EFFECT OF MANURE AND MICRONUTRIENTS (BORON AND ZINC) ON GROWTH AND YIELD OF POTATO

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JUNE, 2020

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A Thesis
Submitted to the Department of Soil Science
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

SOIL SCIENCE

SEMESTER: JANUARY- JUNE, 2020

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF MANURE AND MICRONUTRIENTS (BORON AND ZINC) ON GROWTH AND YIELD OF POTATO"** submitted to the Department of Soil Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **SOIL SCIENCE**, embodies the result of a piece of bonafide research work carried out by **Md. Firoz Miah**, Registration No. **12-04761** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

June, 2019

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Dedicated to

My

Beloved Parents

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the almighty Allah for there ever ending blessings for the successful completion of the research work.

The author wishes to express his gratitude and best regards to his respected Supervisor, ***Dr. Md. Asaduzzaman Khan****, Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for his continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.*

The author wishes to express his earnest respect, sincere appreciation and enormous indebtedness to his reverend Co-supervisor, ***Mst. Afrose Jahan****, Professor, Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.*

The author feels to express his heartfelt thanks to the honorable Chairman, ***Prof. Dr. Alok Kumar Paul****, Department of Soil Science along with all other teachers and staff members of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation during the period of the study.*

The author feels proud to express his deepest and endless gratitude to all of his course mates and friends to cooperate and help him during taking data from the field and preparation of the thesis. The author wishes to extend his special thanks to his lab mates, class mates and friends for their keen help as well as heartiest co-operation and encouragement.

The author expresses his heartfelt thanks to his beloved parents, Elder Sister and Brother and all other family members for their prayers, encouragement, constant inspiration and moral support for his higher study. May Almighty bless and protect them all.

The Author

EFFECT OF MANURE AND MICRONUTRIENTS (BORON AND ZINC) ON GROWTH AND YIELD OF POTATO

ABSTRACT

To study the effect of manure, zinc and boron on growth and yield of potato, an experiment was conducted in the farm under the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2018 to February, 2019. The experiment was laid out into Randomized Complete Block Design (RCBD) with three replications. Single factor was comprised with the study *viz*. T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 kgK ha^{-1} + 20 kgS ha^{-1}), T_2 (T_1 + 4 t CD ha^{-1}), T_3 (T_1 + 3 t PM ha^{-1}), T_4 (T_1 + 5 kg Zn ha^{-1}), T_5 (T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}), T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) and T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}). Data were recorded on different growth, yield contributing parameters, yield of potato and nutrient content in soil. Most of the parameters showed significant difference among the treatment. Result revealed that most of the parameters showed best results with the treatment T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) regarding growth and yield parameters and also nutrient content in soil and this treatment showed highest dry weight of haulm $hill^{-1}$ (38.26 g), dry weight of 100 g fresh tuber (20.32 g), number of tuber $hill^{-1}$ (8.12), tuber weight $hill^{-1}$ (308.20 g), tuber yield ha^{-1} (26.42 t) and stover yield ha^{-1} (20.44 t) whereas T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) showed lowest results regarding these parameters. So, it can be accomplished that the treatment T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) can be treated as the best compared to others.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	Mili Litre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a tuber crop belongs to the family Solanaccae. It originated in the central Andean area of South America (Keeps, 1979). Potato was introduced in this Indian subcontinent in the sixteenth century. It was grown then in small plots as a vegetable. Potatoes have been grown in Bangladesh since at least in the 19^{th} century. By 1920s, the first commercial production of the crop was established in the country (Islam *et al*., 1980).

Potato popularly known as “The king of vegetables” is very important solanaceous vegetable crop grown all over world due to their richness in carbohydrates and proteins. Potato is considered as the staple food crop in around 40 nations of the world (Islam and Nahar, 2012) and in India it is the fourth important crop after maize, wheat and rice (Ahmed *et al*. 2013). It contains energy, carbohydrate, starch, fibre, fat, protein, vitamin B6 , calcium, iron, sodium and zinc; 77kcal, 17.48 g, 15.45g, 2.20 g, 0.10 g, 2g, 0.29 mg, 12.1 mg, 0.78 mg, 6.0 mg and 0.29 mg per 100 g of potato respectively (Cakmak, 2008).

The agro-based economy of Bangladesh has two main challenges which are vast population to feed and small arable land area. To produce more food for the ever increasing population the arable land is being intensively used. Cropping intensity of this country in 1983-84 was 171% which has become 194% in 2015-16 (BBS, 2017). Moreover, cultivation of HYV and hybrid varieties of different crops is deteriorating soil fertility day by day due to exhaustive nature of those varieties. As a consequence new nutrient deficiency in soil is emerging. Chronologically N, P, K, S, Zn and B deficiencies have arisen in this country’s soils (Islam, 2008).

Globally, potato is sharing about 19.34 million ha in the world, with total production of 376 million tones, and India now ranks third in acreage (2.07

million ha) and 2nd in production (45.95 million tonnes) with productivity of 22.21 t/ha. Recent reports indicate that in 2017-18 year the area coverage (4.8 lakh hectare), production (93.4 lakh MT) and yield (19.8 t ha^{-1}) (BBS, 2018). The average yield of potato was 14.89 t ha^{-1} in Bangladesh (FAO, 2005) that is very low in comparison to that of other leading potato growing countries in the world, such as, USA (43.49 t ha^{-1}), Denmark (39.41 t ha^{-1}) and UK (43.38 t ha^{-1}) (FAO, 2005). The reasons for low yield of potato in Bangladesh are climatic limitation, poor yielding seed tubers and unscientific production practices such as imbalanced fertilizer management and soil moisture regulation.

Micronutrients play a very important role in vital processes of plants. They increase the chlorophyll content of leaves, improve photosynthesis which intensify the assimilating activity of the whole plants (Tripathi *et al*. 2015). Foliar application of microelement solution (B, Cu, Mn, Zn and Mo) on potato leaves increased the uptake of N, P, K; chlorophyll content and photosynthesis in leaves, promoted the tuber expansion and increase potato yield.

Some reasons of micronutrient deficiency in Bangladesh were highlighted by Jahiruddin and Islam (2014) and those are organic matter depletion, unbalanced use of fertilizers, minimum or no use of manure, high cropping intensity, high pH (e.g. calcareous soils), nutrient leaching and light textured soils (Jahiruddin and Islam, 2014). The main reasons also for the occurrence of micronutrient deficiency is the adoption of intensive cropping programme with high-yielding varieties of crops with the increase in irrigation facilities (Jahiruddin and Islam, 2014).

Farmers of Bangladesh are not habituated with the use of micronutrient in crop cultivation that challenge balanced fertilization and creates negative impact in crop production (Rijpma and Jahiruddin, 2004).

There are lots of factors that influence the potato cultivation and availability of zinc and boron is the most prominent factor to determine the growth and yield of potato. It is reported that among micronutrients Zn and B have occupied unique position in enhancing the yield of potato (Trehan and Grewal, 1989).Zn help to increase the rate of photosynthesis and the translocation of photosynthates leading to increased size and number of tubers. Zinc is very important crop nutrient that plays a vital role in growth and development of potato by enhancing the synthesis of growth hormone and chlorophyll (Ali *et al*., 2008; Graham *et al*., 2000). Zinc is present in various forms in the soil i.e. sulphate, water dissolvable, exchangeable, associated with organic content and settled by the auxiliary clay minerals (Alloway, 2008).

Zinc is considered as the most important micronutrient for potato, and low recovery of applied Zn is the main limitation in enhancing the yield of potato crop (Singh *et al*., 2015). Zinc is involved in the synthesis of growth promoting hormones and the reproductive process of many plants (Ram *et al*., 2014). Zinc plays an important role as a metal component of enzymes (alcohol dehydrogenase, superoxide dismutase, carbonic anhydrase and RNA polymerase) or as a functional, structural or regulator cofactor of a large number of enzymes (Ali *et al*., 2013). Depending upon the duration of variety, potato crop is highly sensitive to Zn application. Further, Zn has been found to increase ascorbic acid content, but reduces the tyrosine and total phenol content in tubers which are the important criteria for processing Industries (Mondal*et al*., 2014).

Boron is essential for sugar transport, cell-wall synthesis, lignifications and phenol metabolism. Boron is involved in carbohydrate metabolism and protein synthesis. On molar basis, the requirement of boron for dicotyledons is higher than any other micronutrient (Sathya *et al*., 2009).

