RESPONSE OF GROUNDNUT TO DIFFERENT LEVELS OF NITROGEN AND BORON FERTILIZER

SANJIDA ISLAM TUMPA

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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By

SANJIDA ISLAM TUMPA

REGISTRATION NO.: 15-06713

Email: sanjidaborsa@gmail.com

Mobile: +8801575333725

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APPROVED BY:

Prof. Dr. Tuhin Suvra Roy **Supervisor**	**Prof. Dr. Anisur Rahman** **Co-Supervisor**

Prof. Dr. Md. Abdullahil Baque

Chairman

Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Ref……………………………… Date………………………………….

CERTIFICATE

This is to certify that the thesis entitled ***'RESPONSE OF GROUNDNUT TO DIFFERENT LEVELS OF NITROGEN AND BORON FERTILIZER'*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment 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* ***SANJIDA ISLAM TUMPA****, Registration Number:* ***15-06713,*** *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 duly been acknowledged.

Dated:
Place: Dhaka, Bangladesh

Prof. Dr. Tuhin Suvra Roy
Supervisor
Department of Agronomy

Dedicated to My Beloved Parents

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The Author

RESPONSE OF GROUNDNUT TO DIFFERENT LEVELS OF NITROGEN AND BORON FERTILIZER

ABSTRACT

The experiment was carried out at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during April 2021 to August 2021 to determine the effect of nitrogen and foliar boron fertilizer on growth and yield of groundnut cv. BARI cheenabadam-10. The experiment consisted of two factors; Factor A: Nitrogen (4 levels) *viz.*, N_1: 0 kg urea ha^{-1} (control), N_2: 25 kg urea ha^{-1}, N_3: 30 kg urea ha^{-1} and N_4: 35 kg urea ha^{-1}, and factor B: Foliar boron levels (4 levels) *viz.*, B_1: Control, B_2: 0.1% boric acid (5 kg boric acid ha^{-1}), B_3: 0.2% boric acid (10 kg boric acid ha^{-1}) and B_4: 0.3% boric acid (15 kg boric acid ha^{-1}). The experiment was laid out in Split-plot design with three replications. Plant length, number of leaves $plant^{-1}$, number of branches $plant^{-1}$, number of pods $plant^{-1}$, pod length, pod yield $plot^{-1}$, 100 seeds weight, pod yield, kernel yield, stover yield, biological yield and harvest index were compared among the combinations and individual effects of treatments. Results indicated that, nitrogen and foliar boron application had significant influence on most of the growth, yield and yield contributing characters of groundnut. The maximum pod yield (2.09 t ha^{-1}) and kernel yield (1.58 t ha^{-1}) was obtained from N_3 treatment and the minimum pod yield (1.56 t ha^{-1}) and kernel yield (0.98 t ha^{-1}) was obtained from N_1 treatment. In the case of foliar boron application, the maximum pod yield (2.02 t ha^{-1}) and kernel yield (1.49 t ha^{-1}) was obtained from B_3 treatment and the minimum pod yield (1.64 t ha^{-1}) and kernel yield (1.10 t ha^{-1}) was obtained from B_1 treatment. In case of combined effect of nitrogen and foliar boron level, it was revealed that when groundnut was grown on 30 kg urea ha^{-1} with foliar boron spray @0.2% resulted with the highest pod yield (2.37 t ha^{-1}) and kernel yield (1.81 t ha^{-1}). The lowest pod yield (1.49 t ha^{-1}) and kernel yield (0.92 t ha^{-1}) was obtained from the treatment combination N_1B_1 (control). So, concluded from the above study that the treatment combination N_3B_3 (groundnut growing on 30 kg urea ha^{-1} with foliar boron spray @ 0.2%) was found to be most suitable combination for the potential pod yield and kernel yield of groundnut.

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LIST OF ACRONYMS

Acronym		Full meaning
AEZ	=	Agro-Ecological Zone
%	=	Percent
°C	=	Degree Celsius
B	=	Boron
BARC	=	Bangladesh Agricultural Research Council
BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
CV%	=	Percentage of coefficient of variance
cv.	=	Cultivar
DAS	=	Days after sowing
et al.	=	And others
FAO	=	Food and Agriculture Organization
fed^{-1}	=	Per feddan
g	=	Gram
ha^{-1}	=	Per hectare
kg	=	Kilogram
LSD	=	Least Significant Difference
MoP	=	Muriate of Potash
N	=	Nitrogen
No.	=	Number
NPK	=	Nitrogen, Phosphorus and Potassium
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resource and Development Institute
t	=	Ton
TSP	=	Triple Super Phosphate
viz.	=	Videlicet (namely)
Wt.	=	Weight

CHAPTER I

INTRODUCTION

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INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a valuable food and oilseed crop. It is commonly called as the king of vegetable oilseed crops or poor man's nut. It belongs to family Fabaceae. Groundnut appeared to have originated in South America. At the global level 50% of the groundnut produced is used for oil extraction, 37% for confectionary use and 12% for seed purpose (Shendage *et al*., 2018).

Groundnut is one of the principal economic crops of the world that ranks 13th among the food crops (Mouri *et al*., 2018). Groundnut is also known as earthnuts, peanuts, goobers, goober peas, pindas, jack nuts, pinders, manila nuts, g-nuts and monkey nuts; the last of these is often used to mean the entire pod (Annadurai and Palaniappan, 2009). In Bangladesh, it is popularly known as ''cheenabadam''. Besides its food value, groundnut is a major oil seed crop. In Bangladesh, groundnut is grown in an area of 30791 hectare with a production of 55108 metric tons in Rabi and Kharif season (BBS, 2020).

The importance of groundnut in the world's economy is increasing rapidly due to its demand as oil for making margarine, cooking oil, soaps and many other domestic uses (Vessey and Buss, 2002). It is very useful in crop rotation as it has the ability to fix atmospheric nitrogen into the soil, hence enriching the fertility of the soil for greater benefit of subsequent crops on the same farm land (Oranekwulu, 1995). On an average, seed contains about 38-50% oil, 26% protein, 11.5% carbohydrate, 2.3% ash, 2.5% minerals and 6% water (Oyewole *et al*., 2020). It is also rich in calcium, potassium, phosphorus, magnesium and vitamin B and E (Oyewole *et al*., 2020 and Mouri *et al*., 2018).

Groundnut is a major crop in the char lands of Bangladesh, but because of poor yields, farmers derive a limited income from the crop. It is a photo insensitive crop and allows cultivation throughout the year. Despite its insensitivity, it is grown mainly in Rabi season in 'charlands' due to high land scarcity in Kharif season (FAOSTAT, 2013).

One of the major constraints for low yield of groundnut relates to deficiency of macro and micro nutrients. Intensification of agriculture, usage of straight fertilizers, rising crop requirements due to increasing productivity levels have heightened the micronutrients demand in soil fertility management and are increasingly becoming major constraints to achieve agricultural production. Adjusted nutrient management is considered as one of the essential requirements to accomplish the expected yield. Among all other management practices, plant nutrition is considered to be the important one (Yadav *et al.*, 2017; Kheravat *et al.*, 2020).

Groundnut gives better yield and yield quality when good cultivars are planted on soils with an optimal soil nutrients management system (Veeramani and Subrahmaniyan, 2011). Among the essential nutrients, nitrogen is the most important nutrient. Nitrogen element is an important and critical nutrient for developing and producing of plant (Leghari *et al.*, 2016). By far, N is the most needed mineral nutrient in all cropping systems, due to its key roles in different biochemical and physiological processes of the plant (Leghari *et al.*, 2016; Pourranjbari *et al.*, 2019). Foliar or soil application of N fertilizers has been shown to significantly influence the growth, yield and quality of many crops (Dehnavard *et al.*, 2017; Souri *et al.*, 2019). Nitrogen is also present in the plant metabolisms as amino acids in the functional proteins positively affects the content of protein and increases the scope of amino acids (Kasap *et al.*, 1999; Rowland *et al.*, 2012). The nitrogen necessity of groundnut is a lot higher than cereals in a view of its high protein content. Nitrogen is fundamental for enthusiastic vegetative and reproductive development of plant, photosynthesis, nutrient absorption and generation of assimilates for pod filling. It is fundamental constituent of many compounds of plant, such as chlorophyll, proteins, nucleotides, alkaloids, enzymes, chemicals and vitamins (Sagvekar *et al.*, 2017). It is the key element that stimulates root and shoot growth. Though it fixes atmospheric nitrogen, to meet the requirement of plant the nitrogen supply to groundnut crop is very crucial. The impact of nitrogen fertilizer addition on soil organic matter builds up and soil substantial properties is crucial to agrarian manageability and to procuring of crop yield. Besides, N fertilization influences dry matter generation as well as N accumulation and apportioning into different portions of yield plants for the development, advancement and other activities (Khaliq and Cheema, 2005).

Boron (B) is considered to be an essential micronutrient element for plant growth and development. Boron is a micronutrient required by plants in a very small quantity which are rapidly becoming deficient in soils (Tahir *et al.*, 2009). Boron is an essential element needed for normal growth and development of peanut plant (Gascho and Davis, 1995; Haris and Brolman, 1966). Boron makes the stigma receptive and sticky, makes pollen grain fertile, and enhances the pollination (Kaisher *et al.*, 2010). It regulates carbohydrate metabolism and plays role in seed formation (BARC, 2012). Application of boron in soil significantly increases the growth and yield of groundnut (Kabir *et al.*, 2013; Singaravel *et al.*, 2016). Boron has the ability to increase photosynthetic and enzymatic activity in plant; moreover, it causes pollen grain germination, pollen tube growth and viability of pollen grains (Darwish *et al.*, 2002). It was evident that application of B enhanced the seed and oil yields ha^{-1} and protein percentage in groundnut (Datta *et al.*, 1998). But boron deficiency problems for crop production have been identified (Ahmed and Hossain, 1997) because application of boron in crops is limited at farmer's field (Nasreen *et al.*, 2015). Boron deficiency leads to several physiological damages in plant. It is considered to be essential for sugar transport, synthesis of cell wall, cell wall structure, metabolism of carbohydrate, RNA, phenol and indole acetic acid, respiration and membrane integrity. Additionally, foliar spray enables plants to absorb the applied nutrients from the solution through their leaf surface and thus, may result in the economic use of fertilizer (Helmy and Shaban, 2008). So, the proper micronutrient fertilizer management of groundnut crop with reference to amount, method and time of application has significant effect on yield and quality (Veeramani and Subramaniyan, 2011).

Therefore, this study was aimed to examine the effect of nitrogen and foliar application of boron on growth, yield components and yield of groundnut. Under the above circumstances, the present experiment was undertaken with the following objectives:

- ✓ To determine the effect of nitrogen on growth and yield of groundnut
- ✓ To determine the optimal doses of foliar application of boron for better growth and yield of groundnut, and
- ✓ To find out the optimum level of nitrogen and foliar application of boron for better yield of groundnut.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

In this section, an attempt was made to gather and study relevant information accessible in the country and worldwide in order to gain knowledge that would be useful in performing the current research and then writing up the results and discussion. In this chapter, some of the most significant and instructive publications and research findings on the effects of nitrogen and foliar application of boron on groundnut growth and yield have been examined under the following headings and sub-headings:

2.1 Effects of nitrogen on growth and yield of groundnut

Bharathi *et al.* (2021) conducted a field experiment during Kharif season 2020 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj to study about the "Effect of Nitrogen levels and Biofertilizers on growth and yield of Groundnut (*Arachis hypogaea* L.)". The experiment was laid out in Randomized Block Design, with nine treatments which were replicated thrice. The treatment consists of three levels of nitrogen and biofertilizers *viz.*, T_1 (10 kg N ha^{-1} + Rhizobium), T_2 (10 kg N ha^{-1} + PSB), T_3 (10 kg N ha^{-1} + Rhizobium + PSB), T_4 (15 kg N ha^{-1} + Rhizobium), T_5 (15 kg N ha^{-1} + PSB), T_6 (15 kg N ha^{-1} + Rhizobium + PSB), T_7 (20 kg N ha^{-1} + Rhizobium), T_8 (20 kg N ha^{-1} + PSB), T_9 (20 kg N ha^{-1} + Rhizobium + PSB), The maximum results showed in growth and yield attributing characters *viz.*, plant length (102.19 cm), dry weight (45.78 g), no. of nodules $plant^{-1}$ (157.78), no. of pods $plant^{-1}$ (28.80), no. of kernels pod^{-1} (2.07), seed index (47.06), seed yield (2655.58 kg ha^{-1}), haulm yield (3587.20), harvest index (42.31) were recorded significantly higher in the treatment T_9 (20 kg N ha^{-1} + Rhizobium + PSB) while net returns (91858.24 Rs. ha^{-1}) and B:C ratio (2.44) were also recorded in application of T_9 was found to be more productive as well as economic.

