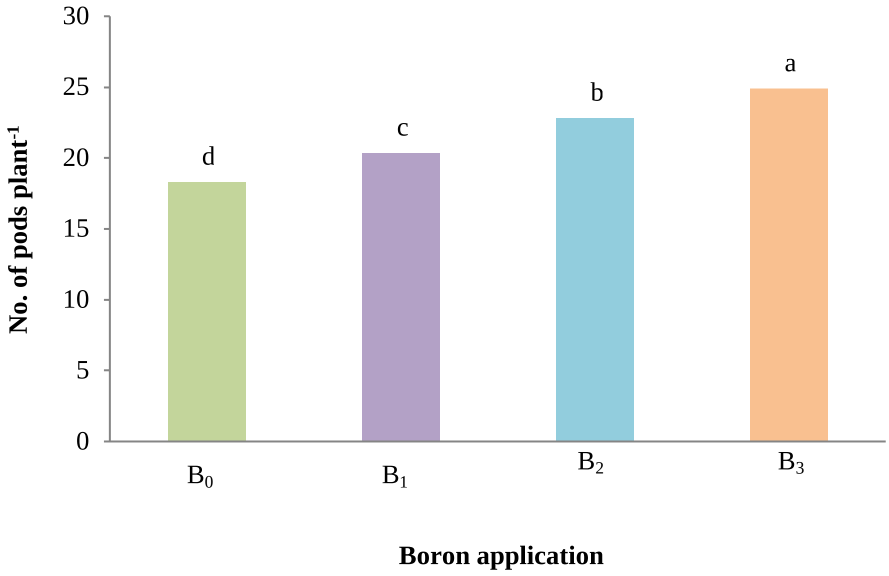


Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage.

Figure 9. Effect of different zinc application methods and concentrations onnumber of pods plant^{-1} of chickpea [$LSD_{(0.05)}$=0.24]

Effect of boron application

The number of chickpea pods on plant^{-1} was significantly influenced by the various B application methods and concentrations (Figure 10). According to the experimental results the highest number of pods plant^{-1} (24.89) was observed in the B_3 treatment. However,the B_0 treatment had the lowest number of pods plant^{-1} (18.28). Chatterjee and Bandyopadhyay (2015) reported that combined use of seed treatment with Mo (0.5 g kg^{-1} seed) and bio-fertilizers along with foliar spray of B at 4 weeks of planting registered and increased of 42 % and 54 % in number of pods and pod yield plant^{-1}, respectively, over control.



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 10. Effect of different boron application methods and concentrations onnumber of pods plant^{-1} of chickpea [$LSD_{(0.05)}$=0.87]

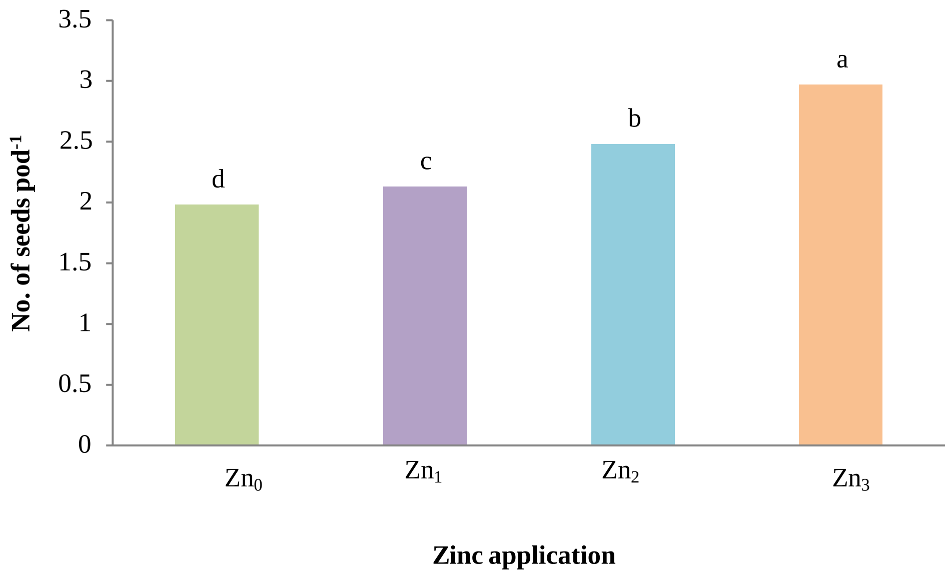
Combined effect of zinc and boron application

Combined effect of different Zn and B application shown significant effect on number of pods plant^{-1} of chickpea (Table 4). Experimental result showed that the highest number of pods plant^{-1} (32.97) was found in Zn_3B_3 treatment combination. While the lowest number of pods plant^{-1} (14.27) was found in Zn_0B_0 treatment combination

4.2.2 No. of seeds pod^{-1}

Effect of zinc application

The number of seeds pod^{-1} of chickpea was significantly influenced by various Zn application methods and concentrations (Figure 11). The highest number of seed pod^{-1} (2.97) was observed in the Zn_3 treatment. While the Zn_0 treatment had the lowest number seeds pod^{-1} (1.98). The differences of number of seeds pod^{-1} may be explained by the fact that Zn has an impact on how proteins and carbohydrates are metabolized. This effect is directly related to the processes of sugar conversion and also has an impact on photosynthesis, which is crucial for producing the carbohydrates and proteins required for the growth of vegetative parts as well as the development of reproductive parts. Kayan *et al.* (2015) also reported that the number of seed pod^{-1} increased by the application of Zn through foliar application. The dose of 0.6% with Zn-EDTA was the optimum combination for Zn enrichment in seed of chickpea. The results showed that increased Zn doses caused an increase in Zn content of seed number per plant.