Boron Requirement of boron for potato crop is higher than monocotyledons. Boron application in potato increases the percentage of large and medium tubers and decreases the proportion of small tubers (Das and Jena, 1973). Bari, *et al*., (2001) showed that application of 1.1 kg B/ha from borax increased potato fresh haulm weight/hill, No. of tuber/hill, dry matter % of tubers and yield of tuber/ha, but decreased plant height. Omission of boron application in potato reduces the tuber yield and quality of potato significantly compared to balanced use of fertilizers (Prasad *et al*., 2014).Soil organic matter is a source nutrient and accumulation of nutrient may be affected by manure application. Application of cowdung 4 t/h and poultry manure 3 t/h increased plant height, potato tuber size, and weight of tuber significantly.

With a view of considering the above points, a study was conducted for evaluating the effect zinc, boron and manure on yield and quality of potato with the following objectives:

1. To study the effect of different zinc, boron and manure on yield and quality of potato;
2. To know the effect of zinc, boron and manure application on the micro-nutrient accumulation in potato ;
3. To study the application of micro-nutrient on the improvement of soil fertility.

CHAPTER II

REVIEW OF LITERATURE

Potato (*Solanum tuberosum* L.) is one of the major food crops of the world. A few reports are available regarding the requirement of zinc and boron for growth, and tuber production of potato. The N, P and K levels on potato has been studied in various part of the world. But very limited studies have been done on this crop under the agro-ecological condition of Bangladesh in respect of zinc and boron requirement. A brief review of these pertinent to the present study has been given below:

2.1 Effect of zinc (Zn)

Miyu and Sarma (2019) conducted a field experiment with the treatments of T1 (control) [FYM (25 t/ha) + RDF (150:120:100 kg NPK/ha], T2 (control + 0.1% Borax), T3 (control + 0.2% Zinc Sulphate), T4 (control + 0.2% Manganese Sulphate), T5 (control + 0.1% Borax + 0.2% Zinc Sulphate), T6 (control + 0.1% Borax + 0.2% Manganese Sulphate), T7 (control + 0.2% Zinc Sulphate + 0.2% Manganese Sulphate) and T8 (control + 0.1% Borax + 0.2% Zinc Sulphate + 0.2% Manganese Sulphate). The result revealed that, for growth parameters T8 (T1 or control + 0.1% Borax + 0.2% Zinc Sulphate + 0.2% Manganese Sulphate) was found to be the best. For yield attributes, T6 (T1 or control + 0.1% Borax + 0.2% Manganese Sulphate) and T8 (T1 or control + 0.1% Borax + 0.2% Zinc Sulphate + 0.2% Manganese Sulphate) were found to be the best. For quality parameters, T5 (T1 or control + 0.1% Borax + 0.2% Zinc Sulphate) was found to be the best with high dry matter content and less sugar.

Sati (2017) carried out a field experiments to investigate the response of zinc sulphate application on quality of potato tubers. The lay-out of experimental field was laid in randomized block design with 10 treatments with three replications. The results indicated that dry matter (22.57, 22.27 and 22.42%), starch (18.56, 19.11 and 18.83%) and protein (8.20, 8.45 and 8.33%) were maximum under treatment T9 (zinc sulphate @ 12.5 kg/ha at the time of planting and 12.5 kg/ha at the time of earthing-up), whereas available zinc content of potato tubers (52.27, 55.60 and 53.93 ppm) was higher under treatment T7 (zinc sulphate @ 25 kg/ha at the time of planting) during both the years and pooled analysis over the years, respectively. Results also indicated that specific gravity of potato tuber did not vary significantly with the treatments during both the years and pooled analysis over the years. Based on present investigation, it can be concluded that basal and/or split application of zinc sulphate at 25 kg/ha improved potato tuber quality under present agro-climatic conditions.

Banerjee and Sarkar (2017) carried out an experiment to assess the advantages of Zn nutrition in potato cv. Kufri Jyoti under alluvial soil having five treatments and four replications The potato was fertilized with five zinc levels (0, 1.5, 3.0, 4.5 and 6.0 kg Zn ha^{-1}) through zinc sulphate heptahydrate i.e. ZnSO4, 7H2O (commercial grade Multi-Zn contained 21% Zn) at the time of planting. A uniform dose of NPK at 200:150:150 kg ha^{-1} RDF was applied in all the plots in the form of urea (46% N), single super phosphate (16% P2O5), and muriate of potash (60% K2O). Results: Application Zn fertilizer at 4.5 kg ha^{-1} recorded significantly higher germination %, plant height, leaf area index (LAI), dry matter accumulation (DMA) and number of tubers $hill^{-1}$. Total number and yield of tuber ha^{-1} were also changed significantly ($P \leq .05$) with the levels of Zn fertilization. Quality parameters like total soluble solids (TSS), total acidity, ascorbic acid, starch and amount of total sugar contents of fresh potato tuber as well as organoleptic quality of chips (colour) also influenced significantly ($P \leq .05$) with varied levels of Zn fertilization. Results suggest that application of 4.5 kg Zn ha^{-1} in combination with recommended dose fertilizer (RDF) of NPK (i.e. 200:150:150 kg ha^{-1}) is vital for optimizing yield components, yield and quality of potato (cv. Kufri Jyoti).

Sarker and Moslehuddin (2018) conducted a study to explore the response of potato to application of micronutrients in soil. Seven treatments including a control were tested. Additive element trial technique was followed while designing the treatments taking six micronutrients i. e. Zn, B, Cu, Mn, Fe and Mo at the rate of 3, 2, 2, 3, 5 and 1 kg ha-1, respectively. Macronutrients, such as N, P, K and S were applied at recommended rates to all plots. The highest tuber yield (28.7 t ha^{-1}) was produced by the combined application of Zn and B. Only Zn application was sufficient to obtain the highest content of protein as well as content of almost all the nutrients in potato tuber. Antagonistic relation between Zn and P in soil-plant system was recorded in the study. Zinc and boron application influenced different growth and yield parameters of potato while the other four added micronutrients did not have any significant effect but combined application of Zn, B, Cu, Mn, Fe and Mo had beneficial role for better plant growth and production. Proper management of zinc and boron fertilizers including optimization of application rates of those nutrients can help to uphold the yield and quality of potato in floodplain soil.

Singh and Singh (2018) carried out a field experiment In order to study the response of potato cv. Kufri Pukhraj to foliar application of zinc. The experiment was conducted with eight different treatments namely; T1 - control, T2 – zinc @ 5 ppm, T3 - zinc @ 10 ppm, T4 - zinc @ 15 ppm, T5 - zinc @ 20 ppm, T6 - zinc @ 25 ppm, T7 - zinc @ 30 ppm and T8 - zinc @ 35 ppm, following Randomized Block Design with three replications. The observations recorded during the research, showed that foliar application of T7 - zinc @ 30 ppm had significant effect on growth, yield and quality characters of potato. The range of plant height (22.87cm and 31.91cm) and number of leaves (132.45 and 199.03) were recorded maximum in T7 - zinc @ 30 ppm, at 45 and 75 days after sowing respectively. Tuber yield (18.89 t ha-1), carbohydrate (19.52 g/100g) and TSS (7.55%) were also recoded maximum in T7 - zinc @ 30 ppm. Based upon the present investigation, it can be concluded that for commercial cultivation of potato cv. Kufri Pukhraj foliar application of Zn @ 30 ppm is very effective for getting the higher tuber yield with best quality tubers.

Kanwar (2019) carried out a field experiments to investigate the response of zinc application on quality of potato tubers. The results indicated that dry matter per cent (19.9 %), starch (17.5%), specific gravity (1.04%) and available zinc content (52.64 ppm) in potato tubers were recorded maximum in treatment T5 (Recommended dose of fertilizer of NPK + 6.0 kg zinc at the time of planting). Results also indicated that specific gravity of potato tuber did not vary significantly with the treatments. Based on present investigation, it can be concluded that basal application of zinc at 6.0 kg/ha along with recommended dose of fertilizer improved potato tuber quality

Mousavi (2007) conducted an experiment to study effect of foliar application of Zinc and Manganese on yield and quality of potato crop. All combinations of 4 levels of both elements (including 0, 2, 4 and 8 ppt solution as sulfate compound ZnSO4, MnSO4), Which formed 16 different treatments, were distributed randomly in each block. Solutions were sprayed 10 days before and 20 days after flowering. Plants were harvested after ripened and plant characteristics including tuber weight, number of tuber per plant, tuber yield, percent of dry matter, specific weight, protein and starch percent on tuber were measured. Results showed that Zn and Mn application increased all plant characteristics relating to yield and quality of potato crop. These were tuber yield per plant, dry matter percentage, specific weight, protein and starch contents of the tuber. Application of Zn at 8 ppt increased yield to 34170 kg ha-1 which, was 25% higher compare with control, meanwhile application of Mn at 4 ppt level increased yield to 33866 kg ha-1 which was only 15% higher than control. However application of Mn at 8 ppt decreased both quality and yield of potato tuber compare with 2 and 4 ppt. maximum yield (38950 kg ha-1) was obtained at 8 ppt of Zn and 4 ppt of Mn foliar application. Fertilizers were significantly affected on elements percentage in tuber. Zinc increased Zn percentage and decrease phosphorus percentage in tuber. Manganese increased Mn percentage of tuber, but no significantly effected on Zn, P and K in tuber. Zinc and manganese Fertilizers together increased Zn and Mn percentage and decrease P percentage in tubers, that they no significant.