Boydak *et al.* (2021) conducted a research to determine most suitable irrigation level and nitrogen fertilizer dose for peanut in the Harran conditions (Şanlıurfa, Turkey). In this study, different amounts of the nitrogen (N_1: 0, N_2: 40, N_3: 80, and N_4: 120 kg N ha^{-1}) were applied as ammonium nitrate in two times as planting and flowering times to peanut plants. The irrigation levels were determined as 100, 75, 50, and 25% of the irrigation required and labeled as I_1 (first irrigation), I_2 (second irrigation), I_3 (third irrigation), and I_4 (fourth irrigation), respectively. In this study, positive and significant effect were found that the need protein and the increasing of peanut yield with its components were increased with 120 kg ha^{-1} nitrogen fertilization (N_4) and no-deficit water (100%: I_1) while the variable 100 fruit weight were increased with 80 kg ha^{-1} nitrogen fertilization (N_3) and no-deficit water (100%: I_1) application on plant. The plant length and 100-seed weight except 2nd year were also increased with 80 kg ha^{-1} nitrogen (N_3) and no-deficit water (100%: I_1).

Mondal *et al.* (2020) carried out an investigation during the winter seasons of 2015-2016 and 2016-2017 at the district seed farm of Bidhan Chandra Krishi Viswavidyalaya, an Agricultural University in West Bengal, India to facilitate the comprehensive study of plant growth, productivity and profitability of an irrigated peanut crop under varied levels of nitrogen: with and without a rhizobium inoculants and with and without polythene mulch. Quality traits and nutrient dynamics were also itemized. Fertilizing with 100% of the recommended dose of nitrogen combined with rhizobium inoculant and polythene mulch significantly enhanced peanut plant growth, yield and yield-attributing traits, while resulting in the maximum fertilizer (i.e., nitrogen, phosphorus and potassium) uptake by different plant parts. The greatest number of root nodules occurred in the treatment that received 75% of the recommended dose of nitrogen with rhizobium supplementation under polythene mulch, while 50% of the recommended dose of nitrogen with no rhizobium resulted in maximum fertilizer nitrogen use efficiency. Applying the full recommended dose of nitrogen with the rhizobium inoculants and mulch resulted in maximum profitability in the peanut crop.

Tekulu *et al.* (2020) conducted a study to investigate the effects of nitrogen (N) and phosphorus (P) fertilizers on parameters of phenology, growth performance, grain yield, yield components, grain protein content of groundnut, and residual soil nitrogen content in the northern Ethiopia during the growing season of 2017. Three levels of N (0, 15 and 30 kg ha^{-1}) and four levels of P_2O_5 (0, 23, 46 and 69 kg ha^{-1}) were set in factorial combinations of randomized complete block design with three replications. Results showed that an average total biomass yield increased by 22.5% for separate individual application of 15 kg N ha^{-1} and by 16.6% for 46 kg P_2O_5 ha^{-1} compared to control plots. Haulm yield increased by 29.17% for plots treated with N fertilization compared to control plots. Average pod yield increased by 85.4% for a combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} fertilizers compared to the control plots. Plots fertilized with the highest combined rates of N and P have attained lower grain yield compared to combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}. The highest grain protein contents were obtained for a combined application of 30 kg N ha^{-1} and zero P, and 15 kg N ha^{-1} plus 46 kg P_2O_5 ha^{-1}. The highest N harvest index was obtained for control treatments and for plots treated with combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}. Residual soil N content increased by 119% on plots with combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} compared to control plots. Based on results, combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} was recommended for increasing grain yield, grain protein content and residual soil nitrogen. The results of this study are crucial to improve groundnut productivity, grain protein content and also to provide implication on soil fertility management in a crop rotation system.

Fagbemigun and Oguntola (2019) carried out a field experiment at the Teaching and Research farm at Ladoke Akintola University of Technology, Ogbomoso in the year 2012 to determine the optimum rate of starter nitrogen on growth and yield of groundnut (*Arachis hypogea* L.) using organomineral fertilizer (Alesinloye Asejere fertilizer). Two cultivars; Samnut 23 and Campala which were sown together on two different dates (02/06/2012 and 16/06/2012) with the application of five nitrogen rates which are 0, 5, 10, 15 and 20 kg N ha^{-1} altogether translate to give 20 treatment combinations. The treatments were replicated three times and were a split-split-plot experiment laid out in random complete block design. The responses of groundnut to treatment were assessed starting from four weeks after planting (WAP) and at two weeks interval. Data were collected on plant length, number of nodules, number of leaves, fresh weight of root, stem and leaves, number of pods, total dry matter, length of leaves and breadth of leaves were taken and subjected to the analysis of variance and means were separated using Duncan multiple range test (DMRT) at 5% level of probability. Analysis of results revealed that Campala had the higher number of leaves production capacity (93.80 per plant at 10 WAP) compared with Samnut 23 (50.53 per plant at 10 WAP). However Samnut 23 produced higher pod yield (16.50 per plant at 10 WAP) and Campala (12.10 per plant at 10 WAP). The result also revealed that Campala is better for foliage production especially as fodder or soil management purposes. Early planting and application of 10 kg N ha^{-1} produced significantly higher yield.

Hasan *et al.* (2019) conducted a pot experiment in ladang 15 at the Faculty of Agriculture; Universiti Putra Malaysia. The experiment was performed Randomized Complete Block Design (RCBD). The size of the pot was 65.94 cm^2. The experiment was conducted in a factorial design with four levels of N (0, 10, 20, 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}). In this study, N and P fertilizer was played dominating role for vegetative growth of the plant. Plant length (20.65 cm), leaves number (262), leaf area (2140.54 cm^2), number of pod (47.25) and pod weight (22.8 g) increased with the application of level of N and P. Vegetative growth and yield of the plant was better at $N_{30}P_{60}$ kg ha^{-1} than the all other treatments. It can be concluded that by using $N_{30}P_{60}$ kg ha^{-1} growth and yield of bambara groundnut is maximum.

Purbajanti *et al.* (2019) conducted a research to study the growth and physiology of peanuts on different doses of cow manure and NPK fertilizers. The study was carried out in research field of the Laboratory of Ecology and Plant Production, Agriculture Department, Faculty of Animal and Agricultural Sciences Diponegoro University, Semarang. The design used was split plot. As the main plot was doses of cow manure (0, 5 and 10 tons ha^{-1}), subplots was NPK fertilizer (0, 25, 50, 75, and 100 kg N ha^{-1}), with three times replications. Parameters observed were plant length, number of leaves, activity of nitrate reductase (ANR) and chlorophyll contents. There was interaction between manure and NPK doses to total chlorophyll content of leaves. Separately, cow manure and NPK significantly affected the plant length, ANR and total chlorophyll but not significantly effect on number of leaves. Cow manure and NPK affected on increasing of plant length, ANR and total chlorophyll contents of peanuts.

Kulkarni *et al.* (2018) carried out an experiment to evaluate the effects of different combinations of organic and inorganic fertilizers on yield and yield attributes of groundnut and wheat. These two crops were tested during 2013 and 2014 under six fertilizer treatments (T_1= 75% N (FYM) + 25% N (Vermicompost), T_2= 50% N (FYM) + 50% N (Castor Cake), T_3= 50% N (FYM) + 25% N (V.C.) + *Azotobactor/Rhizobium* + PSB (Seed treatment)), T_4= NPK as per STV, T_5= RDF + 5 t FYM ha^{-1}) and T_6= RDF + $ZnSO_4$/Gypsum) in a randomized block design. The results of present investigation revealed that the application of 50% N (FYM) + 25% N (V.C.) + *Rhizobium* + PSB (ST) (T_3) had significant effect on haulm yield of groundnut (4622 kg ha^{-1}),and the application RDF-NPK as per STV (T_4) had significant effect on grain yield of wheat. The increased haulm yield in groundnut was to the extent of 11.8% over treatment T_4, which received NPK as per STV and recorded minimum yield of 4067 kg ha^{-1} haulm. The increase in yield of wheat grain under inorganic treatment T_4 was to the extent of 14.1% respectively over other treatments. The yield attributes also exhibited similar trend with a significantly increased response due to organic and inorganic treatments in groundnut and wheat respectively.

Andriani *et al.* (2017) carried out a study aims to determine the effect of treatment of fertilization time and dosage of nitrogen to the growth and yield of peanut plants. This experiment is a two-factor experiment with incomplete randomized block design. The first factor is the time (S) of fertilizer consisting of three levels: During planting (S_0), 15 days after planting (S_1), 30 days after planting (S_2), The second factor is the dosage of Nitrogen (N) fertilizer consisting of three levels: 25 kg ha^{-1} (N_1), 50 kg ha^{-1} (N_2). The results showed that treatment of fertilization time and a dose of nitrogen showed no significant effect on plant length, maximum leaf number, leaf area index, the total pod containing, total void pod, total pod number, oven dry weight of oven plants, and harvesting index. The interaction of nitrogen dose with a time of fertilization gave a very real effect to most observed variables except for maximum plant length, maximum leaf number, leaf area, harvest index that is not significant. The high dry weight of seed oven per plant was obtained at the fertilizer interaction treatment at 15 days after planting and the dose of nitrogen 25 kg ha^{-1} was 30.33 g and or increased by 152.75% and when compared with the control of 12.00 g. From a result of regression analysis got an optimum dose of nitrogen fertilizer that is 34.15 kg ha^{-1} with the dry weight of oven seeds per plant maximum 26.73 g.

Mahrous *et al.* (2015) carried out an experiment titled "Integrated use of organic, inorganic and bio fertilizers on yield and quality of two peanut (*Arachis hypogaea* L.) cultivars grown in a sandy saline soil". These two peanut cultivar were tested under eight fertilizer treatments (T_1: 50% mineral fertilizer; the recommended NPK (40:30:48), T_2: 50% mineral fertilizer; the recommended (40:30:48) + bio fertilizer, T_3: 100% mineral fertilizer; the recommended NPK (40:30:48), T_4: 100% mineral fertilizer; the recommended NPK (40:30:48) + bio fertilizer, T_5: 50% mineral fertilizer; the recommended NPK (40:30:48) + 6 ton compost/fed + bio fertilizer, T_6: 50% mineral fertilizer; the recommended NPK (40:30:48) + 9 ton compost fed^{-1} + bio fertilizer, T_7: 50% mineral fertilizer; the recommended NPK (40:30:48) + 12 ton compost fed^{-1} + bio fertilizer and T_8: 12 ton compost fed^{-1}) in a split-plot design in a randomized complete blocks arrangement. The main plots were devoted to the peanut cultivars and sub-plots to the eight fertilizer treatments for the possibility of reducing mineral fertilization levels and replacing chemical fertilizers by using bio-organic fertilization, in addition to identifying the most suitable cultivar to a sandy soil under saline conditions. It was clear that Gregory cultivar showed the highest weight of pods plant^{-1} (49.2 g), weight of seeds plant^{-1} (27.2 g), seed index (51.8 g), weight of seeds fed^{-1} (0.857 ton) [one feddan= 4200 sq. m], seed oil (50.15%), seed protein (24.7%), seed P (0.41%) and seed 2 K (2.17 %). The highest values of pods number plant^{-1} (49.4), weight of pods plant^{-1} (58.9 g), seed index (57.5 g), weight of seeds fed^{-1} (1.193 ton), seed oil (53.05%), seed protein (26.75%), seed P (0.50%) and seed K (2.63%) were resulted from 1/2 NPK + 12 ton compost + Bio fertilizer with Gregory cultivar. Finally, the data indicated that growing peanuts in such newly reclaimed soil under balanced nutrition is profitable.