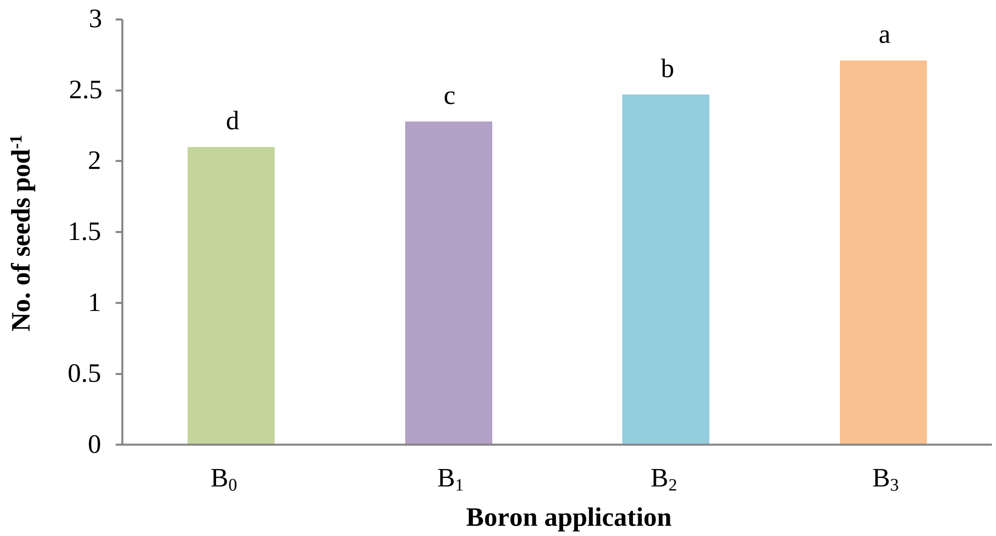


. Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage.

Figure 11. Effect of different zinc application methods and concentrations onnumber of seeds pod^{-1} of chickpea [$LSD_{(0.05)}$=0.08]

Effect of boron application

Different B application levels had a significant effect on number of seeds pod^{-1} of chickpea (Figure 12). Experimental result showed that the highest number of seeds pod^{-1} of chickpea (2.71) was observed in B_3 treatment. While the B_0 treatment had the lowest number of seeds pod^{-1} (2.10). Islam *et al*. (2018) reported foliar B application might have enhanced the seed setting that resulted in an increasing number of seeds per pod. Agronomic biofortification might have enhanced the seed setting that resulted in an increasing number of seeds per pod. Dragan *et al*. (2008) reported that foliar application of 0.5 % boric acid on alfalfa increased number of pods per plant of around 7 % compared to control. Foliar application with B improved seed germination and increased seed vigor.



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 12. Effect of different boron application methods and concentrations onnumber of seeds pod^{-1} of chickpea [$LSD_{(0.05)}$=0.07]

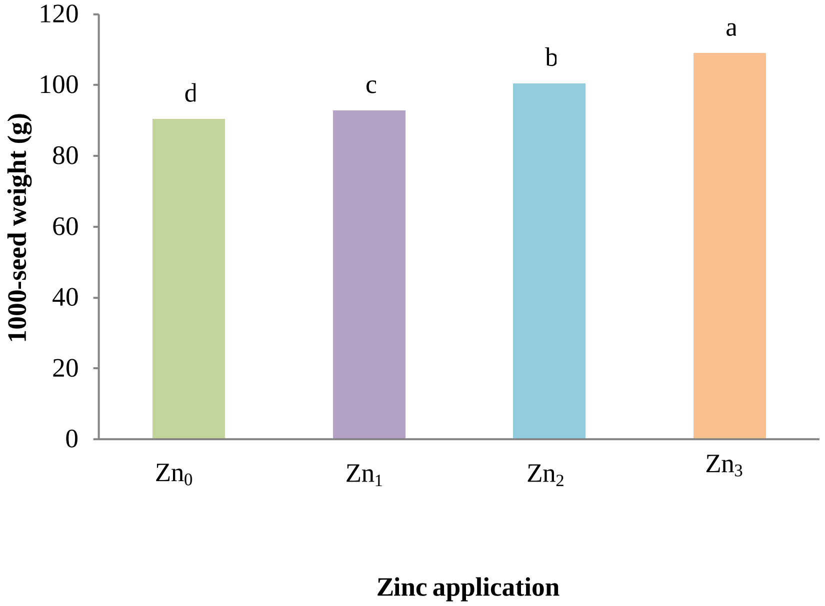
Combined effect of zinc and boron application

The number of seeds pod^{-1} of chickpea had been significantly affected by the combined effects of various Zn and B application methods and concentrations (Table 4). The Zn_3B_3 treatment combination rerecorded the highest number of seeds pod^{-1} (3.62). While the Zn_0B_0 treatment combination had the lowest number of seeds pod^{-1} (1.71).

4.2.3 1000-seed weight

Effect of zinc application

The effect of different concentrations of Zn application significantly affected the 1000 seed weight of chickpea (Figure 13). Experimental result showed that the highest 1000 seed weight (109.06 g) was found in Zn_3 treatment. While the lowest 1000 seed weight (90.46 g) was found in Zn_0 treatment. The variation of 1000 seed weight among different treatment due to reason that foliar application of micronutrients was more suitable than soil application due to the rapid availability, ease of use and reduced toxicity that could be caused by accumulation and element stabilization in the soil. Moreover, nutrient availability to plant from soil application could be reduced due to binding in the soil and restricted uptake when moisture is limiting. The result was similar with the findings of Singh *et al*. (2015) who reported that 1,000 seed weight was significantly higher in foliar treated chickpea plants rather than their control. Pathak *et al*. (2012) also stated that seed weight of chickpea increased as Zn doses was increased.

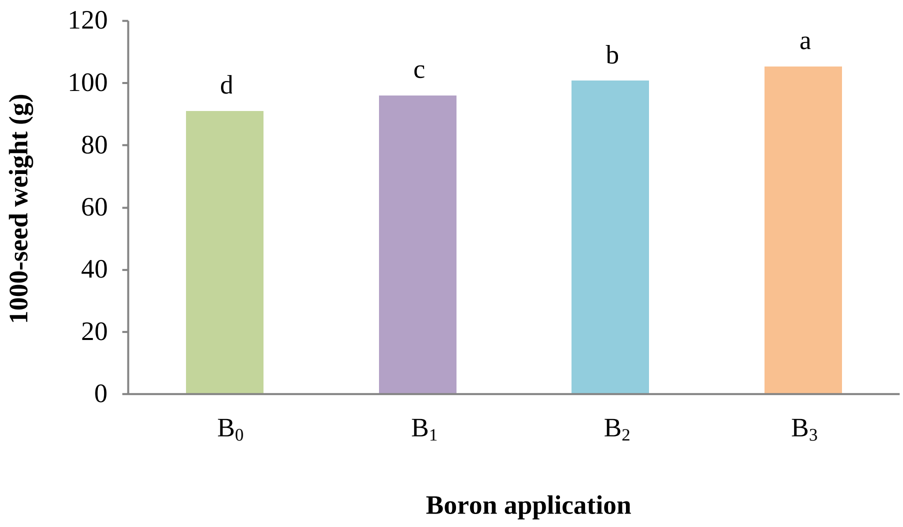


Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage.