Dhakal (2019) carried out the research entitled “Effect of foliar application of zinc on potato (*Solanum tuberosum* L.)” with the objective to increase the yield of potato through foliar application of zinc. The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications and 7 treatments. The treatments employed were control (water spray), single spray with 60ppm Zn-EDTA, single spray with 120ppm Zn-EDTA, single spray with 180ppm Zn-EDTA, double spray with 60ppm Zn-EDTA, double spray with 120ppm Zn-EDTA and double spray with 180ppm Zn-EDTA at 45DAP and 65DAP. The growth parameters including plant height, stem diameter and plant canopy were recorded at 45 DAE and 60DAE whereas yield parameters including number of tubers per plant, individual tuber weight and tuber yield were measured at harvest. Results revealed that the growth and yield contributing characters of potato were significantly affected by foliar application of zinc. It was observed that all the concentrations of zinc increased the plant height compared to control. Minimum plant height of 27.53cm was recorded with control and maximum height of 43.20cm was recorded with two foliar spray with 180ppm Zn-EDTA solution. The results obtained with 180ppm was found significantly superior to its lower doses and control for increasing stem diameter and plant canopy too. The highest stem diameter (9.66mm) and the maximum plant canopy (48.67cm) was recorded with double pray of 180ppm Zn-EDTA whereas the lowest stem diameter (7mm) and the lowest canopy (31.90cm) was recorded with control. Tuber yield was also found as the highest (23.29 mt/ha) with two foliar spray of 180ppm Zn-EDTA solution. The tuber yield of potato was found quite strongly correlated with individual tuber weight (R2 = 0.6876).

Rahman **(**2011**)** conducted a field experiment to study the effects of Zinc and Manganese on growth and yield of potato cv. Granola. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. There were four levels of Zinc. viz. 0, 3, 4 and 5 kg Zn ha^{-1} and also 4 levels of Manganese, i.e. 0, 1, 2 and 3 kg Mn ha^{-1} in this study. The results of the experiment revealed that the tallest plant, maximum number of leaves $plant^{-1}$, maximum number of main stems $hill^{-1}$, highest number of tubers $hill^{-1}$, maximum weight of tubers $hill^{-1}$ and the highest weight of tubers $plot^{-1}$ and $hectare^{-1}$ were found with 4kg Zn ha^{-1}, while Mn had no significant effect on the growth and yield of potato. Increasing doses of Zinc resulted in higher yield than the control. The results also showed that the plant height, number of leaves $plant^{-1}$, number of main stems $hill^{-1}$, number of tubers $hill^{-1}$, weight of tubers $hill^{-1}$, weight of tubers $plot^{-1}$ as well as weight of tuber $hectare^{-1}$ were maximum at 4kg Zn+lkg Mn ha^{-1}, while the minimum values were recorded from the control treatment. The maximum yield of tuber (23.82 t ha^{-1}) was recorded in the combination of 4kg Zn + l kg Mn ha^{-1}.

2.2 Effect of boron

Sarkar (2018) conducted an experiment to investigate the effect of soil and foliar boron fertilization on the growth, productivity and quality well as benefit in processing grade potato (Kufri Chipsona-3) in alluvial soil. The experiment comprised of five treatments [T , Recommended dose of fertilizer (RDF) of NPK;

T , RDF of NPK + 2.0 kg soil applied B/ha; T , RDF of NPK + 0.1% boric acid spray at 40 days after planting (DAP); T , RDF of NPK + 0.1% boric acid spray at 40 and 60 DAP; and T, RDF of NPK + 0.1% boric acid spray at 40, 50 and 60 DAP] arranged in a completely randomized block design replicated four times. Plant growth, yield, nutrient concentration and quality parameters of potato tuber (specific gravity, total soluble solids, tuber hardness, total acidity, Vitamin C and protein) were analyzed in the experiment. Experimental findings showed that RDF of NPK + 0.1% boric acid spray (thrice) produced significantly higher number (3.70 × 10 ha) and yield (33.49 t ha) of processing grade tuber than other boron levels (foliar and soil) tested. Application of RDF of NPK + 0.1% boric acid spray (thrice) exhibited its superiority by producing tubers with significantly higher specific gravity, total soluble solids, tuber hardness, total acidity, Vitamin C, protein and starch content with lowest phenol content and lighter chip colour. The results of this study indicate that application of boron (0.1% boric acid at 40, 50 and 60 DAP) in combination with RDF (200 kg N, 150 K O and 150 kg P O ha) is required for optimum yield of processing grade potato (cv. Kufri Chipsona-3) in alluvial.

El-Dissoky and Abdel-Kadar (2013) conducted two field experiments at season of 2012/2013 to evaluate the effect of boron as a foliar application on some potatoes cultivars. Results revealed that foliar spray of B-levels significantly affected potato growth parameters (i.e. plant height, No. of leaves/plant, fresh weight of plant, dry weight of plant and leaf area). Also all of total tuber yield, dry shoot yield and average weight of tubers significantly increased. Potato tubers yield increased by 17.39 % with foliar application of 60 mg L^{-1} B in the first location and by 16.95 % with 90 mg L^{-1} B in the second location; whereas dry shoot yield increased by 33.47 and 30.02 % in both locations, respectively with 60 mg L^{-1} B foliar spray. The highest average weight of tubers was 267 g in the first location and 275 g in the second location at foliar spray of 60 mg L^{-1} B. Quality of potato tuber parameters (i.e. dry matter, protein and starch percentage) significantly increased with foliar B application, also the uptake of N, P, and K significantly increased by foliar B application. Potato variety valor appeared superiority in plant growth, total tuber yield (19.905 Mg fed^{-1}), dry shoot yield and total NPK-uptake. Also potato varieties affected significantly N and K uptake. However, the increment of P-uptake, B-concentration, tuber dry matter %, protein % and starch % was not significant.

Yadav *et al.* (2006) evaluated the effects of boron (0.0, 0.10, 0.15, 0.20, 0.25, 0.30 or 0.35%), applied to foliage after transplanting, on the yield of tomato cv. DVRT-1. The highest number of fruits per plant (44.0), number of fruits per plot (704.0), yield per plant (0.79 kg), yield per plot (12.78 kg) and yield/ha (319.50 quintal) were obtained with 0.20% boron, whereas the greatest fruit weight (27.27 g) was recorded for 0.10% boron.

Oyinlola (2004) conducted a field trial in the Sudan savanna ecological zone in Nigeria to identify the effects of 0, 1, 2, 3, 4, and 5 kg B/ha on the growth, dry matter yield and nutrient concentration of tomato cultivars Roma VF and Dandino. Application of boron significantly ($P<0.05$) increased the number of leaves and dry matter yield of the crop. Nutrient concentrations of potassium and phosphorus in the plant tissue fell within the deficiency range established for tomato plants, while calcium, magnesium, boron, zinc, manganese and copper concentrations fell within and iron concentrations above the sufficient nutrient range. Significant correlation existed between growth, yield parameters and nutrient concentrations and also among the nutrient concentrations. Plants supplied with 2 kg B/ha recorded the highest number of leaves and dry matter yield in both years. Cultivar Dandino recorded higher number of leaves and dry matter yield than cv. Roma VF.

Amarchandra and Verma (2003) conducted an experiment to evaluate the effects of boron and calcium on the growth and yield of tomato cv. Jawahar Tomato 99. Boron (1, 2, and 3 kg/ha, calcium carbonate), along with phosphorus (60 kg/ha) and potassium (40 kg/ha), were applied before transplanting, whereas nitrogen (100 kg/ha) was applied in split doses at 25 and 50 days after transplanting. Data were recorded for plant height, number of branches per plant, fruit yield and seed yield. Application of 2 kg B/ha + 2 kg Ca/ha recorded the highest yield.

Piexoto et al. (1996) conducted an experiment in Brazil. They found that dry matter, yield and average tuber weight increased linearly with increasing rate of N, P, and K. B had no significant effect on yield of potato tubers.