Kumar *et al.* (2014) conducted a field experiment at Main Agricultural Research Station (MARS), Dharwad to know the effect of nitrogen and phosphorus levels and ratios on yield and nutrient uptake by groundnut in northern transition zone of Karnataka. Groundnut cultivar JL 24 was tried during 2012 with eleven ratios of nitrogen (N) and phosphorus (P_2O_5) fertilizers with potassium level as constant (25 kg K_2O ha^{-1}). The yield attributing characteristics, dry pod yield and nutrient uptake were increased due to increasing N/P fertilizer ratios from 0.00 to 1.00. The treatment receiving N/P fertilizer ratio of 0.50 (30 kg N, 60 kg P_2O_5, 25 kg K_2O ha^{-1}) produced significantly higher dry pod yield (3310 kg ha^{-1}), number of filled pods plant^{-1} (17.47), total number of pods plant^{-1} (18.80) and 100-kernel weight (38.50 g). Further, the same treatment recorded significantly higher uptake (147.04 kg N, 23.30 kg P_2O_5, 118.48 kg K_2O, 10.93 kg S ha^{-1}) as compared to all other N/P fertilizer ratios. The treatment receiving N/P fertilizer ratio of 0.50 (30 kg N, 60 kg P_2O_5, 25 kg K_2O ha^{-1}) produced higher kernel yield (2441 kg ha^{-1}). However, it was on par with the treatment receiving N/P fertilizer ratio of 0.33 (2344 kg ha^{-1}).

El-Habbasha *et al.* (2013) carried out an experiment to study the effect of nitrogen fertilizer and Zn foliar application at different growth stages on yield, yield attributes and some chemical traits of groundnut. Results showed that increasing N levels from 30 to 40 kg N fed^{-1} significantly increased number of pods plant^{-1}, weight of pods plant^{-1}, weight of seeds plant^{-1}, 100-seed weight, pod yield fed^{-1}, seed yield fed^{-1} and straw yield fed^{-1}. Use of Zn foliar application either at flowering or seed filling stages significantly increased number of pods plant^{-1}, weight of pods plant^{-1}, number of seed plant^{-1}, weight of seeds plant^{-1}, 100-pod weight, 100-seed weight, pod, seed and straw yield fed^{-1}, oil yield, seed protein content, N and K content in the seed and straw compared to control treatment. The studied characters of yield and yield attributes were significantly affected by the interaction between nitrogen fertilizer levels and foliar Zn application. Groundnut treatment with 40 kg N fed^{-1} + Zn foliar application at seed filling stage recorded the highest significant values of most studied characters than the other treatments followed by the same nitrogen level and Zn foliar application at flowering stage. The data of nitrogen use efficiency calculated (kg seeds kg^{-1} N) revealed that there were synergistic effects of the combined application of nitrogen and zinc either at flowering or seed filling stages. Such synergistic effect was more pronounced when the lower level of N (30 kg N fed^{-1}) was applied. The maximum efficient use of N for producing seeds was attained at seed filling stage (37.1 and 31.45 kg seeds kg^{-1} N) when zinc was combined with 30 kg and 40 kg N fed^{-1}, respectively.

Gohari and Niyaki (2010) conducted an experiment to evaluate the effects of iron and nitrogen fertilizers on yield and yield components of peanut (*Arachis hypogaea* L.) in Astaneh Ashrafiyeh, North of Iran. A randomized complete block design was used to incorporate factorial combinations of four levels of nitrogen fertilizer (0, 30, 60 and 90 kg ha^{-1}) and four levels of iron fertilizer (0, 1.5, 3 and 4.5 g L^{-1} per plot) with three replications in agricultural year of 2010. The results showed that maximum numbers of pod and seed yield values of 2916 and 1828 kg ha^{-1}, respectively were recorded for the 4.5 g L^{-1} iron fertilizer treatment. Furthermore, the use of 60 kg ha^{-1} nitrogen fertilizer resulted in the highest pod and seed yields amounting to 2314 and 1376 kg ha^{-1}, respectively. Results obtained in this study suggested 4.5 g L^{-1} iron (6 m^2) and 60 kg ha^{-1} nitrogen as the most suitable fertilizer management for peanuts grown under the region’s conditions.

Hossain and Hamid (2007) carried out a field experiment to evaluate the effect of N and P application on the root growth, leaf photosynthesis and yield of groundnut (var. Basantibadam). Four levels of N (0, 20, 40 and 60 kg N ha^{-1}) and four levels of P (0, 13, 26 and 39 kg P ha^{-1}) were the treatment variables. The trial was set up in a randomized complete block design under factorial arrangement with three replications. Application of N and P fertilizer exerted significant effects on root development, photosynthesis, yield contributing characters and pod yield of the crop. Plant receiving 60 kg N and 39 kg P ha^{-1} had larger root system, greater photosynthetic rate and better yield contributing characters that resulted in the maximum pod yield which, however, was not significantly different from $N_{60}P_{26}$ treatment. Hence, it is recommended that higher yield of Basantibadam can be obtained from $N_{60}P_{26}$ kg ha^{-1} in salna silty clay loam soil of Madhupur tract (AEZ 28) of Bangladesh.

2.2 Effect of boron on growth and yield of groundnut

Nandi *et al.* (2020) conducted a pot experiment to investigate the effect of combination between foliar zinc and boron on groundnut growth, yield, nutrient uptake and its accumulation in pods. The pot experiment was comprised of three levels of Zn (0, 0.5 and 0.75% Zn), three levels of B (0, 0.3 and 0.45% B) and their combinations. The treatments were replicated thrice. Zn and B were applied through foliar spray twice at vegetative and flower initiation stage. Chlorophyll content, leaf area, root-shoot dry biomass, plant length, nutrient uptake and nutrient concentrations in pods were studied. Foliar spray of Zn and B jointly increased the leaf area to the tune of 55% and 29% at flowering and pod formation stages, respectively. Despite sole application of B and Zn increased the leaf chlorophyll content in groundnut; the combined applications were much more prominent. Moreover, lower level of Zn combined with higher level of B significantly ($p<0.05$) had higher uptake of N (18.8%), P (11.5%) and K (5.9%) over higher level of sole Zn application. The improved biomass accumulation of groundnut amplified the efficient utilization of primary nutrients and resulted in higher nutrient uptake as well as their concentration in pods. Groundnut when sprayed with elevated doses of Zn and B produced the maximum yield (30.8 g $plant^{-1}$). Spraying of Zn and B increased plant biomass, leaf area, chlorophyll content noticeably and with the increase in concentration of Zn and

B in spray, the increment became quite intense. The combined spray of Zn and B at critical growth stages promoted better growth and productivity of groundnut.

Mekdad (2019) conducted two field trials using four phosphorus fertilizer levels (P_1: 30, P_2: 45, P_3: 60 and P_4: 75 kg P_2O_5 fed^{-1}) and three foliar spray with boron levels (B_0: tap water, B_1: 100 ppm and B_2: 150 ppm) on peanut. Results indicated that yield components, yield and its quality of peanut were positively ($P \leq 0.01$) affected by the two factors individually, also had positively ($P \leq 0.05$) affected by the various interactions on pod yield. The best pod yield was obtained by the bilateral interaction application of $P_4 \times B_2$. Correlation analysis appeared appearance of highly significant with r values between oil and pod yields.

Poonguzhali *et al.* (2019) conducted a field experiment in vylogam soil series with different levels of boron application in soil and foliar along with RDF and results are reported that the application of 15 kg ha^{-1} of B as soil application plus 0.5% foliar application of B at critical stages recorded the highest oil and crude protein content in the soil series with the values of 50.6% oil content 15.0% of crude protein content in the soils of Vylogam soil series.

Mehmood *et al*. (2018) reported that soil application of B @ 2 kg ha^{-1} recorded the highest oil content of 36.6% over control 32.2% and the achene protein was enhanced upto 20.38% over control (14.7 %).

Poonguzhali and Pandian (2018) conducted a field experiment in Madurai district with different levels of boron application in soil and foliar along with RDF and results are reported that the application of 15 kg ha^{-1} of B as soil application plus 0.5% foliar application of B at critical stages recorded the maximum plant length (61.7 cm), number of branches $plant^{-1}$ (14.5), number of nodules $plant^{-1}$ (107.6). The soil and foliar application of B improved the growth accompanied by increased B concentration in plant parts.

Quamruzzaman *et al.* (2016) conducted a field experiment to study the response of boron and light on morph-physiology and pod yield of two peanut varieties. Treatments considered two peanut varieties, namely, Dhaka-1 and BARI Chinabadam-8, three levels of boron (B), namely, 0 kg B ha^{-1} (B_0), 1 kg B ha^{-1} (B_1), and 2 kg B ha^{-1} (B_2), and two levels of light, namely, normal day light (≈12 h light) and normal day light + 6 h extended red light at night (≈18 h light). Result revealed that days to first-last emergence and days to first-50% lowering took shorter times and vegetative growth, pods dry weight plant^{-1}, pod yield, and germination were markedly increased with the application of boron. Vegetative growth and germinations were significantly increased in light, but the lowest leaf area, pods dry weight plant^{-1}, and pod yield were found in light. Without germination, the highest vegetative growth, reproductive unit, and pod yield were observed from BARI Chinabadam-8. Days to first-last emergence, days to first-50% lowering, and number of branches plant^{-1} were found linearly related to pod yield.

Kabir *et al.* (2013) conducted a study to observe the effect of Phosphorus (P), Calcium (Ca) and Boron (B) on the growth and yield of groundnut cv. BARI Cheenabadam 7. Fertilizer doses of P (P_0= 0, P_1= 25 and P_2= 50 kg ha^{-1}), Ca (Ca_0= 0, Ca_1= 110 and Ca_2= 165 kg Ca ha^{-1}) and B (0, 2 and 2.5 kg ha^{-1}) were used. Among the growth parameters plant length, number of branches plant^{-1}, dry weight plant^{-1}, LAI and CGR were highest at 100 DAS in $P_2 \times Ca_1 \times B_2$ treatment combination. Among the yield attributing characters number of total pods plant^{-1} was highest for $P_1 \times Ca_2 \times B_2$, 100 pod weight plant^{-1} for $P_1 \times Ca_2 \times B_1$, shelling percentage, pod yield, biological yield, straw yield and harvest index for $P_2 \times Ca_1 \times B_2$. The lowest values of all these parameters were found at control treatment. The combined dose of P_2, Ca_1 and B_2 produced the highest values for almost all the above parameters. So, it can be concluded that the fertilizer level for P, Ca and B should be 50 kg ha^{-1}, 110 kg ha^{-1} and 2.5 kg ha^{-1}, respectively for obtaining the highest yield of groundnut under this particular soil.

El-Kader and Mona (2013) carried out a field experiment during the summer seasons of 2011 and 2012 on peanut (*Arachis hypogaea* L.) cv. (Giza 6) grown in a sandy soil at a farm at El-Quassasin region, Ismailia Governorate, Egypt, to study the effect of sulfur (S) application at rate of 200 kg fed^{-1}, foliar spraying with Zn, B and their combinations on yield and its components as well as seed quality and some chemical contents of seeds. The experiment was designed in complete randomized blocks with three replicates. Results indicated that, application of sulfur (S) and foliar spraying with micronutrient (Zn and B) together had the significant effect on peanut seed yield and its attributes. Their highest values were obtained when plants treated with sulfur (S) combined with foliar spraying with (Zn + B). Meanwhile, the highest amount of nutrient contents was obtained with 200 kg S fed^{-1}. Combined with foliar spraying with 3.33 g ($ZnSO_4$-$7H_2O$) L^{-1} $plot^{-1}$, (2.7 kg $ZnSO_4$ fed^{-1}) and 0.83 g ($Na_2B_4O_7$-$10H_2O$) L^{-1} $plot^{-1}$ (0.7 kg borax fed^{-1})), for Zn and B respectively. Application of different treatments had the significant effect on available N, P, K and S in soil. The highest values of available N, P, K and S were observed with the combined treatment of (S + Zn + B). The highest values of available Zn and B were obtained due to the application of sulfur (S).

Kaisher *et al*. (2010) reported that the application of boron increase in plant length of groundnut crop might be due to soil and foliar applied B, which could be attributed to metabolic regulation and enzymatic process including photosynthesis, respiration and symbiotic N-fixation.