Figure 13. Effect of different zinc application methods and concentrations on1000-seed weight of chickpea [$LSD_{(0.05)}$=3.61]

Effect of boron application

The 1000 seed weight of chickpea was significantly affected by the different B application methods and concentrations (Figure 14). In this experiment the highest 1000 seed weight (105.29 g) was found in B_3 treatment. While B_0 treatment had the lowest 1000 seed weight (90.99 g). B was more pronounced on most of the yield attributes of chickpea, because it plays a positive role in improving the vegetative structure for nutrient absorption and supply strong sink through evolution of reproductive structure as well as production of assimilates to fill important economical site i.e. pods and seed. Raza *et al.* (2014) founded significant increase in 1000-grain weight in wheat with B spray. This increase in grains weight is primarily owing to role of B in grain setting and sugar translocation. B may have played its role in translocation and that is why grains gained more weight. Shaker and Mohammed (2011) also reported that insunflower application of B as foliar spray during budding stage on different genotypes recorded the significant increase in 1000 seed weight both in spring and autumn season.



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 14. Effect of different boron application methods and concentrations on1000-seed weight of chickpea [$LSD_{(0.05)}$=2.62]

Combined effect of zinc and boron application

The combined effects of various Zn and B application methods and concentrations had a significant impact on 1000 seed weight of chickpea (Table 4). The maximum 1000 seed weight was recorded with the Zn_3B_3 treatment combination (122.98 g). However, the lowest 1000 seed weight was achieved with the Zn_0B_0 treatment combination (80.20 g).

Table 4. Combined effect of zinc and boron application methods and concentration on number of pods plant^{-1}, seeds pod^{-1} and 1000-seed weight of chickpea

Treatment combinations	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000-seed weight (g)
Zn_0B_0	14.27 n	1.71 i	80.20 l
Zn_0B_1	15.97 l	1.88 h	90.65 j
Zn_0B_2	17.77 k	2.05 g	92.59 i
Zn_0B_3	18.20 j	2.26 e	98.41 f
Zn_1B_0	15.20 m	1.81 h	88.50 k
Zn_1B_1	19.07 i	2.15 f	92.89 i
Zn_1B_2	20.97 g	2.27 e	95.87 g
Zn_1B_3	21.63 f	2.30 e	94.20 h
Zn_2B_0	18.83 i	2.24 e	94.57 h
Zn_2B_1	20.20 h	2.43 d	99.10 f
Zn_2B_2	25.17 e	2.61 c	103.07 d
Zn_2B_3	26.77 c	2.65 c	105.55 c
Zn_3B_0	24.83 e	2.65 c	100.68 e
Zn_3B_1	26.07 d	2.66 c	101.37 e
Zn_3B_2	27.27 b	2.95 b	111.23 b
Zn_3B_3	32.97 a	3.62 a	122.98 a
LSD (0.05)	0.44	0.08	0.88
CV (%)	4.78	3.64	3.18

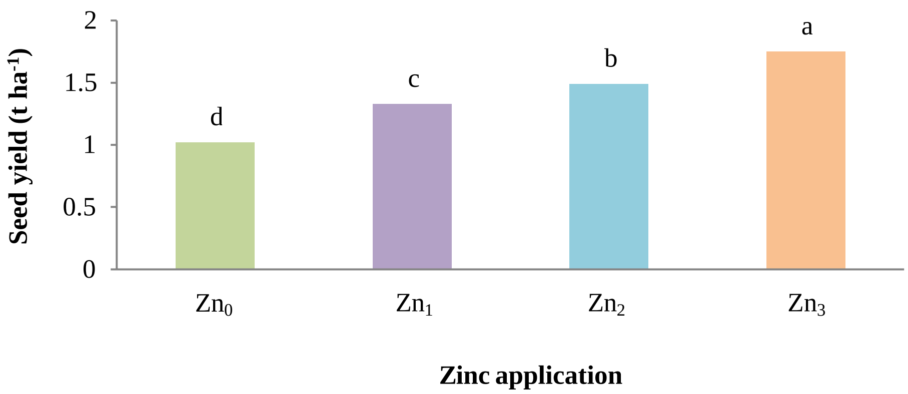
Here, in a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

4.3 Yield characters

4.3.1 Seed yield

Effect of zinc application

Due to different methods and concentrations of Zn application seed yield of chickpea was significantly influenced (Figure 15). In this experiment result revealed that the Zn_3 treatment recorded the highest seed yield of chickpea (1.75 t ha^{-1}). While Zn_0 treatment had the lowest seed yield (1.02 t ha^{-1}). Foliar spraying during the pre-flowering stage was more effective because nutrients applied during pre-flowering stage were readily used for photosynthesis and assimilates quickly mobilized for grain filing and protein accumulation in grain. The increased yield might be due to enhanced yield attributes like number of pods $plant^{-1}$, number of seeds pod^{-1}, 1000-seed weight due to increased uptake of nutrients by chickpea by effective translocation of nutrients from sink to reproductive area of crop. El Habbasha *et al*. (2013) reported that when Zn is applied as foliar spray at flowering and grain filling stages, it increased grain yield in chickpea. Zn is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops. Growth and development would stop if specific enzymes were not present in plant tissue. Carbohydrate, protein, and chlorophyll formation is significantly reduced in zinc-deficient plants. Therefore, a constant and continuous supply of Zn is needed for optimum growth and maximum yield. Hadi *et al*. (2013) also reported that the Zn foliar application manipulates the growth of chickpea, resulting in beneficial changes in yield and yield components.