Efkar *et al*. (1995) conducted an experiment to investigate the responses of potato cv. Desiree to the application of boron fertilizer in Pakistan using 4 levels of boron (0, 1, 1.5, and 2 kg B/ha). The crop also received a basal dressing of NPK fertilizers and FYM (5 t/ha). They evaluate that generally all the fertilizer treatments increased yield over control. Application of 1.5 kg B/ha gave the highest tuber yield of 10.9 t/ha compared with the control yield of 7.8 t/ha.

Pregno and Arour (1992) conducted an experiment to find out boron deficiency and toxicity in potato cv. Sebago on an oxisol of the Atherton Tablelands at North Queensland, Australia. In this field trial 5 doses of boron (0, 2, 4, 8, and 12 kg B/ha) were used. They evaluated that total tuber yield was the highest when 2 kg B/ha was applied and it was followed by 4 kg B/ha. Plant height was not increased by low rates of boron but was reduced by 8 and 12 kg B/ha compared with no B

Porter et al. (1986) conducted a field experiment to study the responses of potato cv. Kathdin to B application. They evaluated that band application in a complete fertilizer was the most efficient technique and the tuber yield was not affected by application of 4.5 kg B/ha. They concluded that reduced yield was associated with tubers per hill rather than the reduced tuber size.

Kiryukhin and Bezzubtseva (1980) evaluated the responses of potatoes to application of zinc and boron with NPK fertilizers on derho-podzolic soil in Moscow region. It was found that zinc and boron increased 9-12.9% and 5-13% average tuber yields, respectively over control. It was also found that Zn and B increased dry matter and starch, protein and ascorbic acid contents of tubers.

2.3 Combined effect of zinc and boron

Lenka (2019) conducted a field experiment to determine the effect of boron and zinc on growth and yield of potato (*Solanum tuberosum* L.). The experiment was laid out in a randomized block design with 4 replications, having 7 treatments. Micronutrient-management practices could not significantly affected plant emergence of potato, and it was above 98.3%. Application of both zinc and boron improved the growth and yield of potato significantly. Zinc and boron acted synergistically in increasing the tuber yield. The highest total tuber yield (30.12 t/ha) of potato was recorded with foliar application of 0.1% boron + 0.1% zinc along with recommended dose of fertilizer (RDF) of NPK. Soil application of only boron, only zinc and boron + zinc increased the total yield of tubers by 12.7%, 3.23% and 22.41%, respectively, over RDF of NPK only. The foliar application of only boron, only zinc and boron + zinc increased the total yield of tubers by 18.71%, 7.70% and 29.55%, respectively, over RDF of NPK only. The effect of boron in increasing tuber yield of potato was found more pronounced than zinc in our study experimental situation. Foliar application of B and Zn was found superior in increasing tuber yield to their soil application. The highest uptake of N, P, K, B and Zn were recorded with foliar application of B and Zn over RDF. Soil application of B and Zn significantly increased the B and Zn concentration in soil. Foliar application of B and Zn over RDF of NPK resulted in the highest net returns.

Osman (2019) conducted an experiment to investigate the effect of boron and zinc on the growth and yield of tomato. Three levels of boron (*viz*., 0, 1 and 2kg H_3BO_3 ha^{-1}) and zinc (*viz*., 0, 1 and 2kg $ZnSO_4$ ha^{-1}) were applied for each experiment. Results revealed that boron had significant effect on all yield attributes and yield of tomato. Application of 2kg H_3BO_3/ha produced the highest tomato yield (79.2 ton ha^{-1}) through increasing plant height, number of leaves per plant, number of branches per plant, number of flower clusters per plant, number fruits per plant, weight of fruits per plant, fruit weight, individual fruit length, fruit diameter and yield ha^{-1} of fruits. On the other hand, maximum yield of tomato was obtained from 2kg $ZnSO_4$ ha^{-1}. A combination of 2kg H3B03 and 2kg ZnS04 ha^{-1} gave the highest yield of Tomato (83.50 ton ha^{-1}). So, application of 2kg H3B03 along with 2kg ZnS04 ha^{-1} was the best for growth and yield of tomato.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during November 2018 to February, 2019 to study the effect of Zinc and Boron on yield and quality of potato. The materials used and methodology followed in the investigation have been presented details in this chapter.

3.1 Description of the experimental site

3.1.1 Geographical location

The experimental area was situated at $23^0$77' N latitude and $90^0$33' E longitude at an altitude of 9 meter above the sea level (Anon., 2004).

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of “The Modhupur Tract”, AEZ-28 (Anon., 1988a). 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 (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3 Soil

The soil of the experimental site belongs to the general soil type, shallow red brown terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was6.5 and had organic matter 1.10-1.99%. The experimental area was flat having available irrigation and drainage system and above flood level. The physico-chemical properties of soil is presented in Appendix II.

3.1.4 Climate

The area has subtropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). Climatic condition of the experimental site is presented in Appendix III.

3.2 Experimental details

3.2.1 Treatments

The single factor experiment considered as different micronutrients (Zinc and Boron) were as follows:

1. T_1 = N - 100 kg N ha^{-1} + P - 35 kg P ha^{-1} + K - 100 K kg ha^{-1} + S - 20 kg ha^{-1}
2. T_2 = T_1 + cowdung - 4 t ha^{-1}
3. T_3 = T_1 + poultry manure - 3 t ha^{-1}
4. T_4 = T_1 + Zn - 5 kg ha^{-1}
5. T_5 = T_1 + Zn - 5 kg ha^{-1} + B - 2 kg ha^{-1}
6. T_6 = T_1 + cowdung - 4 t ha^{-1} + Zn - 5 kg ha^{-1} + B - 2 kg ha^{-1}
7. T_7 = T_1+ poultry manure - 3 t ha^{-1} + Zn - 5 kg ha^{-1} + B - 2 kg ha^{-1}

3.2.2 Layout of the experiment

The experiment was laid out into Randomized Complete Block Design (RCBD)with three replications.There were 7 treatments including crontrol, in total 21 plots for 3 replications. Each block consisted of 7 unit plots. The size of each unit plot was 5 m ×3 m. The distance maintained between two replications and two plots were 0.5 m and 0.5 m, respectively. The layout of the experiment is shown in Appendix III.

3.2.3 Planting materials

In this research work, potato genotype - Cardinal (BARI Alu-8) variety was used as plant materials and the seeds were collected from BADC, sales centre Kashimpur, Gazipur.

3.3 Preparation of the experimental field

The land was opened with the help of a tractor drawn disc harrow on November2, 2018, and then ploughed with rotary plough twice followed by laddering to achieve a medium tilth required for the crop under consideration. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on November10, 2018 according to experimental specification. Individual plots were cleaned and finally prepared the plot.

3.4 Fertilizer application

During final land preparation, the land was fertilized as per treatment. 7 levels of fertilizer treatments were used under the present study as below:

Name of nutrients	Rate ha^{-1}
N	100 kg
P	35 kg
K	100 kg
S	20 kg
Zn	As per treatment
B	As per treatment
Cowdung	As per treatment
Poultry manure	As per treatment

Source: BARI, 2014 (Krisi Projukti Hat Boi, P. 54)

The total amount of nitrogen in the form of urea was divided into three equal portions; one third was applied during final land preparation. The rest two portions were applied as split doses at 25 DAS and 45 DAS, respectively. Whole amount of TSP, MOP, Gypsum and $ZnSO_4$, cowdung and poultry manure were applied at the time of final land preparation.

3.5 Preparation of planting materials

The seed tubers were procured from BADC sales centre Kashimpur, Gazipur and kept under diffused light condition in order to obtain healthy and well sprouted whole seed tubers, which were used for planting.

3.6 Sowing of tuber

Sprouted, healthy and disease free seeds were planted in furrows on 11 November 2018 at 5-7cm depth maintaining a spacing of 60 cm × 20 cm. After planting, the seeds were covered with soil.

3.7 Intercultural operations

3.7.1 Weeding

The crop field was infested with some weeds during the early stage of crop establishment. Two hand weedings were done; first weeding was done at 25 days after sowing followed by second weeding at 45 days after sowing.

3.7.2 Earthen up

Earthing up was done twice during the growing period. The first earthing up was done after 30 days of planting and the second one after 25 days of first earthing up.

3.7.3 Irrigation and drainage

Irrigation water was added to each plot, first irrigation was done as pre-sowing and other two were given at 30 and 50 days after sowing. Drainage channels were properly prepared to easy and quick drained out of excess water.

3.7.4 Plant protection measures

Dithane M-45@ 2.25 kg/ha was sprayed after complete emergence of the crop at an interval of 15days to protect the incidence of late blight disease. Furadan 5G was applied against soil insects during final land preparation at the rate of 10 kg/ha.