Singh *et al*. (2008) reported that application of B has pronounced influence on flowering and yield attributes such as shelling percentage and 100-seed weight in groundnut. Soil application of 1.0 kg B ha^{-1} as agricol, solubor and borosol increased pod yield by 8-23, 6-18, 12-18%, respectively compared to 9-28% by borax and 5-24% by boric acid. Foliar application (0.1% aqueous solution) of borosol, chemiebor and solubor showed similar response in increasing the pod yield by 7-39, 6-32, and 6-35%, respectively.

Chitdeshwari and Poongothai (2003) had reported that the soil application of Zn 5 kg ha^{-1} + B 1 kg ha^{-1} + S 40 kg ha^{-1} significantly increased the groundnut pod yield to the tune of 24.2% for TMV 7 and 14.8% for JL 24 over control.

Subrahmaniyan *et al.* (2000) reported that combined application of $ZnSO_4$@ 5 kg ha^{-1} + borax @ 5 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1} recorded the maximum yield attributes *viz*., number of matured pods $plant^{-1}$ (14.6), 100-kernel weight (47.61 g) and shelling percentage (70.60%) compared to other treatments under red sandy loam soil with low fertility status.

Kumar *et al*. (1996) conducted a field experiment in B deficient acid sedentary soils of Ranchi and they found that the groundnut responded significantly to boron application @ 3 kg ha^{-1} and pod yield increased remarkably from 1140 kg ha^{-1} in control to 1530 kg ha^{-1}. However, further increase in B application up to 4.5 kg ha^{-1} reduced pod yield.

From the above review of literature it is evident that nitrogen has a significant influence on growth and pod yield of groundnut. The literature suggests that lower doses rather than optimum doses reduce the pod yield of groundnut which is directly related to the growth and seed yield of groundnut. From the above review of literature it is apparent that boron application as foliar spray itself influenced the growth and pod yield of groundnut. The literature revealed that accurate knowledge of the optimum doses of boron application for any particular groundnut variety at a particular area is critical to achieve a higher seed yield of groundnut.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from April 2021 to August 2021 to study the effect of different levels of nitrogen and foliar boron fertilizer on growth and yield of groundnut. The materials and methods that were used for conducting the experiment are presented under the following headings:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site was 90°33´E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix II.

3.3 Climate and weather

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter 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). Details on the meteorological data of air temperature, relative humidity and rainfall during the period of the experiment were collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.4 Test crop

The groundnut variety, BARI cheenabadam-10 was considered as the test crop for the present study.

3.5 Experimental details

There were two factors in the experiment namely nitrogen levels and foliar application of boron as mentioned below:

Factor A: Nitrogen levels (4)

N_1= 0 kg urea ha^{-1} (Control)

N_2= 25 kg urea ha^{-1}

N_3= 30 kg urea ha^{-1}

N_4= 35 kg urea ha^{-1}

Factor B: Foliar boron levels (4 levels)

B_1= Control (no boric acid)

B_2= 0.1% boric acid (5 kg boric acid ha^{-1})

B_3= 0.2% boric acid (10 kg boric acid ha^{-1})

B_4= 0.3% boric acid (15 kg boric acid ha^{-1})

Treatment combinations - Sixteen treatment combinations: N_1B_1, N_1B_2, N_1B_3, N_1B_4, N_2B_1, N_2B_2, N_2B_3, N_2B_4, N_3B_1, N_3B_2, N_3B_3, N_3B_4, N_4B_1, N_4B_2, N_4B_3 and N_4B_4.

3.6 Experimental design and layout

The experiment was laid out in a Split-plot Design with three replications where different nitrogen levels were considered in the main plot and foliar boron levels in sub plot. Four levels of nitrogen fertilizer and four levels of foliar boron applications gave altogether 16 treatment combinations of the experiment. The area of the experimental plot was divided into three equal blocks. Each block was divided into 4 equal main plots and the main plots were further divided into 4 unit plots. The size of each unit plot was 2.00 m × 2.00 m. Distances between replications and plots were 0.75 m and 0.5 m, respectively. The layout of the experimental field is presented in Appendix IV.

3.7 Seed collection

The seed of groundnut variety, BARI cheenabadam-10 was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.

3.8 Description of the variety

Developed by	Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh
Year of release	2016
Main characteristics	Plant is erect type, plant length is about 40-45 cm, number of pods plant^{-1} is 22-25, cluster pod bearing, surface of the pod is not smooth and vain is prominent, seeds brown in color and medium in size, 100 seeds weight is about 45 g. Crop duration in Rabi season is 140-155 days and kharif season is 120-135 days. Oil content is 48-50% and this variety is tolerant to drought and diseases.
Planting season and time	This variety is cultivated throughout the country in Rabi and Kharif season, sowing time in Rabi season Mid October to Mid-November and Kharif season July to August.
Yield	2.2-2.5; 2.0-2.2 t ha^{-1}

3.9 Land preparation

The plot selected for the experiment was opened in the last week of March, 2021 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for seed sowing. The land preparation was completed on 2nd April 2021. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.10 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis and subsequently analyzed from Soil Resources Development Institute (SRDI), Farmgate, Dhaka- 1215.

3.11 Fertilizers and manure application

Application of fertilizers (basal dose) was completed on 3rd April, 2021. Fertilizers were applied to the experimental plot considering the recommended doses of BARI (2019).

Fertilizers	Doses ha^{-1}
Urea	As per treatment
TSP	160 kg
MoP	85 kg
Gypsum	170 kg
$ZnSO_4$	4 kg
Boric acid	As per treatment

Half of urea along with other fertilizers were applied during final land preparation as basal dose as per treatment and thoroughly mixed with soil. The rest half urea was applied at 45 days after sowing (DAS) when flowers were initiated by side dressing. Foliar applications of boron were applied at 30 days after sowing (DAS) and at 60 days after sowing (pod development stage).

3.12 Seed sowing

Seeds of the groundnut variety (BARI cheenabadam-10) were sown at the rate of 100 kg ha^{-1} (unshelled groundnut) on 4th April, 2021. The groundnuts were first unshelled and treated with Bavistin 250 WP @ 2 g kg^{-1} seed, then sown in lines maintaining a line to line distance of 30 cm and seed to seed distance of 15 cm having 2 seeds $hole^{-1}$ in the well prepared plot.

3.13 Intercultural operations

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the groundnut.

3.13.1 Irrigation and drainage

Pre-sowing irrigation was given to ensure the maximum germination percentage. Generally for upland soil 2 irrigations are required but considering the experiment field soil condition several time irrigations was given. Irrigations were given depending on the soil moisture content after soil moisture testing by hand. Before harvesting a last irrigation was given for convenience harvesting.

3.13.2 Gap filling, thinning, weeding and mulching

Thinning and gap filling were done at 20 and 23 DAS, respectively to maintain the uniformity of plant population. The crop was infested with some weeds during the early stage of crop establishment. Two hand weedings were done. After irrigation the soil surface became crusty, so there needed several operations done manually to break down the hard soil crust.

3.13.3 Earthing up

Earthing up was done lightly at 40 days after sowing. It was done to encourage pegging and potential pod development.

3.13.4 Plant protection

Bavistin 250 WP was directly applied in the row to control ant. Insecticide Ripcord 10 EC @ 1 ml $litre^{-1}$ water were mixed and then sprayed on the leaves two times by knapsack sprayer to control jute hairy caterpillar, jessed and cutworm to protect the crop. Autistin 50 WDG and Mancer 75WP were used as fungicide to control foot and root rot of groundnut.

3.14 Harvesting and post-harvest operation

There is a thumb rule that the crop should be harvested when about 75% of the pods became mature at 115 DAS. After observing some maturity indices such as leaf became yellow, spots on the leaf, pod became hard and tough and dark tannin discoloration inside the shell crops were harvested. The samples were collected from the area of 1 m^2 of each plot avoiding the border plants. During harvest the pod contained 35% moisture. The harvested crops were tied into bundles and carried to the threshing floor. Then the pods were separated from the plants. The separated pod and the stover were sun dried by spreading those on the threshing floor. The seeds were separated from the pod and dried in the sun for 3 to 5 consecutive days for achieving safe moisture content (8%) of seed.

3.15 Data collection and recording

Experimental data were recorded from stipulated dates and continued until harvest. The following data were recorded during the experimentation:

i. Plant length
ii. Number of leaves plant^{-1}
iii. Number of branches plant^{-1}
iv. Pod length
v. Number of pods plant^{-1}
vi. Pod yield plot^{-1}
vii. 100-seed weight
viii. Pod yield
ix. Kernel yield
x. Stover yield
xi. Biological yield
xii. Harvest index

3.16 Procedure of recording data

3.16.1 Plant length

Five plants were selected randomly from the inner rows of each plot. The length of the plants was measured from the ground level to the tip of the plant at 25, 50, 75, 100 DAS and at harvest. The mean value of plant length was recorded in cm.

3.16.2 Number of leaves plant^{-1}

Five plants were selected randomly from the inner rows of each plot. Leaves plant^{-1} was counted from each plant sample and then averaged at 25, 50, 75, 100 DAS and at harvest.

3.16.3 Number of branches plant^{-1}

The branches plant^{-1} was counted from five randomly sampled plants at 25, 50, 75, 100 DAS and at harvest, respectively. It was done by counting total number of branches of all sampled plants then the average data were recorded.

3.16.4 Pod length

Pod length was recorded from randomly selected 10 pods of each plot and the average was taken and expressed in centimeter (cm).

3.16.5 Number of pods plant^{-1}

The pods plant^{-1} was counted from five randomly sampled plants. It was done by counting total number of pods of all sampled plants then the average data were recorded.

3.16.6 Pod yield plot^{-1}

Pod yield plot^{-1} was calculated from unshelled, cleaned and well dried grains collected from each plot and expressed as kilogram (kg) on 8 % moisture basis.

3.16.7 Weight of 100-seed

From the seed stock of each plot 100 seeds were counted randomly and the weight was measured by an electrical balance. It was recorded in gram (g).

3.16.8 Pod yield

Pod yield was calculated from unshelled, cleaned and well dried pods collected from the central 1 m^2 area of inner rows of each plot (leaving boarder rows) and expressed as t ha^{-1} on 8 % moisture basis.

3.16.9 Kernel yield

Kernel yield was calculated from shelled, cleaned and well dried grains collected from each plot and expressed as t ha^{-1} on 8 % moisture basis.

3.16.10 Stover yield

Stover yield was determined from the central 1 m^2 area of inner rows of the each plot. After threshing, the sub sample was oven dried to a constant weight and finally converted to t ha^{-1}.

3.16.11 Biological yield

It was the total yield including both the economic and stover yield as follows:

$$\text{Biological yield (t ha}^{-1}\text{)} = \text{Grain yield (t ha}^{-1}\text{)} + \text{Stover yield (t ha}^{-1}\text{)}$$

3.16.12 Harvest index

Harvest index is the ratio of economic (grain) yield and biological yield. It was calculated by dividing the grain yield from the harvested area by the biological yield of the same area and multiplying by 100.

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.17 Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and then mean differences were adjusted by Least Significance difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

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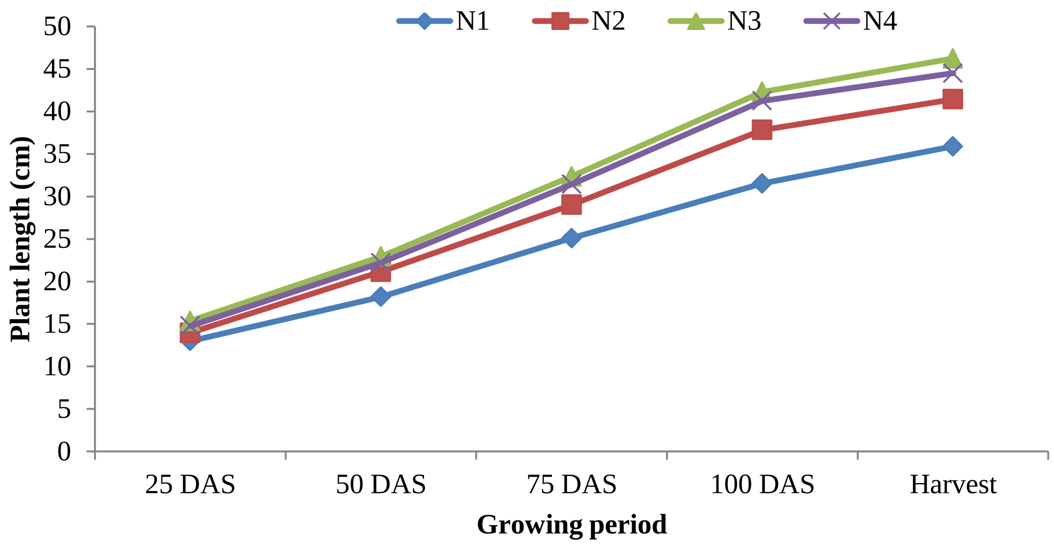
In this chapter the present study's findings have been provided and analyzed in order to investigate the effects of different levels of nitrogen and foliar boron on the growth and yield of groundnut cv. BARI cheenabadam-10. The information is presented in different tables and figures. The findings have been discussed, and possible interpretations are provided under the headings listed below.