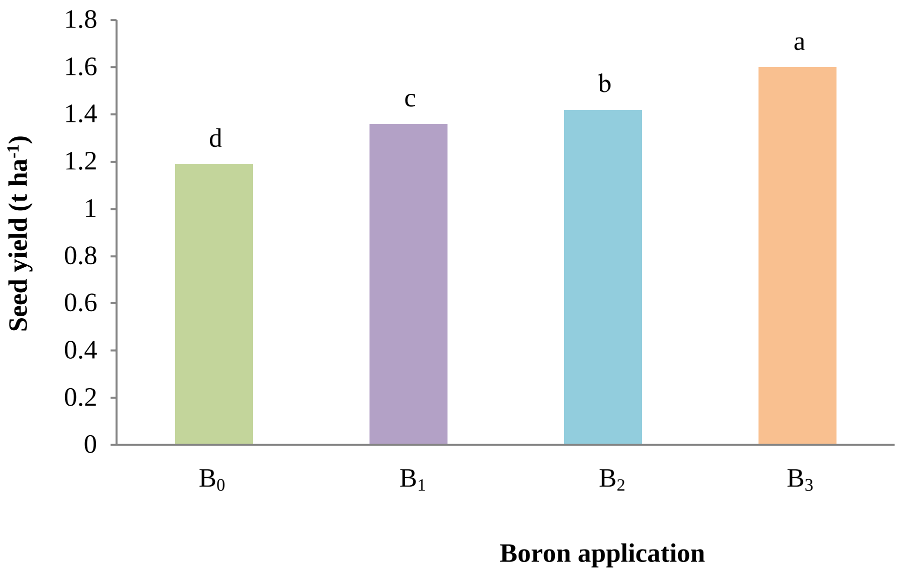


Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zincat pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage

Figure 15. Effect of different zinc application methods and concentrations on seed yield of chickpea [$LSD_{(0.05)}$=0.02]

Effect of boron application

Different B application methods and concentrations had a significant effect on chickpea seed yield (Figure 16). The results of this experiment showed that the B_3 treatment had the highest seed yield of chickpea (1.60 t ha^{-1}). While seed yields from B_0 treatment had the lowest yield (1.19 t ha^{-1}). Bozoglu *et al.* (2008) reported that foliar application of boron brings improvement in flower formation and development, pollen formation, fertilization and seed development. Therefore, these improvements reduced the rate of flower and fruit shedding and ultimately resulted in higher number of pods and seed weight and thus increases seed yield of chickpea. Mohammad *et al.* (2012) reported that foliar application of B had a positive effect on yield parameters of safflower. Foliar spray@ 1 % B produced higher seed yield than B applied @ 0.5 %. Micronutrient elements play a critical role in plants that lead to increase of leaf area index and thereby increased light absorption and increase the amount of dry matter accumulation and economic yield



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 16. Effect of different boron application methods and concentrations onseed yield of chickpea [$LSD_{(0.05)}$=0.06]

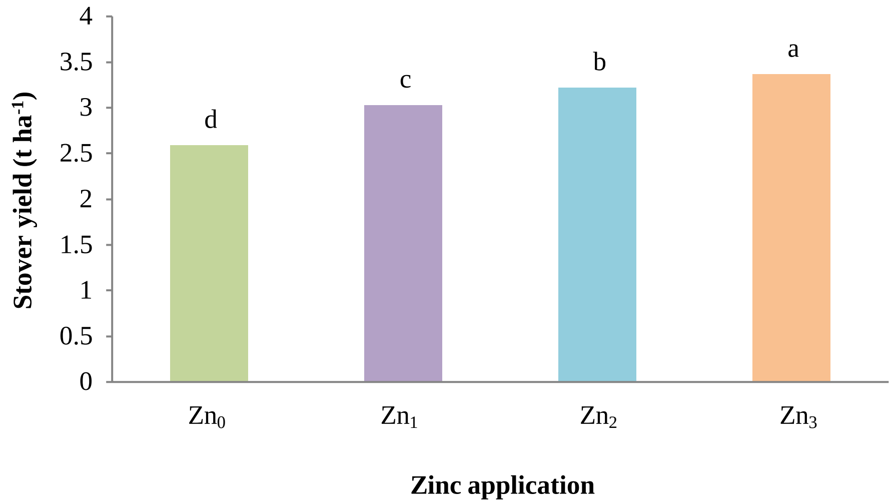
Combined effect of zinc and boron application

The combined effects of different Zn and B application significantly influenced chickpea seed yield (Table 6). Experimental result showed that the Zn_3B_3 treatment combination had the highest seed yield (2.01 t ha^{-1}). However, the Zn_0B_0 treatment combination resulted in the lowest seed yield (0.83 t ha^{-1}) which was statistically similar with Zn_0B_1 (0.92 t ha^{-1}) treatment combination.

4.3.2 Stover yield

Effect of zinc application

The way in which Zn fertilizer was applied had a significant effect on chickpea's stover yield (Figure 17). The results of the experiment indicated that the Zn_3 treatment had the highest stover yield (3.37 t ha^{-1}). While Zn_0 treatment had the lowest stover yield (2.59 t ha^{-1}). The result was similar with the finding of Kumar *et al.* (2017) who reported that basal application of 100 kg DAP ha^{-1} and two foliar sprays of 2 % $ZnSO_4$ (25 and 45 DAS) resulted in highest stover yield, consumptive use and water use efficiency of chickpea.

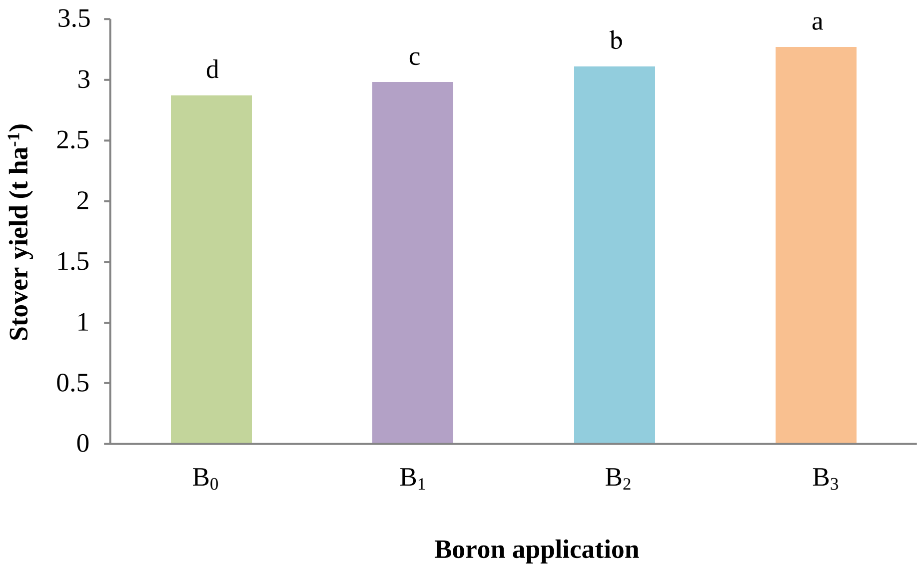


Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage.