3.8 Recording of data

Data were recorded on the following parameters from the sample plants during the course of experiment.

3.8.1 Growth parameters

1. Plant height
2. Number of stems hill^{-1}
3. Number of leaves hill^{-1}
4. Plant dry matter content

3.8.2 Yield and yield contributing parameters

1. Number of tuber hill^{-1}
2. Individual tuber weight (g)
3. Tuber weight hill^{-1} (g)
4. Tuber yield plot^{-1} (kg)
5. Tuber yield (t ha^{-1})
6. Stover yield (t ha^{-1}) and
7. Harvest index (%)

3.8.3 Yield parameters

1. Number of tuber hill^{-1}
2. Individual tuber weight (g)

3. Tuber weight hill^{-1} (g)
4. Tuber yield plot^{-1} (kg)
5. Tuber yield ha^{-1} (t)
6. Stover yield ha^{-1} (kg)
7. Harvest index (%)

3.8.4 Yield parameters

Soil plant nutrients – Organic matter, N, P, K, B and Zn

3.9 Procedures of recording data

A brief outline of the data recording procedure followed during the study isgiven below:

3.9.1 Growth characters

Plant height (cm)

Plant height was recorded at 30 and 60 days after sowing (DAS) and at harvest. The height was measured from the base of the plant to the longest end of the stem and was expressed in centimeter (cm).

Number of stems hill^{-1}

The number of main stems per hill of the sample plants was recorded at 30 and 60 days after sowing (DAS) and at harvest, and the average number of stems produced per hill was recorded.

Number of leaves hill^{-1}

The number of leaves per hill of the sample plants was recorded at 30 and 60 days after sowing (DAS) and at harvest, and the average number of leaves produced per hill was recorded.

Fresh weight (g)

Fresh weight of haulm was measured at harvest. Sample plants from each plot were collected. The average weight of haulm was recorded from selected plants for each plot at the time of harvesting. The mean values were recorded.

Plant dry matter content (g)

Dry matter content of haulm was measured at harvest. Sample plants from each plot were collected. The plant parts were packed in paper packets then kept in the oven at 80°C for 72 hrs to reach a constant weight. Then the dry weights were taken with an electric balance. The mean values were determined.

Dry weight of 100 g fresh tuber (g)

Sample 100 g tuber from each plot were collected then it was preserved in paper packets and kept in the oven at 80°C for 72 hrs to reach a constant weight. Then the dry weights were taken with an electric balance. The mean values were recorded.

Number of tuber hill^{-1}

The number of tubers from 10 selected plants was counted and average number of tubers was calculated.

Tuber weight hill^{-1} (g)

The weight of tubers from 10 selected hills was recorded and average weight of tubers per hill was calculated.

Tuber yield plot^{-1} (kg)

To obtain yield per hill, weight of tuber was taken from ten harvested sample plants and the tuber yield per unit plot was found out as total tuber weight of all the plants from each unit plot.

Tuber yield ha^{-1} (t)

After collection of tuber weight per plot, it was converted to ton per ha.

Stover yield ha^{-1} (kg)

Weight cleaned and well dried stover were collected from each plot and then weights were taken and converted into hectare and were expressed in t ha^{-1}.

Harvest Index (%)

It denotes the ratio of economic yield to biological yield and was calculated with following formula (Donald, 1963; Gardner *et al.*, 1985).

$$\text{Harvest Index (\%)} = \frac{\text{Tuber yield}}{\text{Tuber yield + Stover yield}} \times 100$$

3.10 Statistical analysis

The data obtained for different characters were statistically analyzed using MSTATC software. The mean values of all the characters were evaluated and analysis of variance was performing by the 'F' test. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present study are presented in several terms. The experiment was conducted to study the effect of zinc, boron and manureon yield and quality of potato. The results are presented and discussed under the following parameters:

4.1 Growth parameters

4.1.1 Plant height (cm)

Application of zinc, boron and manure significantly influenced the plant height of potato at different growth stages (Table 1 and Appendix 5). Results showed that the highest plant height (20.53, 60.36 and 66.40cm at 30 and 60 DAS and at harvest, respectively) was found from T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) at 60 DAS and at harvest followed by T_5 (T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}). The lowest plant height (16.18, 54.27 and 60.48cm at 30 and 60 DAS and at harvest, respectively) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was statistically similar with T_4 (T_1 + 5 kg Zn ha^{-1}) at 60 DAS and at harvest. Similar result was also observed by Osman (2019) who found together application of B and Zn gave maximum plant height.

Table 1. Plant height of potato as influenced by micronutrients (Zn and B) and manure

Treatments	Plant height (cm)		
	30 DAS	60 DAS	At harvest
T_1	16.18 e	54.27 d	60.48 d
T_2	18.91 c	56.87 bc	62.95 bc
T_3	18.67 c	56.48 bc	62.73 bc
T_4	17.44 d	55.63 cd	61.52 cd
T_5	19.36 bc	57.74 b	64.02 b
T_6	20.12 ab	59.15 a	65.78 a
T_7	20.53 a	60.36 a	66.40 a
$LSD_{0.05}$	0.9889	1.402	1.425
CV(%)	5.26	8.23	9.67

In a column means having similar letters arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

CD = Cowdung, PM = Poultry manure

T_1 = 100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}
T_2 = T_1 + 4 t CD ha^{-1}
T_3 = T_1 + 3 t PM ha^{-1}
T_4 = T_1 + 5 kg Zn ha^{-1}
T_5 = T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
T_6 = T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
T_7 = T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}

4.1.2 Number of stems hill^{-1}

Significant variation was found on number of stems hill^{-1}of potato at different growth stages due to application of zinc, boron and manure (Table 2 and Appendix 6). Results revealed that the highest number of stems hill^{-1}(3.92, 4.68 and 4.92 at

30 and 60 DAS and at harvest, respectively) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) at all growth stages (at 30, 60 DAS and at harvest) followed by T_5 (T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}).The lowest number of stems $hill^{-1}$(2.94, 3.11 and 3.22 at 30 and 60 DAS and at harvest, respectively) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was statistically similar with T_4 (T_1 + 5 kg Zn ha^{-1}) at 60 DAS and at harvest. Singh and Singh (2018) found that Zn has significant effect on increased number of leaves in potato. Again, El-Dissoky and Abdel-Kadar (2013) observed leaves obtained with higher rate of boron. Similar result was also observed by Osman (2019).

Table 2.Number of stems $hill^{-1}$ potato as influenced by micronutrients (Zn and B) and manure

Treatments	Number of stems $hill^{-1}$		
	30 DAS	60 DAS	At harvest
T_1	2.940 c	3.110 d	3.220 d
T_2	3.330 bc	3.930 b	3.960 bc
T_3	3.240 bc	3.780 bc	3.800 bc
T_4	3.070 c	3.360 cd	3.450 cd
T_5	3.680 ab	4.040 b	4.140 b
T_6	3.920 a	4.680 a	4.920 a
T_7	3.880 a	4.520 a	4.770 a
$LSD_{0.05}$	0.4570	0.4774	0.5512
CV(%)	4.05	4.24	5.33

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

CD = Cowdung, PM = Poultry manure

T_1 = 100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}
T_2 = T_1 + 4 t CD ha^{-1}
T_3 = T_1 + 3 t PM ha^{-1}
T_4 = T_1 + 5 kg Zn ha^{-1}
T_5 = T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
T_6 = T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
T_7 = T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}

4.1.3 Number of leaves hill^{-1}

Number of leaves hill^{-1}of potato was at different growth stages significantly affected due to application of and manure (Table 3 and Appendix 7). Results indicated that the highest number of leaves hill^{-1}(13.24, 30.36 and 32.68 at 30 and 60 DAS and at harvest, respectively) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) at the time of harvest but it was significantly same at 30 DAS and 60 DAS. The lowest number of leaves hill^{-1}(9.44, 25.12 and 28.34 at 30 and 60 DAS and at harvest, respectively) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was statistically same with T_4 (T_1 + 5 kg Zn ha^{-1}) at the time of harvest.