4.1 Plant length

4.1.1 Effect of nitrogen level

Plant length exhibits an important morphological attribute that acts as a potential indicator of availability of growth resources in its approach. Plant length exerted significant differences due to nitrogen levels under the present study (Figure 1). From the experimental result it revealed that plant length showed significant variation at 25, 50, 75, 100 DAS and at harvest due to nitrogen application. The longest plant (15.34, 22.93, 32.34, 42.29 and 46.22 cm at 25, 50, 75, 100 DAS and at harvest, respectively) were obtained from N_3 treatment. On the other hand, the shortest plant (13.00, 18.19, 25.09, 31.52 and 35.87 cm at 25, 50, 75, 100 DAS and at harvest, respectively) were obtained in N_1 treatment. The findings of the experiment was in coincided with the findings of Bharathi *et al.* (2021) who reported that nitrogen fertilizer along with biofertilizers application increases the plant growth parameters viz., plant length. Hasan *et al.* (2019) reported that N and P fertilizer was played dominating role for vegetative growth of the plant.

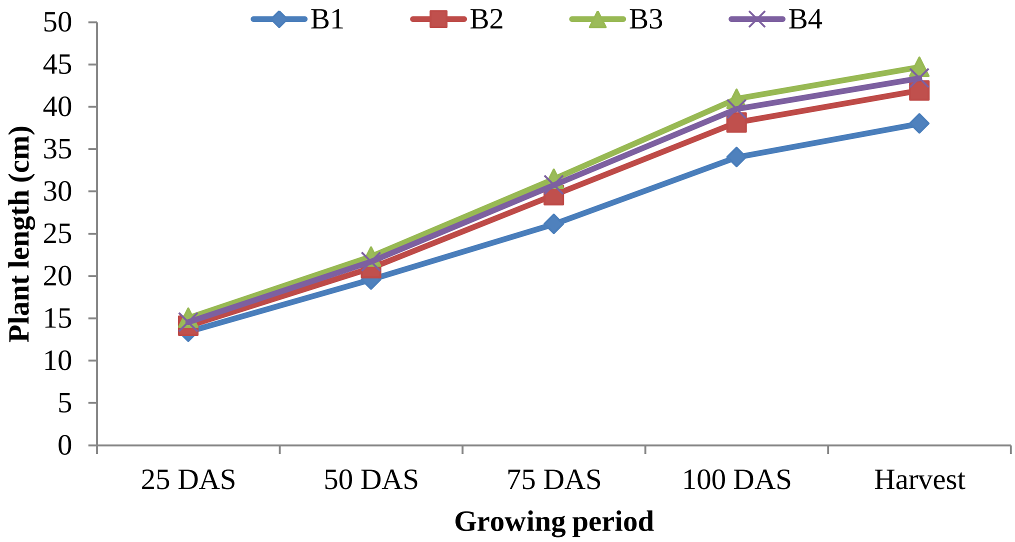


N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 1. Effect of nitrogen level on plant length at different days after sowing of groundnut ($LSD_{0.05}$= 0.39, 0.35, 0.39, 0.99 and 1.13 at 25, 50, 75, 100 DAS and at harvest, respectively).

4.1.2 Effect of foliar boron level

Significant differences on plant length of groundnut at different growth stages were observed due to foliar application of boron under the study (Figure 2). Results from the experiment revealed that the longest plant (15.04, 22.28, 31.46, 40.94 and 44.69 cm at 25, 50, 75, 100 DAS and at harvest, respectively) were observed in B_3 treatment. On the other hand, the shortest plant (13.40, 19.56, 26.12, 34.03 and 38.00 cm at 25, 50, 75, 100 DAS and at harvest, respectively) were obtained from B_1 treatment. Similar results were also observed by Nandi *et al.* (2020) who reported that the combined spray of Zn and B at critical growth stages promoted better growth and productivity of groundnut. Poonguzhali and Pandian (2018) reported that the application of 15 kg ha^{-1} of B as soil application plus 0.5% foliar application of B at critical stages recorded the maximum plant length. The soil and foliar application of B improved the growth accompanied by increased B concentration in plant parts.



B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 2. Effect of foliar boron level on plant length at different days after sowing (DAS) of groundnut ($LSD_{0.05}$= 0.40, 0.44, 0.50, 0.84 and 1.12 at 25, 50, 75, 100 DAS and at harvest, respectively).

4.1.3 Combined effect of nitrogen and foliar boron level

Significant variation on plant length was observed due to combined effect of nitrogen and foliar boron levels (Table 1 and Appendix V). Results of the present study revealed that the longest plant (16.92, 24.53, 35.25, 45.81 and 50.71 cm at 25, 50, 75, 100 DAS and at harvest, respectively) were obtained from N_3B_3 treatment combination which was statistically similar with N_3B_4 (23.81, 44.67 and 48.67 cm at 50, 100 DAS and at harvest, respectively) and N_4B_3 (44.05 cm at 100 DAS). On the other hand, the shortest plant (12.68, 17.37, 23.68, 29.15 and 34.15 cm at 25, 50, 75, 100 DAS and at harvest, respectively) were observed in N_1B_1 treatment combination which was statistically similar with N_1B_2 (12.89, 17.80 and 36.05 cm at 25, 50 DAS and at harvest, respectively); with N_1B_3, N_1B_4 and N_2B_1 treatment combination at 25 DAS and with N_1B_4 treatment combination at harvest.

Table 1. Combined effect of nitrogen and foliar boron levels on plant length at different days after sowing (DAS) of groundnut

Treatment Combinations	Plant length (cm) at				
	25 DAS	50 DAS	75 DAS	100 DAS	Harvest
N_1B_1	12.68 k	17.37 l	23.68 j	29.15 k	34.15 k
N_1B_2	12.89 jk	17.80 kl	25.15 i	31.29 j	36.05 jk
N_1B_3	13.29 h-k	19.15 ij	26.05 hi	33.47 hi	37.11 j
N_1B_4	13.15 ijk	18.44 jk	25.48 i	32.11 ij	36.17 jk
N_2B_1	13.44 h-k	19.93 hi	26.51 gh	34.67 gh	38.25 ij
N_2B_2	13.93 f-i	21.07 g	28.57 f	37.53 ef	41.51 gh
N_2B_3	14.41 d-g	21.96 ef	30.76 e	40.43 d	43.38 efg
N_2B_4	14.05 e-h	21.55 fg	30.20 e	38.62 e	42.53 fg
N_3B_1	13.82 ghi	20.76 gh	27.39 g	36.49 f	40.13 hi
N_3B_2	14.85 cde	22.61 de	32.67 cd	42.19 cd	45.38 cde
N_3B_3	16.92 a	24.53 a	35.25 a	45.81 a	50.71 a
N_3B_4	15.77 b	23.81 ab	34.05 b	44.67 ab	48.67 ab
N_4B_1	13.67 g-j	20.16 h	26.93 gh	35.81 fg	39.50 hi
N_4B_2	14.67 def	22.19 def	31.81 d	41.55 d	44.75 def
N_4B_3	15.53 bc	23.47 bc	33.77 b	44.05 ab	47.57 bc
N_4B_4	15.18 bcd	22.92 cd	33.23 bc	43.51 bc	46.16 cd
$LSD_{(0.05)}$	**0.81**	**0.88**	**1.00**	**1.68**	**2.24**
CV(%)	**3.42**	**2.49**	**2.02**	**2.62**	**3.18**

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

Notes:

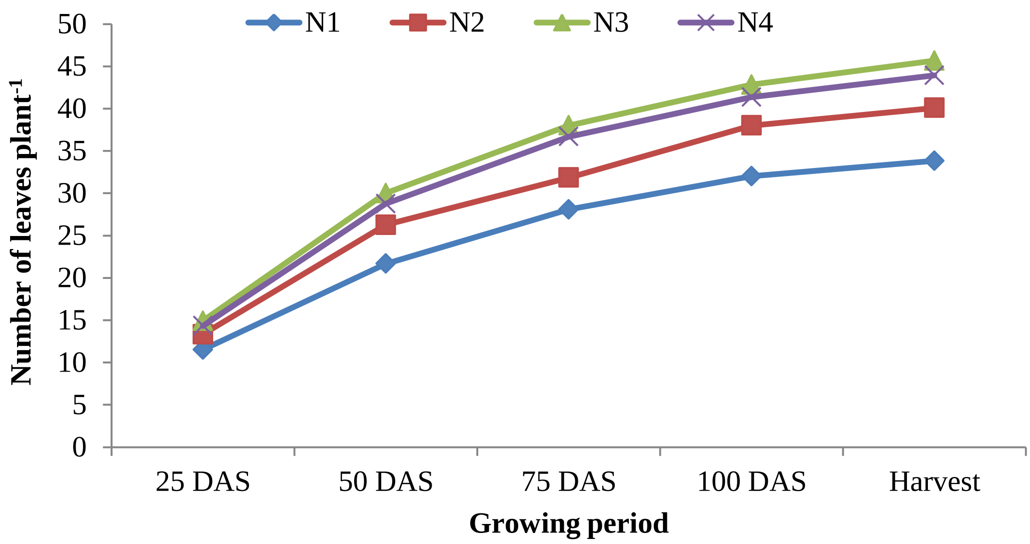
N_1= 0 kg urea ha^{-1}
N_2= 25 kg urea ha^{-1}
N_3= 30 kg urea ha^{-1}
N_4= 35 kg urea ha^{-1}

B_1= control (no boric acid)
B_2= 0.1% boric acid as foliar application
B_3= 0.2% boric acid as foliar application
B_4= 0.3% boric acid as foliar application

4.2 Number of leaves plant^{-1}

4.2.1 Effect of nitrogen level

A leaf is the main lateral part of a vascular plant stem that is normally carried above ground and is specialized for photosynthesis. Significant effect on number of leaves plant^{-1} at different days after sowing was observed due to nitrogen under the present study (Figure 3). Result revealed from the study that the maximum number of leaves plant^{-1} (14.92, 30.00, 38.00, 42.83 and 45.67 at 25, 50, 75, 100 DAS and at harvest, respectively) were obtained from N_3 treatment which was statistically similar with N_4 treatment at 25 and 50 DAS while the minimum number of leaves plant^{-1} (11.50, 21.67, 28.08, 32.00 and 33.83 at 25, 50, 75, 100 DAS and at harvest, respectively) were observed in N_1 treatment. Similar result was also observed by Hasan *et al.* (2019) who reported that vegetative growth and yield of the plant was better at $N_{30}P_{60}$ kg ha^{-1} than the all other treatments. Mondal *et al.* (2020) reported that fertilizing with 100% of the recommended dose of nitrogen combined with rhizobium inoculant significantly enhanced peanut plant growth, yield and yield-attributing traits.