Figure 17. Effect of different zinc application methods and concentration on stover yield of chickpea [$LSD_{(0.05)}$=0.05

Effect of boron application

On chickpea stover yield, various B application methods and concentrations had a significant effect (Figure 18). The results of this experiment revealed that the B_3 treatment recorded the highest stover yield (3.27 t ha^{-1}). On the other hand, B_0 treatment, generated the lowest stover yield of chickpea (1.19 t ha^{-1}). Application of B enhanced more uptakes of major nutrients resulting greater photosynthetic activities and led to greater vegetative growth of plants. Ultimately this accelerated growth due to proper metabolic activities produced higher stover yield in chickpea. Muhmood *et al.* (2014) reported that the stover yield of wheat increased with application of B. The grain and straw yield improved significantly with B application because pollen tube germination and grain setting at booting stage might be enhanced by B.



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 18. Effect of different boron application methods and concentrations onstover yield of chickpea [$LSD_{(0.05)}$=0.06]

Combined effect of zinc and boron application

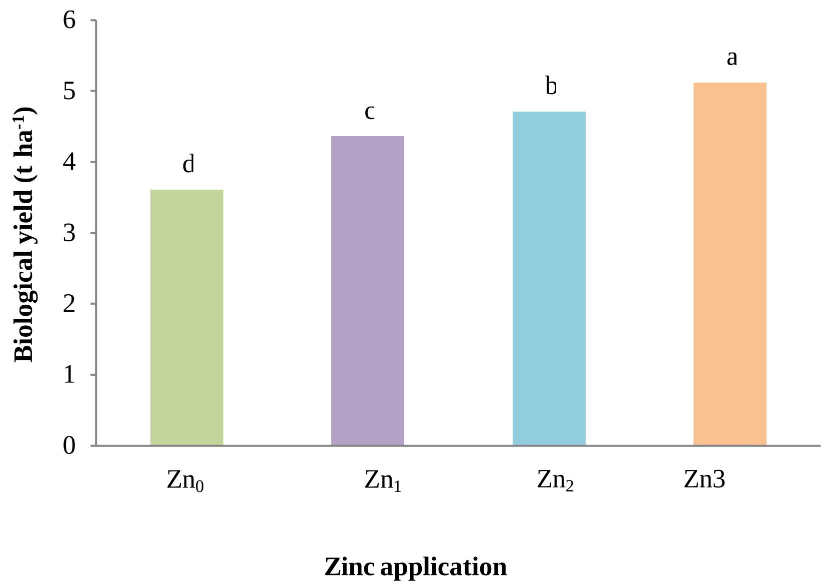
Different Zn and B application methods and concentrations had a significant effect on chickpea stover yield (Table 5). According to experimental results, the Zn_3B_3 treatment combination recorded the highest stover yield, (3.58 t ha^{-1}) which was statistically comparable to the Zn_2B_3 treatment combination (3.52 t ha^{-1}). The Zn_0B_0

treatment combination, however, recorded the lowest stover yield (2.42 t ha^{-1}), which was statistically comparable to the Zn_0B_1 treatment combination (2.48 t ha^{-1}).

4.3.3 Biological yield

Effect of zinc application

Different methods and concentrations of Zn application had a significant effect on the biological yield of chickpea (Figure 19). The experiment's findings showed that the Zn_3 treatment recorded the highest biological yield (5.12 t ha^{-1}) of chickpea. While the lowest biological yield was founded with the Zn_0 treatment (3.61 t ha^{-1}). Kobraee (2019) reported that the spraying treatments had a significant effect on dry weight of stems, leaves, seeds, pods and total plant of chickpea. They noticed that Zn spraying had the greatest effect on biological yield, dry weight of leaves, seeds, pod dry weight, grain yield and protein content.



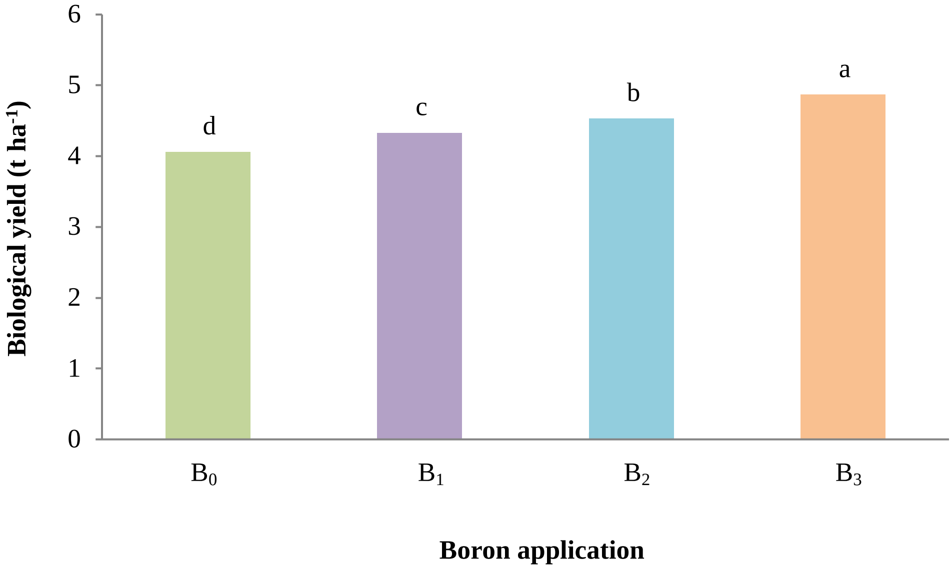
Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage.

Figure 19. Effect of different zinc application methods and concentrations onbiological yield of chickpea [$LSD_{(0.05)}$=0.09]

Effect of boron application

The biological yield of chickpea was significantly influenced by various B application methods and concentrations (Figure 20). The results of the experiment revealed that the B_3 treatment had the highest biological yield of chickpea (4.87 t ha^{-1}).