Table 3.Number of leaves hill^{-1} of potato as influenced by micronutrients (Zn and B) and manure

Treatments	Number of leaves hill^{-1}		
	30 DAS	60 DAS	At harvest
T_1	9.440 e	25.12 e	28.34 d
T_2	11.56 bc	28.17 bc	30.25 c
T_3	11.39 c	27.84 c	29.63 c
T_4	10.71 d	26.44 d	28.71 d
T_5	12.18 b	29.00 b	31.71 b
T_6	13.24 a	30.36 a	32.68 a
T_7	12.97 a	30.12 a	32.36 ab
$LSD_{0.05}$	0.6239	0.9793	0.8268
CV(%)	4.87	7.28	9.39

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

CD = Cowdung, PM = Poultry manure

T_1 = 100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}
T_2 = T_1 + 4 t CD ha^{-1}
T_3 = T_1 + 3 t PM ha^{-1}
T_4 = T_1 + 5 kg Zn ha^{-1}
T_5 = T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
T_6 = T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
T_7 = T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}

4.1.4 Fresh Weight of haulm hill^{-1} at harvest

Application of zinc and boron significantly influenced the fresh weight of haulm hill^{-1}of potato (Table 4 and Appendix 8). Results showed that the highest fresh weight of haulm hill^{-1}(244.70g) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) followed by T_5 (T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest fresh weight of haulm hill^{-1}(186.50g) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}).

Table 4. Percent dry matter content of potato as influenced by micronutrients (Zn and B) and manure

Treatments	Weight of haulm hill^{-1} at harvest	
	Fresh weight (g)	Dry weight (g)
T_1	186.50 e	27.42 e
T_2	216.70 c	32.52 c
T_3	212.80 c	31.14 cd
T_4	197.80 d	29.88 d
T_5	227.40 b	35.29 b
T_6	244.70 a	38.26 a
T_7	239.90 a	37.47 a
$LSD_{0.05}$	6.199	1.385
CV(%)	9.94	6.47

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

CD = Cowdung, PM = Poultry manure

T_1 = 100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}
T_2 = T_1 + 4 t CD ha^{-1}
T_3 = T_1 + 3 t PM ha^{-1}
T_4 = T_1 + 5 kg Zn ha^{-1}

$T_5 = T_1$ + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
$T_6 = T_1$ + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
$T_7 = T_1$+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}

4.1.5 Dry weight of haulm $hill^{-1}$ at harvest (g)

Significant variation was found on dry weight of haulm $hill^{-1}$of potato due to application of zinc and boron (Table 4 and Appendix 8). Results revealed that the highest dry weight of haulm $hill^{-1}$(38.26g) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}). The lowest dry weight of haulm $hill^{-1}$(27.42g) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was significantly different from other treatments.

4.2 Yield contributing parameters

4.2.1 Dry weight of 100 g fresh tuber (g)

Dry weight of 100 g fresh tuber of potato was significantly affected due to application of zinc, boron and manure (Table 5 and Appendix 9). Results indicated that the highest dry weight of 100 g fresh tuber (20.32 g) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) followed by the treatment T_5 (T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}). The lowest dry weight of 100 g fresh tuber (17.60 g) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was significantly different from other treatments. El-Dissoky and Abdel-Kadar (2013) found that B had significant influence for increasing of dry matter content of fresh tuber which result supported the present study.

4.2.2 Number of tuber hill^{-1}

Number of tuber hill^{-1} of potato was significantly affected due to application of zinc, boron and manure (Table 5 and Appendix 9). Results indicated that the highest number of tuber hill^{-1} (8.12) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with the treatment T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest number of tuber hill^{-1} (6.32) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was statistically similar with T_4 (T_1 + 5 kg Zn ha^{-1}).

4.2.3 Tuber weight hill^{-1} (g)

Application of zinc, boron and manure significantly influenced the tuber weight hill^{-1}of potato (Table 5 and Appendix 9). Results showed that the highest tuber weight hill^{-1}(308.20 g) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with the treatment T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}).The lowest tuber weight hill^{-1}(246.40 g) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was significantly different from other treatments.

Table 5. Yield contributing parameters of potato as influenced by micronutrients (Zn and B) and manure

Treatments	Yield contributing parameters		
	Dry weight of 100 g fresh tuber (g)	Number of tuber hill^{-1}	Tuber weight hill^{-1} (g)
T_1	17.60 e	6.320 d	246.40 f
T_2	19.22 c	7.120 b	278.30 c
T_3	18.88 cd	6.780 c	262.50 d
T_4	18.42 d	6.520 cd	255.40 e
T_5	19.77 b	7.430 b	287.60 b
T_6	20.32 a	8.120 a	308.20 a
T_7	20.04 ab	7.930 a	305.50 a
$LSD_{0.05}$	0.4774	0.3232	5.446
CV (%)	8.71	5.52	10.46

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

CD = Cowdung, PM = Poultry manure

T_1 = 100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}
T_2 = T_1 + 4 t CD ha^{-1}
T_3 = T_1 + 3 t PM ha^{-1}
T_4 = T_1 + 5 kg Zn ha^{-1}
T_5 = T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
T_6 = T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
T_7 = T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}

4.3 Yield parameters

4.3.1 Tuber yield plot^{-1} (kg)

Significant variation was found on tuber yield plot^{-1}of potato due to application of zinc and boron (Table 6 and Appendix 10). Results revealed that the highest tuber yield plot^{-1} (39.63 kg) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) followed by the treatment T_5 (T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest tuber yield plot^{-1}(30.21 kg) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was significantly different from other treatments.

4.3.2 Tuber yield ha^{-1} (t)

Significant variation was found on tuber yield ha^{-1} of potato due to application of zinc, boron and manure (Table 6 and Appendix 10). Results revealed that the highest tuber yield ha^{-1} (26.42 t) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) followed by T_5 (T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest tuber yield ha^{-1} (20.14 t) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was significantly different from other treatments. Similar result was also observed by Lenka (2019) who found that application of both zinc and boron improved the growth and yield of potato significantly. Soil application of only boron, only zinc and boron + zinc increased the total yield of tubers by 12.7%, 3.23% and 22.41%, respectively, over RDF of NPK only.

4.3.3 Stover yield ha^{-1} (t)

Application zinc, boron and manure significantly influenced the stover yield ha^{-1} of potato (Table 6 and Appendix 10). Results showed that the highest stover yield ha^{-1}(20.44 t) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest stover yield ha^{-1}(16.48 t) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was statistically similar with T_4 (T_1 + 5 kg Zn ha^{-1}).

4.3.4 Harvest index (%)

Harvest index of potato was significantly affected due to application of zinc, boron and manure (Table 6 and Appendix 10). Results indicated that the highest harvest index (57.40%) was found from T_5 (T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with the treatment T_2 (T_1 + 4 t CD ha^{-1}) and T_3 (T_1 + 3 t PM ha^{-1}). The lowest harvest index (55.00%) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was significantly different from other treatments.

Table 6. Yield parameters of potato as influenced by micronutrients (Zn and B) and manure

Treatments	Yield parameters			
	Tuber yield $plot^{-1}$ (kg)	Tuber yield ha^{-1} (t)	Stover yield ha^{-1} (t)	Harvest index (%)
T_1	30.21 e	20.14 d	16.48 d	55.00 d
T_2	36.30 bc	24.20 b	18.14 bc	57.16 a
T_3	35.82 c	23.88 b	17.86 bc	57.21 a
T_4	33.90 d	22.60 c	17.22 cd	56.76 b
T_5	37.31 b	24.87 b	18.46 b	57.40 a
T_6	39.63 a	26.42 a	20.44 a	56.38 c
T_7	39.27 a	26.18 a	19.92 a	56.79 b
$LSD_{0.05}$	1.392	1.008	1.027	0.2578
CV(%)	9.28	9.33	7.38	10.14

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

CD = Cowdung, PM = Poultry manure

T_1 = 100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}
T_2 = T_1 + 4 t CD ha^{-1}

$T_3 = T_1 + 3$ t PM ha^{-1}
$T_4 = T_1 + 5$ kg Zn ha^{-1}
$T_5 = T_1 + 5$ kg Zn ha^{-1} + 2 kg B ha^{-1}
$T_6 = T_1 + 4$ t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
$T_7 = T_1 + 3$ t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}

4.4 Plant nutrient content in soil

4.4.1 Organic matter (%)

Application of zinc, boron and manure significantly influenced the organic matter content in soil (Table 7 and Appendix 11). Results showed that the highest organic matter content in soil (0.66%) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically similar with T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) and T_2 (T_1 + 4 t CD ha^{-1}). The lowest organic matter content in soil (0.32%) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was statistically same with T_4 (T_1 + 5 kg Zn ha^{-1}) and T_5 (T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}).

4.4.2 Nitrogen (N) (%)

Non-significant variation was found on N content in soil due to application of zinc, boron and manure (Table 7 and Appendix 11). However, the the highest N concentration in soil (0.10%) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest N content in soil (0.04%) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}).

4.4.3 Phosphorus (P) (ppm)

P content in soil was significantly affected due to application of zinc and boron (Table 7 and Appendix 11). Results indicated that the highest P concentration in soil(24.40 ppm) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) which was statistically same with T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest P concentration in soil(14.22 ppm) was found from T_1 (100 kg

N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) which was significantly different from other treatments.