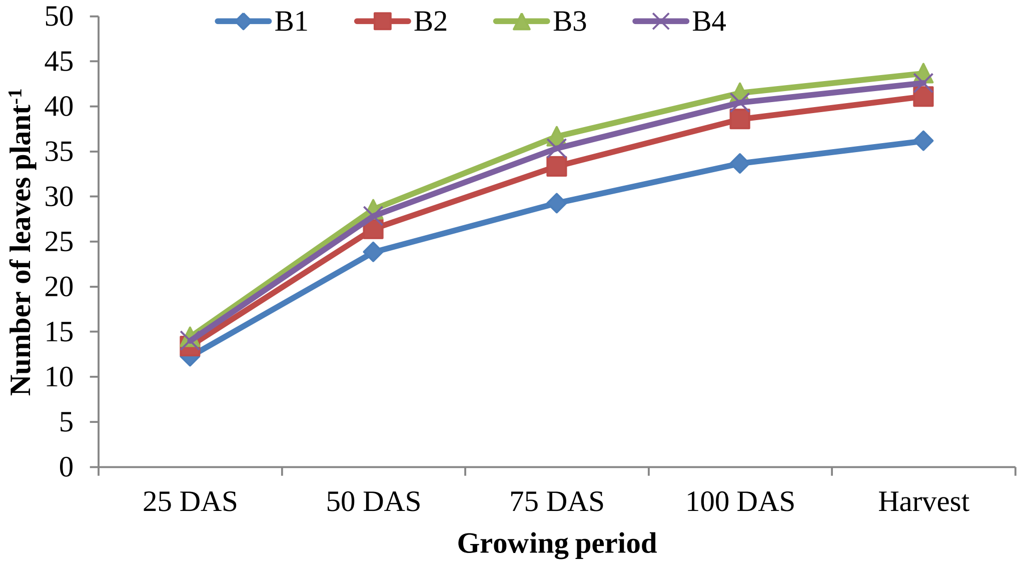


N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 3. Effect of nitrogen level on number of leaves plant^{-1} at different days after sowing (DAS) of groundnut ($LSD_{0.05}$= 0.67, 0.55, 0.37, 0.86 and 0.62 at 25, 50, 75, 100 DAS and at harvest, respectively).

4.2.2 Effect of foliar boron level

Significant effect showed on number of leaves plant^{-1} at different days after sowing due to foliar boron levels (Figure 4). From the experiment result revealed that the maximum number of leaves plant^{-1} (14.42, 28.58, 36.67, 41.50 and 43.67 at 25, 50, 75, 100 DAS and at harvest, respectively) were obtained from B_3 treatment which was statistically similar with B_4 at 25 DAS. On the other hand, the minimum number of leaves plant^{-1} (12.25, 23.83, 29.25, 33.67 and 36.17 at 25, 50, 75, 100 DAS and at harvest, respectively) was observed in B_1 treatment. The findings of study was in coincided with the findings of Nandi *et al.* (2020) who reported that spraying of Zn and B increased plant biomass, leaf number, leaf area, chlorophyll content noticeably and with the increase in concentration of Zn and B in spray, the increment became quite intense.



B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 4. Effect of foliar boron level on number of leaves plant^{-1} at different days after sowing (DAS) of groundnut ($LSD_{0.05}$= 0.41, 0.60, 0.64, 0.83 and 0.81 at 25, 50, 75, 100 DAS and at harvest, respectively).

4.2.3 Combined effect of nitrogen and foliar boron level

Significant variation was marked for number of leaves plant^{-1} of groundnut due to combined effect of nitrogen and foliar boron levels (Table 2 and Appendix VI). Results from the experiment revealed that the maximum number of leaves plant^{-1}

(16.33, 33.33, 42.67, 47.00 and 50.33 at 25, 50, 75, 100 DAS and at harvest, respectively) were achieved from N_3B_3 treatment combination which was statistically similar with N_3B_4 treatment combination at 25 and 100 DAS, respectively. On the other hand, the minimum number of leaves plant^{-1} (11.00, 20.00, 27.33, 30.67 and 32.33 at 25, 50, 75, 100 DAS and at harvest, respectively) were obtained from N_1B_1 treatment combination which was statistically similar with N_1B_2 treatment combination at 25, 75, 100 DAS and at harvest, respectively; with N_1B_4 treatment combination at 25, 75 and 100 DAS, respectively.

Table 2. Combined effect of nitrogen and foliar boron levels on number of leaves plant^{-1} at different days after sowing (DAS) of groundnut

Treatment Combinations	Number of leaves plant^{-1} at				
	25 DAS	50 DAS	75 DAS	100 DAS	Harvest
N_1B_1	11.00 n	20.00 k	27.33 k	30.67 l	32.33 j
N_1B_2	11.33 mn	21.67 j	28.00 jk	31.33 kl	33.67 ij
N_1B_3	12.00 klm	22.67 j	28.67 ij	33.33 ij	35.00 hi
N_1B_4	11.67 lmn	22.33 j	28.33 ijk	32.67 jk	34.33 i
N_2B_1	12.33 jkl	24.00 i	29.33 hi	34.00 hij	36.33 gh
N_2B_2	13.33 ghi	26.67 fg	31.00 g	37.67 g	40.67 e
N_2B_3	14.00 efg	27.33 ef	34.67 e	40.67 ef	42.00 e
N_2B_4	13.67 fgh	27.00 fg	32.33 f	39.67 f	41.33 e
N_3B_1	13.00 hij	26.00 gh	30.33 gh	35.33 h	38.67 f
N_3B_2	14.67 cde	29.00 d	37.67 d	43.33 cd	45.67 cd
N_3B_3	16.33 a	33.33 a	42.67 a	47.00 a	50.33 a
N_3B_4	15.67 ab	31.67 b	41.33 b	45.67 ab	48.00 b
N_4B_1	12.67 ijk	25.33 h	30.00 gh	34.67 hi	37.33 fg
N_4B_2	14.33 def	28.33 de	36.67 d	42.00 de	44.33 d
N_4B_3	15.33 bc	31.00 bc	40.67 b	45.00 bc	47.33 b
N_4B_4	15.00 bcd	30.33 c	39.33 c	43.67 cd	46.67 bc
$LSD_{(0.05)}$	**0.83**	**1.21**	**1.28**	**1.67**	**1.62**
CV(%)	**3.67**	**2.69**	**2.27**	**2.58**	**2.36**

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

Notes:

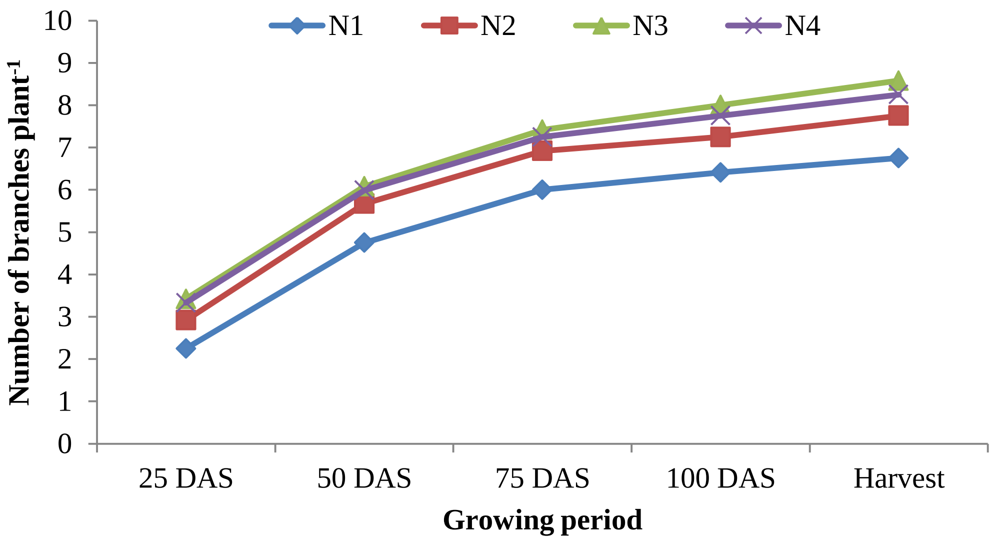
N_1= 0 kg urea ha^{-1}
N_2= 25 kg urea ha^{-1}
N_3= 30 kg urea ha^{-1}
N_4= 35 kg urea ha^{-1}

B_1= control (no boric acid)
B_2= 0.1% boric acid as foliar application
B_3= 0.2% boric acid as foliar application
B_4= 0.3% boric acid as foliar application

4.3 Number of branches plant^{-1}

4.3.1 Effect of nitrogen level

Significant effect on number of branches plant^{-1} at different days after sowing was observed due to nitrogen under the present study (Figure 3). Result revealed from the study that the maximum number of branches plant^{-1} (3.42, 6.08, 7.42, 8.00 and 8.58 at 25, 50, 75, 100 DAS and at harvest, respectively) were obtained from N_3 treatment which was statistically similar with N_4 treatment at 25 and 100 DAS. On the other hand, the minimum number of branches plant^{-1} (2.25, 4.75, 6.00, 6.41 and 6.75 at 25, 50, 75, 100 DAS and at harvest, respectively) were observed in N_1 treatment. Similar trend also found by Hossain and Hamid (2007) who reported that application of N and P fertilizer exerted significant effects on plant growth parameters, root development, photosynthesis, yield contributing characters and pod yield of the crop. El-Habbasha *et al.* (2013) reported that groundnut treatment with 40 kg N fed^{-1} + Zn foliar application at seed filling stage recorded the highest significant values of most studied characters than the other treatments followed by the same nitrogen level and Zn foliar application at flowering stage.

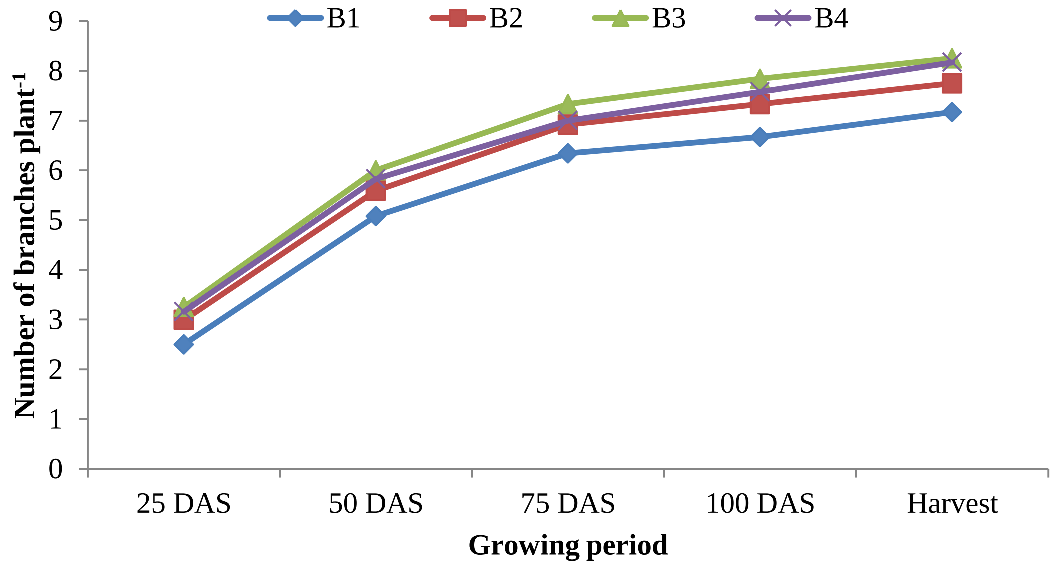


N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 5. Effect of nitrogen level on number of branches plant^{-1} at different days after sowing (DAS) of groundnut ($LSD_{0.05}$= 0.09, 0.08, 0.07, 0.27 and 0.25 at 25, 50, 75, 100 DAS and at harvest, respectively).

4.3.2 Effect of foliar boron level

Significant variation was observed on number of branches plant^{-1} at different days after sowing due to foliar boron levels (Figure 4). From the experiment result revealed that the maximum number of branches plant^{-1} (3.25, 6.00, 7.33, 7.84 and 8.25 at 25, 50, 75, 100 DAS and at harvest, respectively) were obtained from B_3 treatment which was statistically similar with B_4 at harvest. On the other hand, the minimum number of branches plant^{-1} (2.50, 5.08, 6.34, 6.67 and 7.17 at 25, 50, 75, 100 DAS and at harvest, respectively) was observed in B_1 treatment. The result of the experiment was in coincided with the findings of Poonguzhali and Pandian (2018) who reported that the soil and foliar application of B improved the growth accompanied by increased B concentration in plant parts. Quamruzzaman *et al.* (2016) reported that days to first-last emergence and days to first-50% lowering took shorter times and vegetative growth, pods dry weight plant^{-1}, pod yield, and germination were markedly increased with the application of boron.



B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 6. Effect of foliar boron level on number of branches plant^{-1} at different days after sowing of groundnut ($LSD_{0.05}$= 0.06, 0.10, 0.11, 0.17 and 0.17 at 25, 50, 75, 100 DAS and at harvest, respectively).