While the B_0 treatment led to the lowest biological yield (4.06 t ha^{-1}). B plays an important role in regulating plants' hormone levels and promoting proper growth. B increases flower production and retention, pollen tube elongation and germination, and seed and fruit development. Application of B improved yield attributes of chickpea resulted in increase in seed, stover and biological yield. Zahoor *et al.* (2011) reported that application of B increases the biological yield due to its possible positive correlation present between B and other micronutrients and enzymatic activity.



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 20. Effect of different boron application methods and concentrations onbiological yield of chickpea [$LSD_{(0.05)}$=0.13]

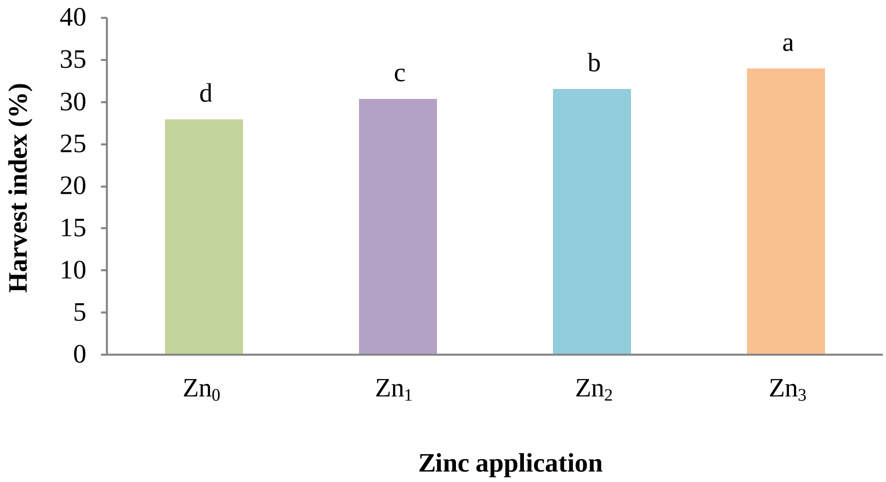
Combined effect of zinc and boron application

The biological yield of chickpea was significantly affected by the different ways that Zn and B were applied (Table 5). The highest biological yield (5.59 t ha^{-1}) was obtained by the Zn_3B_3 treatment combination. However, the lowest biological yield (3.25 t ha^{-1}) was obtained with the Zn_0B_0 treatment combination, which was statistically comparable to the Zn_0B_1 treatment combination (3.40 t ha^{-1}).

4.3.4 Harvest index

Effect of zinc application

The harvest index of chickpea was significantly influenced by various Zn application methods and concentrations (Figure 21). The results of the experiment revealed that the Zn_3 treatment had the highest harvest index (33.99 %) of chickpea. While treatment led to the lowest harvest index (27.95 %) of chickpea. Abid *et al.* (2019) reported that the maximum harvest index (39.06 %) was recorded with Zn spray which was might be due to better starch utilization resulting in more seed set and developing grains which increases the grain size and grain yield. Nandan *et al.* (2018) found that Zn and Fe treatments through foliar as well as soil treatments resulted in significantly higher HI.

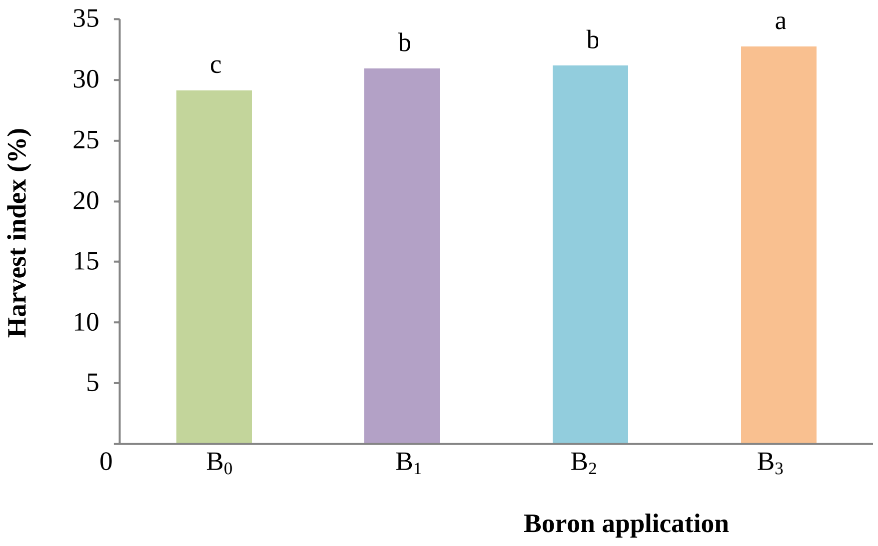


Here, Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage.

Figure 21. Effect of different zinc application methods and concentrations onharvest index of chickpea [$LSD_{(0.05)}$=0.41]

Effect of boron application

Different methods and concentrations of B application had a significant effect on the harvest index of chickpea (Figure 22). According to the findings, the B_3 treatment had the highest chickpea HI (32.72 %). While the lowest HI (29.12 %) for chickpea was founded by the B_0 treatment. Saleem *et al.* (2020) reported that foliar B spray had a significant impact on HI. Also, they discovered that treatment with 1.5% B spray at booting stage recorded the highest HI of wheat (47.88%) compared to other treatments. Ahmad *et al.* (2012) also showed that application of 1% B solution significantly affected harvest index of rice.



Here, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Figure 22. Effect of different boron application methods and concentrations onharvest index of chickpea [$LSD_{(0.05)}$=0.87]

Combined effect of zinc and boron application

The various combined application methods and concentrations of Zn and B had a significant effect on the HI of chickpea (Table 5). The Zn_3B_3 treatment combination obtained the highest HI (35.96 %) which was statistically similar with Zn_3B_2 (34.50 %) and Zn_3B_1 (34.32 %) treatment combination. Although statistically equal to the Zn_0B_1 (25.54 %) treatment combination, the lowest HI (27.06 %) was found with the Zn_0B_0 treatment combination.