4.4.4 Potassium (K) (meq/100 g soil)

Application of zinc, boron and manure had no significantly influenced onK content in soil (Table 7 and Appendix 11). However, the highest K concentration in soil (0.18meq/100 gm soil) was found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest K concentration in soil (0.10meq/100 gm soil) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}).

4.4.5 Boron (B)

Application of zinc and boron was not affected significantly the B concentration in soil (Table 7 and Appendix 11). However, the highest B concentration in soil (0.84ppm) was found from T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest B concentration in soil(0.36ppm) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}).Lenka (2019) found that Soil application of B significantly increased the B concentration in soil.

4.4.6 Zinc (Zn)

Significant variation was not found for Zn in soil due to application of zinc, boron and manure (Table 7 and Appendix 11). However, the highest Zn concentration in soil (3.53 ppm) was found from T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest Zn concentration in soil (3.12 ppm) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}). Lenka (2019) found that Soil application of Zn significantly increased Zn concentration in soil.

Table 7. Plant nutrient content in soil as influenced by micronutrients (Zn and B) and manure

Treatments	Plant Nutrient content in soil					
	Organic matter (%)	Nitrogen (N) (%)	Phosphorus (P) (ppm)	Potassium (K) (meq/100 gm soil)	Boron (B)	Zinc (Zn)
T_1	0.32 c	0.04	14.22 d	0.10	0.36	3.12
T_2	0.53 ab	0.08	21.57 b	0.15	0.67	3.36
T_3	0.44 bc	0.08	20.42 b	0.15	0.59	3.33
T_4	0.38 c	0.05	17.44 c	0.13	0.48	3.22
T_5	0.38 c	0.06	16.32 c	0.12	0.44	3.18
T_6	0.66 a	0.10	24.40 a	0.18	0.79	3.48
T_7	0.58 ab	0.09	23.57 a	0.17	0.84	3.53
$LSD_{0.05}$	0.138	NS	1.388	NS	NS	NS
CV(%)	1.36	1.21	4.72	0.88	1.03	1.44

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

CD = Cowdung, PM = Poultry manure

T_1 = 100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}
T_2 = T_1 + 4 t CD ha^{-1}
T_3 = T_1 + 3 t PM ha^{-1}
T_4 = T_1 + 5 kg Zn ha^{-1}
T_5 = T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
T_6 = T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}
T_7 = T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the farm under the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2018 to February, 2019 to study the effect of micronutrients (Zinc and Boron) on yield and quality of potato. The experiment was laid out into Randomized Complete Block Design (RCBD) with three replications. Single factor was comprised with the study *viz*. T_1 = N - 100 kg N ha^{-1} + P - 35 kg P ha^{-1} + K - 100 K kg ha^{-1} + S - 20 kg ha^{-1}, T_2 = T_1 + cowdung - 4 t ha^{-1}, T_3 = T_1 + poultry manure - 3 t ha^{-1}, T_4 = T_1 + Zn - 5 kg ha^{-1}, T_5 = T_1 + Zn - 5 kg ha^{-1} + B - 2 kg ha^{-1}, T_6 = T_1 + cowdung - 4 t ha^{-1} + Zn - 5 kg ha^{-1} + B - 2 kg ha^{-1} and T_7 = T_1+ poultry manure - 3 t ha^{-1} + Zn - 5 kg ha^{-1} + B - 2 kg ha^{-1}. Data were recorded on different growth, yield contributing parameters and yield of potato. Most of the parameters showed significant difference among the treatment.

In terms of growth parameters, it was found that Zn and B application showed significant variation among the treatments. Result showed that the highest plant height (20.53, 60.36 and 66.40 cm at 30 and 60 DAS and at harvest, respectively) was found from T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) but the highest number of stems $hill^{-1}$ (3.92, 4.68 and 4.92 at 30 and 60 DAS and at harvest, respectively) and number of leaves $hill^{-1}$ (13.24, 30.36 and 32.68 at 30 and 60 DAS and at harvest, respectively) were found from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}). Conversely, the lowest plant height (16.18, 54.27 and 60.48 cm at 30 and 60 DAS and at harvest, respectively), number of stems $hill^{-1}$ (2.94, 3.11 and 3.22 at 30 and 60 DAS and at harvest, respectively) and number of leaves $hill^{-1}$ (9.44, 25.12 and 28.34 at 30 and 60 DAS and at harvest, respectively) were found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) treatment. Again, the highest fresh weight of haulm $hill^{-1}$ (244.70 g), and dry weight of haulm $hill^{-1}$ (38.26 g) were recorded from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) treatment whereas the lowest fresh weight of haulm $hill^{-1}$ (186.50 g), and dry weight of haulm $hill^{-1}$ (27.42 g) were observed from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}) treatment.

In case of yield contributing parameters, it was observed that manure, Zn and B application showed significant variation among the treatments. Result revealed that the highest dry weight of 100 g fresh tuber at harvest (20.32 g), number of tuber $hill^{-1}$ (8.12) and tuber weight $hill^{-1}$ (308.20 g) were recorded from T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest dry weight of 100 g fresh tuber (17.60 g), number of tuber $hill^{-1}$ (6.32) and tuber weight $hill^{-1}$ (246.40 g) were found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}).

Considering yield parameters, it was evident that manure, Zn and B application showed significant variation among the treatments. Results highlighted that the highest tuber yield $plot^{-1}$ (39.63 kg), tuber yield ha^{-1} (26.42 t) and stover yield ha^{-1} (20.44 t)were recorded from T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) treatment but the highest harvest index (57.40%) were recorded from T_5 (T_1 + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) whereas the lowest tuber yield $plot^{-1}$ (30.21 kg), tuber yield ha^{-1} (20.14 t),stover yield ha^{-1} (16.48 t) and harvest index (55.00%) was found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}).

In case of nutrient content in soil, manure, Zn and B application showed non-significant variation in terms of N, K, B and Zn content in soil. However, result showed that the highest organic matter content in soil (0.66%), N concentration in soil (0.10%), P concentration in soil (24.40 ppm) and K concentration in soil (0.18 meq/100 gm soil) were recorded from the treatment T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) while B content in soil (0.84 ppm) and Zn content in soil (3.53

ppm) were found from T_7 (T_1+ 3 t PM ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}).On the other hand, the lowest organic matter concentration in soil (0.32%), N concentration in soil (0.04%), P content in soil (14.22 ppm), K concentration in soil (0.10 meq/100 gm soil), B concentration in soil (0.36 ppm) and Zn in soil (3.12 ppm) were found from T_1 (100 kg N ha^{-1} + 35 kg P ha^{-1} + 100 K kg ha^{-1} + 20 S kg ha^{-1}).

From the above findings, it can be concluded that the highest performance was obtained in T_6 (T_1 + 4 t CD ha^{-1} + 5 kg Zn ha^{-1} + 2 kg B ha^{-1}) treatment regarding growth, yield and yield contributing parameters and yield and also nutrient content in soil. So, this treatment can be treated as the best compared to others.

Further study can be established to justify the present findings. Such study is needed in different Agro-Ecological Zones (AEZ) of Bangladesh for regional adaptability and other performance. Some other combinations of boron and zinc with different management practices may be included for further study.