4.3.3 Combined effect of nitrogen and foliar boron level

Significant variation was marked for number of branches plant^{-1} of groundnut due to combined effect of nitrogen and foliar boron levels (Table 3 and Appendix VII). Results from the experiment revealed that the maximum number of branches plant^{-1} (4.00, 6.67, 8.00, 8.67 and 9.00 at 25, 50, 75, 100 DAS and at harvest, respectively) were achieved from N_3B_3 treatment combination which was statistically similar with N_3B_4 treatment combination at 100 DAS and at harvest, respectively. On the other hand, the minimum number of branches plant^{-1} (2.00, 4.33, 5.67, 6.00 and 6.33 at 25, 50, 75, 100 DAS and at harvest, respectively) were obtained from N_1B_1 treatment combination which was statistically similar with N_1B_2 treatment combination at 100 DAS and at harvest, respectively.

Table 3. Combined effect of nitrogen and foliar boron levels on number of branches plant^{-1} at different days after sowing (DAS) of groundnut

Treatment Combinations	Number of branches plant^{-1} at				
	25 DAS	**50 DAS**	**75 DAS**	**100 DAS**	**Harvest**
N_1B_1	2.00 g	4.33 h	5.67 h	6.00 h	6.33 i
N_1B_2	2.33 f	4.67 g	6.00 g	6.33 gh	6.67 hi
N_1B_3	2.33 f	5.00 f	6.33 f	6.67 fg	7.00 gh
N_1B_4	2.33 f	5.00 f	6.00 g	6.67 fg	7.00 gh
N_2B_1	2.67 e	5.33 e	6.33 f	6.67 fg	7.33 fg
N_2B_2	3.00 d	5.67 d	7.00 d	7.33 de	7.67 ef
N_2B_3	3.00 d	6.00 c	7.33 c	7.67 cd	8.00 de
N_2B_4	3.00 d	5.67 d	7.00 d	7.33 de	8.00 de
N_3B_1	2.67 e	5.33 e	6.67 e	7.00 ef	7.67 ef
N_3B_2	3.33 c	6.00 c	7.33 c	8.00 bc	8.33 cd
N_3B_3	4.00 a	6.67 a	8.00 a	8.67 a	9.33 a
N_3B_4	3.67 b	6.33 b	7.67 b	8.33 ab	9.00 ab
N_4B_1	2.67 e	5.33 e	6.67 e	7.00 ef	7.33 fg
N_4B_2	3.33 c	6.00 c	7.33 c	7.67 cd	8.33 cd
N_4B_3	3.67 b	6.33 b	7.67 b	8.33 ab	8.67 bc
N_4B_4	3.67 b	6.33 b	7.33 c	8.00 bc	8.67 bc
$LSD_{(0.05)}$	**0.12**	**0.20**	**0.21**	**0.34**	**0.34**
CV(%)	**2.57**	**2.11**	**1.89**	**2.75**	**2.63**

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

Notes:

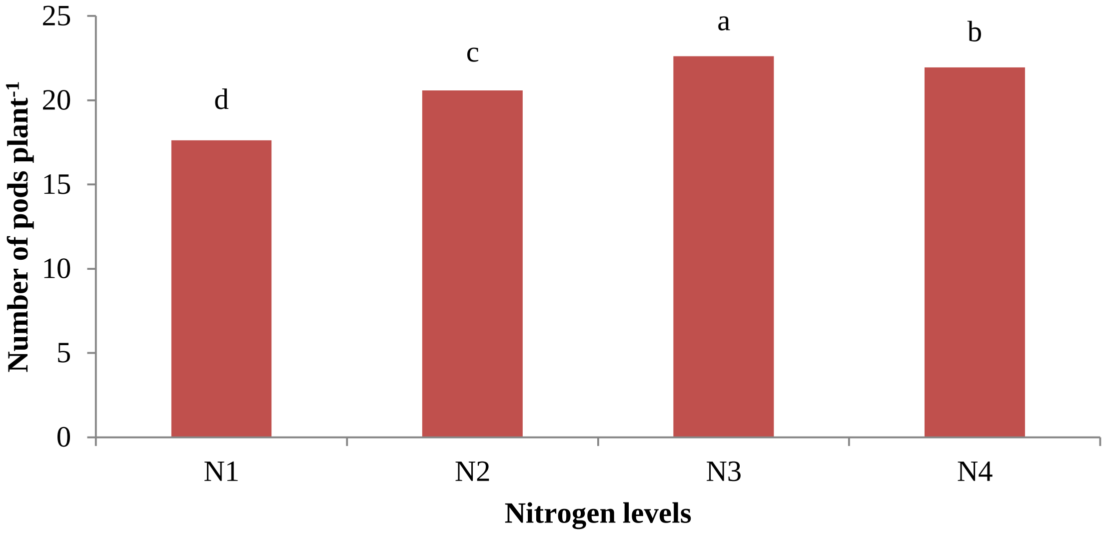
N_1= 0 kg urea ha^{-1}
N_2= 25 kg urea ha^{-1}
N_3= 30 kg urea ha^{-1}
N_4= 35 kg urea ha^{-1}

B_1= control (no boric acid)
B_2= 0.1% boric acid as foliar application
B_3= 0.2% boric acid as foliar application
B_4= 0.3% boric acid as foliar application

4.4 Number of pods plant^{-1}

4.4.1 Effect of nitrogen level

Groundnut exerted marked variation on number of pods plant^{-1} due to the effect of nitrogen (Figure 7). Result from the experiment revealed that the maximum number of pods plant^{-1} (22.61) was obtained from N_3 treatment. On the other hand, the minimum number of pods plant^{-1} (17.62) was observed in N_1 treatment. The result of the experiment was in coincided with the findings of El-Habbasha *et al.* (2013) who reported that increasing N levels from 30 to 40 kg N fed^{-1} significantly increased number of pods plant^{-1}, weight of pods plant^{-1}, weight of seeds plant^{-1}, 100-seed weight, pod yield fed^{-1}, seed yield fed^{-1} and straw yield fed^{-1}. Tekulu *et al.* (2020) reported that average pod yield plant^{-1} and pod yield ha^{-1} increased by 85.4% for a combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} fertilizers compared to the control plots.



The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 7. Effect of nitrogen level on number of pods plant^{-1} of groundnut ($LSD_{0.05}$= 0.46).

4.4.2 Effect of foliar boron level

Number of pods plant^{-1} of groundnut exerted significant variation due to foliar application of boron (Figure 8). Results from the experiment revealed that the maximum number of pods plant^{-1} (21.99) was achieved from B_3 treatment. On the other hand, the minimum number of pods plant^{-1} (18.84) was obtained from B_1 treatment. Similar result was also observed by Kabir *et al.* (2013) who reported that the combined application of fertilizer P, Ca and B increased the yield contributing parameter number of pods plant^{-1} for obtaining the highest yield of groundnut. Quamruzzaman *et al.* (2016) reported that number of pods plant^{-1}, pods dry weight plant^{-1}, pod yield and germination were markedly increased with the application of boron.

The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 8. Effect of foliar boron level on number of pods plant^{-1} of groundnut ($LSD_{0.05}$= 0.62).

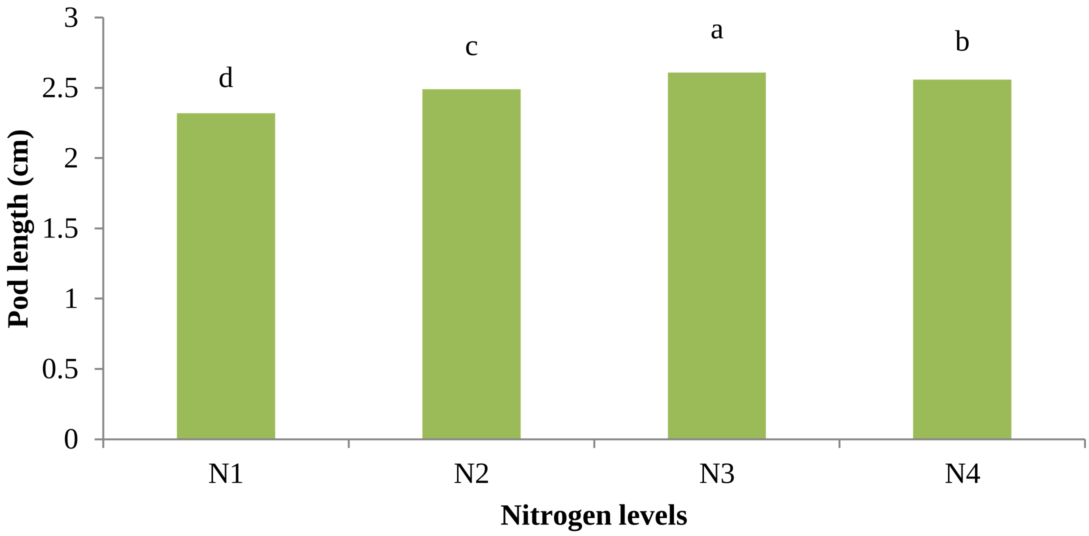
4.4.3 Combined effect of nitrogen and foliar boron level

Significant difference was marked for number of pods plant^{-1} of groundnut due to combined effect of nitrogen and foliar boron levels (Table 4 and Appendix VIII). Results revealed that the maximum number of pods plant^{-1} (24.43) was observed in N_3B_3 treatment combination which was statistically similar with N_3B_4 (23.78) and N_4B_3 (23.55) treatment combination. On the other hand, the minimum number of pods plant^{-1} (16.81) was observed in N_1B_1 treatment combination which was statistically as par with N_1B_2 (17.33) and N_1B_4 (17.87) treatment combination.

4.5 Pod length

4.5.1 Effect of nitrogen level

Pod length of groundnut exerted significant variation due to nitrogen level under the present study (Figure 9). Results from the experiment revealed that the maximum pod length (2.61 cm) was obtained from N_3 treatment while the minimum pod length (2.32 cm) was achieved from N_1 treatment. Similar result was observed by Tekulu *et al.* (2020) reported that combined application of N and P was recommended for increasing yield contributing characters, grain yield, grain protein content and residual soil nitrogen. The results of this study are crucial to improve groundnut productivity, grain protein content and also to provide implication on soil fertility management in a crop rotation system.



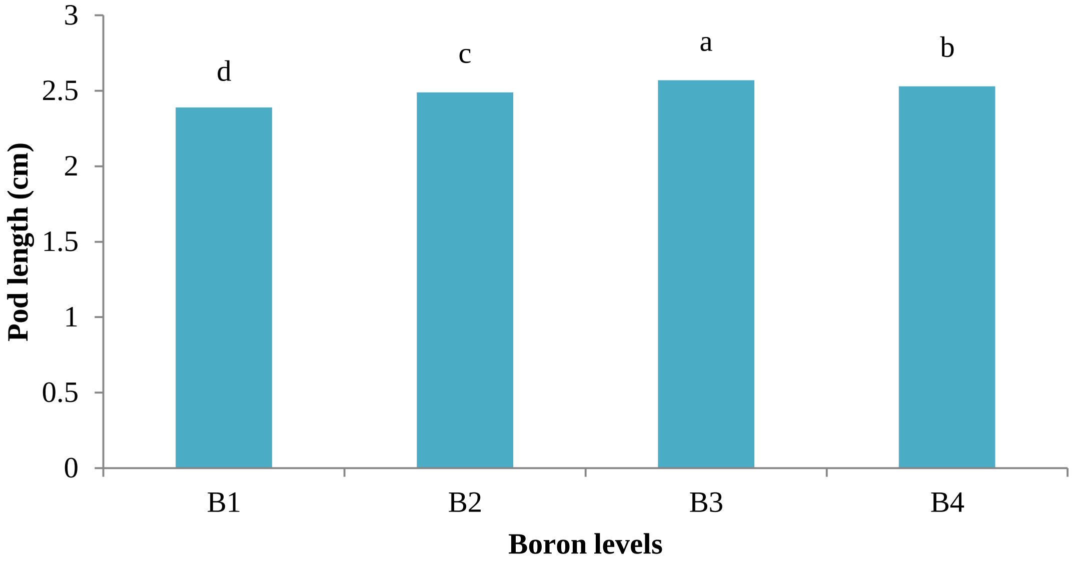
The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 9. Effect of nitrogen level on pod length of groundnut ($LSD_{0.05}$= 0.04).