Table 5. Combined effect of zinc and boron application methods and concentrations on seed, stover, biological yield and harvest indexof chickpea

Treatment Combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Zn_0B_0	0.83 i	2.42 h	3.25 h	25.54 h
Zn_0B_1	0.92 i	2.48 h	3.40 h	27.06 gh
Zn_0B_2	1.03 h	2.64 g	3.67 g	28.07 fg
Zn_0B_3	1.28 fg	2.83 f	4.11 f	31.14 b-d
Zn_1B_0	1.20 g	2.89 ef	4.09 f	29.34 ef
Zn_1B_1	1.30 fg	2.96 e	4.26 ef	30.52 c-e
Zn_1B_2	1.35 ef	3.13 d	4.48 de	30.13 de
Zn_1B_3	1.45 de	3.14 d	4.59 cd	31.59 b-d
Zn_2B_0	1.29 fg	2.95 e	4.24 ef	30.42 c-e
Zn_2B_1	1.46 d	3.14 d	4.60 cd	31.74 bc
Zn_2B_2	1.53 d	3.27 bc	4.80 c	31.88 bc
Zn_2B_3	1.67 c	3.52 a	5.19 b	32.18 b
Zn_3B_0	1.45 de	3.20 cd	4.65 cd	31.18 b-d
Zn_3B_1	1.74 bc	3.33 b	5.07 b	34.32 a
Zn_3B_2	1.78 b	3.38 b	5.16 b	34.50 a
Zn_3B_3	2.01 a	3.58 a	5.59 a	35.96 a
$LSD_{(0.05)}$	0.10	0.11	0.25	1.56
CV (%)	4.89	2.16	3.59	3.33

Here, In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Zn_0 = control (water spray), Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage, B_0 = control (water spray), B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from November-2020 to April 2021 in Rabi season, to study the growth and yield performance of chickpea through foliar application of Zn and B. The experiment consisted of two factors, and followed split plot design with three replications. Factor A. Different levels of zinc application : Zn_0= Control (water spray), Zn_1= Basal application of Zn, Zn_2= 0.5 % foliar application at pre-flowering stage, Zn_3= 1 % foliar application at pre-flowering stage and Factor B. Different level of boron application : B_0= Control (water spray), B_1= Basal application of B, B_2= 0.5 % foliarapplication at pre-flowering stage and B_3= 1 % foliar application at pre-flowering stage. For the purpose of evaluating the experiment's outcomes, data on various parameters were evaluated. These data revealed significant variance in chickpea's growth, yield- contributing and yield traits as a result of Zn and B foliar application and combination of these factors.

In case of different level of Zn application, the lowest dry matter weight plant^{-1} (11.06 g), the lowest number of pods plant^{-1} (16.55) and the lowest seed yield (1.02 t ha^{-1}) was recorded in the control treatment (Zn_0). While pre-flowering Zn fertilizer application @ 1% (Zn_3) played a significant role in the development of chickpea's growth and yield contributing traits, which ultimately influence seed yield. The highest dry matter weight plant^{-1} (16.05 g), highest number of pods plant^{-1} (27.79), seeds pod^{-1} (2.97), 1000-seed weight (109.06 g) and seed yield (1.75 t ha^{-1}) were recorded in Zn_3 treatment (1 % foliar application at pre-flowering stage) treatment. In case of different methods of B application, the lowest dry matter weight plant^{-1} (12.72 g), the lowest number of pods plant^{-1} (18.28) and the lowest seed yield ranges (1.19 t ha^{-1}). The highest seed yield (1.60 t ha^{-1}) was recorded in B_3 (1 % foliar application at pre-flowering stage) treatment which was due to enhanced growth and yield attributes like highest number of dry matter weight plant^{-1} (14.27 g), number of pods plant^{-1} (24.89), seeds pod^{-1} (2.71) , 1000-seed weight (105.29 g).

When applied together 1 % foliar Zn and B at the pre-flowering stage (Zn_3B_3) effected chickpea's plant growth and yield contributing characteristics, leading to the maximum dry matter weight plant^{-1} (18.07 g), number of pods plant^{-1} (32.97), seeds pod^{-1} (3.62), 1000-seed weight (122.98 g), seed yield (2.01 t ha^{-1}) than compare to other treatments combinations. Within terms combined treatment, Zn_0B_0 showed lowest dry matter weight plant^{-1} (9.97 g), number of pods plant^{-1} (14.27), seeds pod^{-1} (1.71), 1000-seed weight (80.20 g), seed yield (0.83 t ha^{-1}). Therefore it is suggested that application of Zn (1 %) and B (1 %) by foliar spray at pre –flowering stage is beneficial for better growth, yield and yield contributing characteristics of chickpea crop.

Conclusion

Our experimental results revealed that different methods and concentrations of Zn and B application significantly influenced the seed yield and yield contributing characteristics of chickpea.

- The study showed that foliar Zn and B spraying is an effective treatment for chickpea growth and development compared to soil application and control. In case of different Zn application methods and concentrations, the lowest seed yield (1.02 t ha^{-1}) was recorded in the control treatment (Zn_0). While pre-flowering Zn fertilizer application @ 1 % (Zn_3) played a significant role in the development of chickpea's yield contributing traits, which ultimately influence seed yield. The highest number of pods $plant^{-1}$ (27.79), seeds pod^{-1} (2.97), 1000-seed weight (109.06 g) and seed yield (1.75 t ha^{-1}) were recorded in Zn_3 (1 % foliar application at pre-flowering stage) treatment.
- In case of different levels of B application, the seed yield ranges between 1.19 to 1.60 t ha^{-1}. The highest seed yield (1.60 t ha^{-1}) was recorded in B_3 (1 % foliar application at pre-flowering stage) treatment which was due to enhanced yield attributes like number of pods $plant^{-1}$ (24.89), number of seeds pod^{-1} (2.71) and 1000-seed weight (105.29).
- When applied together, 1 % foliar Zn and B at the pre-flowering stage (Zn_3B_3) affected chickpea plant growth and yield-contributing characteristics, leading to the maximum seed yield (2.01 t ha^{-1}) than compared to other treatment combinations.

Therefore, it could be suggested that application of Zn (1.0 %) and B (1.0 %) by foliar spray at pre-flowering stage is beneficial for better yield and quality production of chickpea crop.

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APPENDICES

Appendix I. Soil characteristics of the experimental field

Morphological features of the experimental field

Morphological features	Characteristics
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

The initial physical and chemical characteristics of soil of the experimental site (0-15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix II. Monthly meteorological information during the period from October to April, 2020.