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APPENDICES

Appendix 1. Agro-Ecological Zone of Bangladesh showing the experimental location

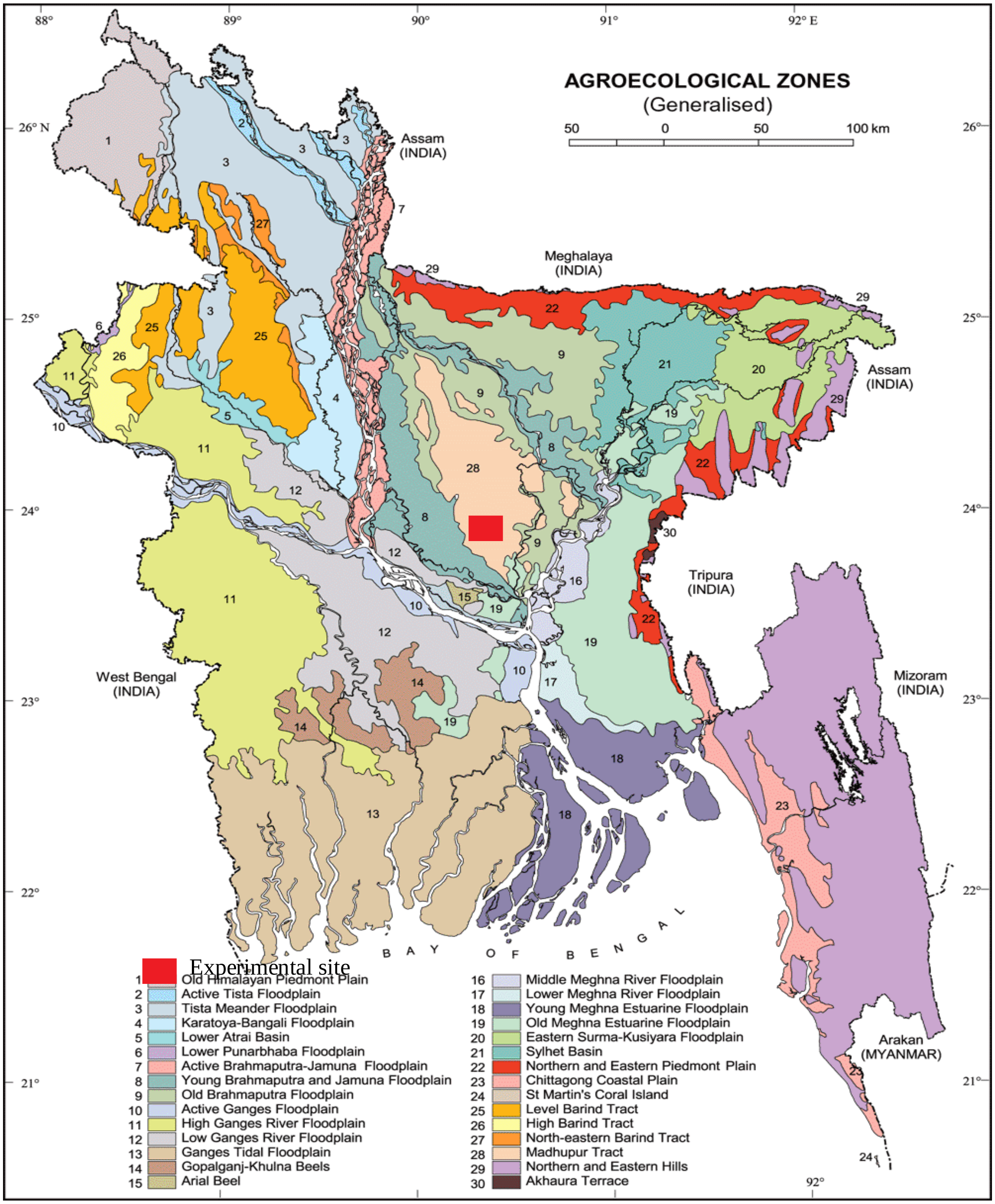


Fig. 1. Experimental site

Appendix 2. Monthly records of air temperature, relative humidity and rainfall during the period from November 2018 to February 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	November	28.60	8.52	18.56	56.75	14.40
2018	December	25.50	6.70	16.10	54.80	0.0
2019	January	23.80	11.70	17.75	46.20	0.0
2019	February	22.75	14.26	18.51	37.90	0.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix 3. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

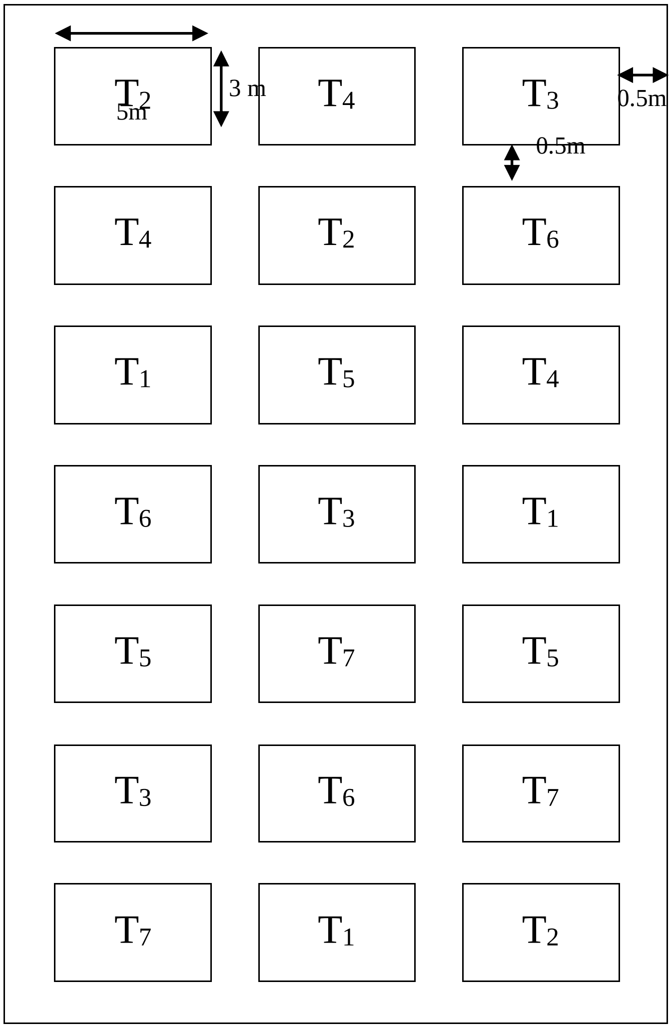
Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix 4. Layout of the experiment field



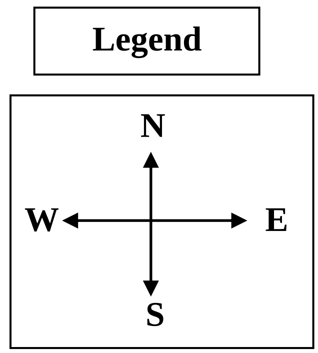


Fig. 2. Layout of the experimental plot

Appendix 5. Plant height of potato as influenced by micronutrients (Zn and B) on yield and quality of potato

Sources of variation	Degrees of freedom	Plant height (cm)		
		30 DAS	60 DAS	At harvest
Replication	2	1.204	2.376	2.652
Factor A	6	87.36**	183.67*	207.46*
Error	12	2.39	3.241	3.277

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Table 6. Number of stems hill^{-1} potato as influenced by micronutrients (Zn and B) on yield and quality of potato

Sources of variation	Degrees of freedom	Number of stems hill^{-1}		
		30 DAS	60 DAS	At harvest
Replication	2	0.065	0.107	0.136
Factor A	6	2.466**	3.714**	3.291**
Error	12	0.052	0.136	0.274

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 7. Number of leaves hill^{-1} of potato as influenced by micronutrients (Zn and B) on yield and quality of potato

Sources of variation	Degrees of freedom	Number of leaves hill^{-1}		
		30 DAS	60 DAS	At harvest
Replication	2	0.532	1.073	2.114
Factor A	6	12.314*	33.362*	23.711*
Error	12	0.453	1.083	0.190

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 8. Percent dry matter content of potato as influenced by micronutrients (Zn and B) on yield and quality of potato

Sources of variation	Degrees of freedom	Weight of haulm hill^{-1} at harvest	
		Fresh weight (g)	Dry weight (g)
Replication	2	4.363	2.057
Factor A	6	604.27	107.36
Error	12	6.294	1.277

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 9. Yield contributing parameters of potato as influenced by micronutrients (Zn and B) on yield and quality of potato

Sources of variation	Degrees of freedom	Yield contributing parameters		
		Dry weight of 100 g fresh tuber (g)	Number of tuber hill^{-1}	Tuber weight hill^{-1} (g)
Replication	2	1.245	0.249	5.711
Factor A	6	67.36**	705.83*	44.29**
Error	12	2.375	7.299	1.468

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 10. Yield parameters of potato as influenced by micronutrients (Zn and B) on yield and quality of potato

Sources of variation	Degrees of freedom	Yield parameters			
		Tuber yield plot^{-1} (kg)	Tuber yield ha^{-1} (t)	Stover yield ha^{-1} (t)	Harvest index (%)
Replication	2	2.314	0.714	0.633	1.561
Factor A	6	106.33*	66.86**	28.59*	44.97*
Error	12	2.36	2.075	0.857	1.283

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 11. Plant nutrient content in soil as influenced by micronutrients (Zn and B) on yield and quality of potato

Sources of variation	Degrees of freedom	Plant nutrient content in soil					
		Organic matter (%)	Nitrogen (N) (%)	Phosphorus (P) (ppm)	Potassium (K) (meq/100 gm soil)	Boron (B)	Zinc (Zn)
Replication	2	0.001	0.001	0.315	0.10	0.36	3.12
Factor A	6	0.473**	NS	6.704 **	NS	NS	NS
Error	12	0.001	0.001	0.512	0.15	0.59	3.33

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level