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2020	October	31.2	23.9	76	52 mm
	November	29.6	19.8	53	00 mm
	December	28.8	19.1	47	00 mm
2021	January	25.5	13.1	41	00 mm
	February	25.9	14	34	7.7 m
	March	31.9	20.1	38	71 mm
	April	34.1°C	23.6°C	67%	138 mm

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix III: Lay out of the experimental field.

R_1				R_2				R_3			
Zn_1B_0	Zn_0B_3	Zn_2B_0	Zn_3B_1	Zn_0B_0	Zn_1B_3	Zn_3B_2	Zn_2B_0	Zn_1B_3	Zn_0B_0	Zn_2B_1	Zn_3B_0
Zn_1B_2	Zn_0B_1	Zn_2B_2	Zn_3B_0	Zn_0B_1	Zn_1B_2	Zn_3B_3	Zn_2B_2	Zn_1B_2	Zn_0B_3	Zn_2B_2	Zn_3B_3
Zn_1B_3	Zn_0B_0	Zn_2B_3	Zn_3B_3	Zn_0B_2	Zn_1B_0	Zn_3B_1	Zn_2B_3	Zn_1B_0	Zn_0B_1	Zn_2B_3	Zn_3B_2
Zn_1B_1	Zn_0B_2	Zn_2B_1	Zn_3B_2	Zn_0B_3	Zn_1B_1	Zn_3B_0	Zn_2B_1	Zn_1B_1	Zn_0B_2	Zn_2B_0	Zn_3B_1

Here R+ Replications, Zn_0 = control, Zn_1 =basal application of zinc, Zn_2 = 0.5 % foliar application of zinc at pre-flowering stage, Zn_3 = 1 % foliar application of zinc at pre-flowering stage, B_0 = control, B_1 =basal application of boron, B_2 = 0.5 % foliar application of boron at pre-flowering stage B_3 = 1 % foliar application of boron at pre-flowering stage.

Appendix IV. Analysis of variance of the data of plant height of chickpea at differentDAS.

Source	**DF**	Mean square of plant height at				
		30 DAS	50 DAS	70 DAS	90 DAS	At harvest (120 DAS)
Replication (R)	2	0.00063	0.3025	1.562	0.063	0.250
Zinc (Zn)	3	9.14125*	20.1331*	234.259*	188.302*	122.563*
Error	6	0.00062	0.3025	0.896	0.396	0.250
Boron (B)	3	3.47985*	4.3068*	58.387*	60.262*	68.462*
Zn×B	9	0.41810*	0.8553*	2.447*	9.835*	7.931*
Error	24	0.16729	0.2358	1.062	2.313	2.917
Total	47					

*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data of number of primary branches plant^{-1} of chickpea at different DAS.

Source	**DF**	Mean square of number of primary branches plant^{-1} at				
		30 DAS	50 DAS	70 DAS	90 DAS	At harvest (120 DAS)
Replication (R)	2	0.03062	0.14440	0.2730	0.0756	0.2500
Zinc (Zn)	3	0.70262*	9.94640*	18.9577*	14.9187*	6.3122*
Error	6	0.03062	0.08340	0.2100	0.3756	0.2500
Boron (B)	3	1.16902*	3.38365*	14.9786*	12.5602*	10.7964*
Zn×B	9	0.19238*	0.69012*	0.6128*	0.8153*	0.2537*
Error	24	0.01062	0.09865	0.0958	0.1506	0.0833
Total	47					

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of number of secondary branches plant^{-1} and dry matter weight plant^{-1}of chickpea at different DAS.

Source	**DF**	Mean square of	
		Number of secondary branches plant^{-1}	Dry matter weight plant^{-1}
Replication (R)	2	0.0056	0.0625
Zinc (Zn)	3	56.8100*	50.2308*
Error	6	0.0056	0.3958
Boron (B)	3	97.1678*	11.1447*
Zn×B	9	2.2836*	5.8381*
Error	24	0.6723	0.3125
Total	47		

*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of number of pods plant^{-1}, seeds pod^{-1} and 1000-seed weight of chickpea.

Source	**DF**	Mean square of		
		Pods plant^{-1}	Seed pod^{-1}	1000-seed weight
Replication (R)	2	0.063	0.01960	33.063
Zinc (Zn)	3	278.317*	2.30745*	848.005*
Error	6	0.063	0.00735	13.063
Boron (B)	3	99.564*	0.80785*	452.959*
Zn×B	9	7.489*	0.08777*	48.999*
Error	24	1.063	0.00758	9.729
Total	47			

*: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of number of seed yield, stover yield,biological yield and harvest index of chickpea.

Source	**DF**	Mean square of			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication (R)	2	0.00031	0.02031	0.06376	0.1722
Zinc (Zn)	3	1.12137*	1.37022*	4.92262*	75.5941*
Error	6	0.00031	0.00307	0.00919	0.1722
Boron (B)	3	0.34562*	0.35903*	1.40092*	26.0418*
Zn×B	9	0.01132*	0.01171*	0.03127*	2.4468*
Error	24	0.00464	0.00435	0.02550	1.0622
Total	47				

*: Significant at 0.05 level of probability

Appendix IX. Some pictorial view during the experimental period.

Plate 1: Seed Sowing of chickpea.

Plate 2: Tagging of the experimental plot.

Plate 3: Pesticide application on the plot.

Ptate 4: Experimental signboard of the field.

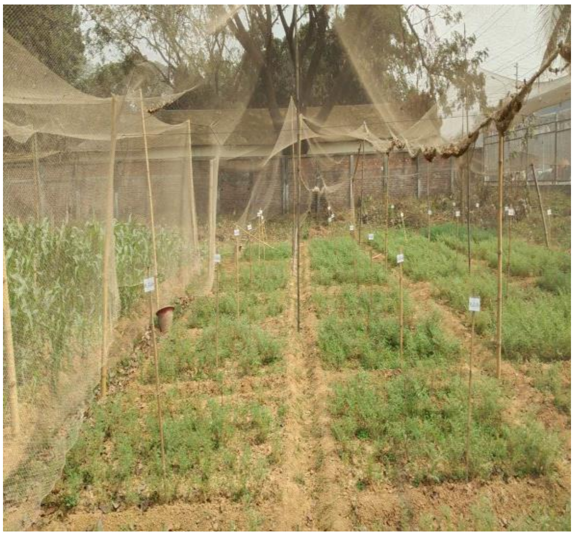

Plate 5: Vegetative stage of chickpea field.

Plate 6: Chickpea plants before harvesting.