4.5.2 Effect of foliar boron level

Significant variation on pod length of groundnut was observed due to foliar boron level under the experiment (Figure 10). Results from the experiment showed that the maximum pod length was observed in B_3 (2.57 cm) treatment while the minimum pod length was obtained from B_1 (2.39 cm) treatment. The result of the study was in coincided with the findings of Nandi *et al.* (2020) reported that spraying of Zn and B increased plant growth parameters and yield contributing characters noticeably and with the increase in concentration of Zn and B in spray, the increment became quite intense. The combined spray of Zn and B at critical growth stages promoted better growth and productivity of groundnut.



The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 10. Effect of foliar boron level on pod length of groundnut ($LSD_{0.05}$= 0.03).

4.5.3 Combined effect of nitrogen and foliar boron level

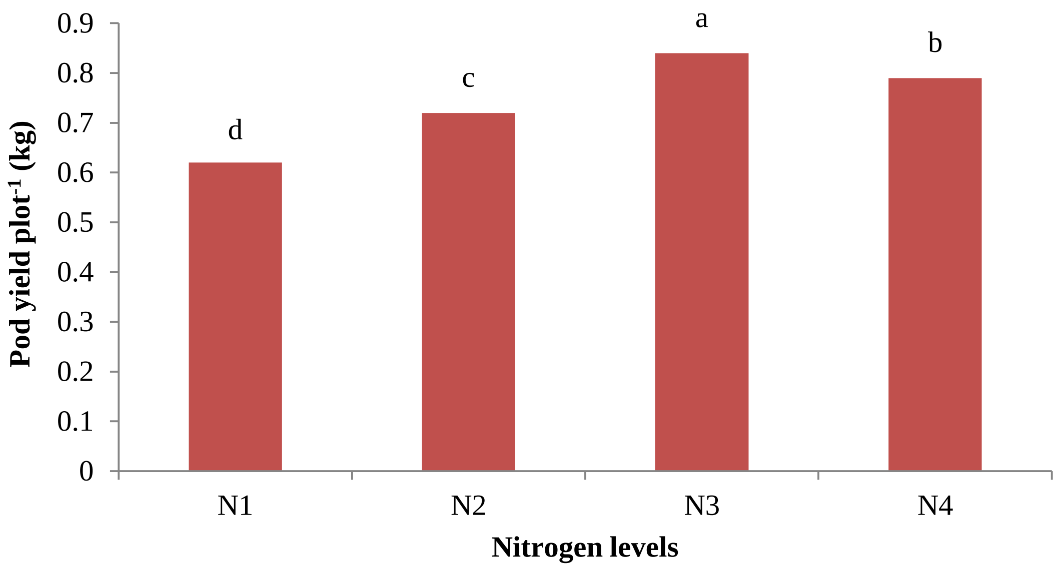
Combined effect of nitrogen and foliar boron levels exerted significant influence on pod length of groundnut under the experiment (Table 4 and Appendix VIII). Result revealed that the maximum pod length (2.72 cm) was obtained from N_3B_3 treatment combination which was statistically similar with N_3B_4 (2.68 cm) and N_4B_3 (2.66 cm) treatment combination. On the other hand, the minimum pod length (2.28 cm) was obtained from N_1B_1 treatment combination which was statistically similar with N_1B_2 (2.30 cm) and N_1B_4 (2.33 cm) treatment combinations.

4.6 Pod yield plot^{-1}

4.6.1 Effect of nitrogen level

Significant variation was recorded for pod yield plot^{-1} by different nitrogen levels of groundnut (Figure 11). The highest pod yield plot^{-1} (0.84 kg) was recorded from N_3

treatment, whereas the lowest pod yield plot^{-1} (0.62 kg) was recorded from N_1 treatment. Similar result also found by Tekulu *et al.* (2020) who revealed that average pod yield increased by 85.4% for a combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} fertilizers compared to the control plots. Hasan *et al.* (2019) reported that vegetative growth and yield of the plant was better at $N_{30}P_{60}$ kg ha^{-1} than the all other treatments. It can be concluded that by using $N_{30}P_{60}$ kg ha^{-1} growth and yield of bambara groundnut is maximum. Kulkarni *et al.* (2018) reported that the yield attributes also exhibited similar trend with a significantly increased response due to organic and inorganic treatments in groundnut.



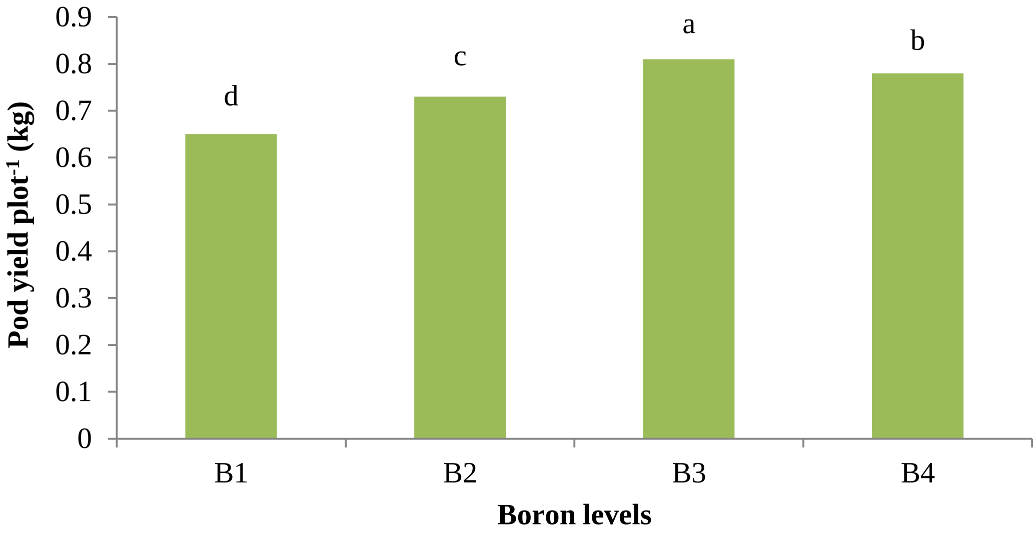
The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 11. Effect of nitrogen level on pod yield plot^{-1} of groundnut ($LSD_{0.05}$= 0.02).

4.6.2 Effect of foliar boron level

Considerable influence was found on pod yield plot^{-1} of groundnut persuaded by foliar boron levels (Figure 12). The highest pod yield plot^{-1} (0.81 kg) was recorded from B_3 treatment. On the other hand, the lowest pod yield plot^{-1} (0.65 kg) was recorded from B_1 treatment. The result of the experiment was also coincided with the findings of El-Kader and Mona (2013) who reported that application of S and foliar spraying with micronutrient (Zn and B) together had the significant effect on peanut seed yield and its attributes as well as seed quality.



The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 12. Effect of foliar boron level on pod yield plot^{-1} of groundnut ($LSD_{0.05}$= 0.01).

4.6.3 Combined effect of nitrogen and foliar boron level

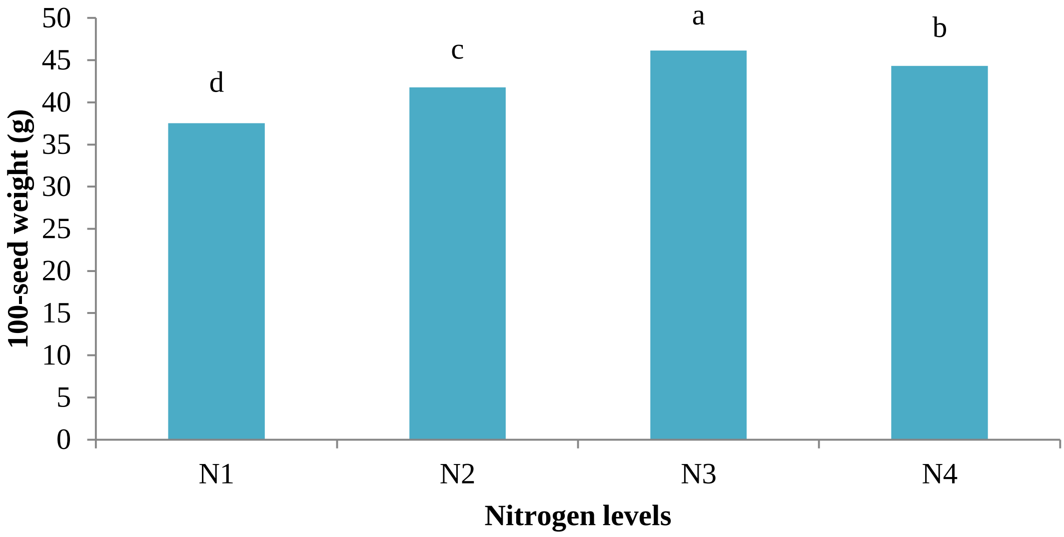
Pod yield plot^{-1} of groundnut affected significantly due to treatment combination of nitrogen and foliar boron levels (Table 4 and Appendix VIII). Results showed that the treatment combination of N_3B_3 gave the highest pod yield plot^{-1} (0.95 kg) followed by N_3B_4, whereas N_1B_1 gave the lowest pod yield plot^{-1} (0.59 kg) which was statistically similar with N_1B_2 and N_1B_4 treatment combinations.

4.7 100 seeds weight

4.7.1 Effect of nitrogen level

Effect of nitrogen exerted significant difference in 100 seeds weight of groundnut (Figure 13). Results from the experiment revealed that the maximum 100 seeds weight of groundnut (46.14 g) was obtained from N_3 treatment while the minimum 100 seeds weight of groundnut (37.52 g) was obtained from N_1 treatment. Similar trends was also observed by Boydak *et al.* (2021) who reported that 100 seeds weight were increased with nitrogen fertilization and no-deficit water application on plant. El-Habbasha *et al.* (2013) revealed that increasing N levels from 30 to 40 kg N fed^{-1}

significantly increased number of pods plant^{-1}, weight of pods plant^{-1}, weight of seeds plant^{-1}, 100-seed weight, pod yield fed^{-1}, seed yield fed^{-1} and straw yield fed^{-1}.



The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 13. Effect of nitrogen level on 100-seed weight of groundnut ($LSD_{0.05}$= 0.81).

4.7.2 Effect of foliar boron level

Significant effect showed on 100 seeds weight of groundnut due to foliar boron levels (Figure 14). Result from the experiment showed that the maximum 100 seeds weight of groundnut was obtained from B_3 (45.00 g) treatment. On the other hand, the minimum 100 seeds weight of groundnut was obtained from B_1 (39.36 g) treatment. Mekdad (2019) revealed that among three foliar spray of boron levels (B_0: tap water, B_1: 100 ppm and B_2: 150 ppm) on peanut results indicated that yield components, yield and its quality of peanut were positively ($P \leq 0.01$) affected by the 150 ppm. Nandi *et al.* (2020) reported that foliar spray of Zn and B jointly increased the 100 seeds weight also the pod yield, respectively.

The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 14. Effect of foliar boron level on 100-seed weight of groundnut ($LSD_{0.05}$= 1.00).

4.7.3 Combined effect of nitrogen and foliar boron level

Combined effect of nitrogen and foliar boron levels showed significant variation on 100 seeds weight of groundnut under the present study (Table 4 Appendix VIII). Result revealed that the maximum 100 seeds weight of groundnut (50.12 g) was observed in N_3B_3 treatment combination which was statistically similar with N_3B_4 (48.81 g) treatment combination. On the other hand, the minimum 100 seeds weight of groundnut (36.45 g) was observed in N_1B_1 treatment combination which were statistically similar with N_1B_2 (37.05 g) and N_1B_4 (37.75 g) treatment combinations.

Table 4. Combined effect of nitrogen and foliar boron levels on number of pods plant^{-1}, pod length, pod yield plot^{-1} and 100-seed weight of groundnut

Treatment Combinations	Number of pods plant^{-1}	Pod length (cm)	Pod yield plot^{-1} (kg)	100-seed weight (g)
N_1B_1	16.81 l	2.28 k	0.59 k	36.45 k
N_1B_2	17.33 kl	2.30 k	0.62 jk	37.05 jk
N_1B_3	18.48 jk	2.37 ij	0.64 ij	38.81 ij
N_1B_4	17.87 kl	2.33 jk	0.63 jk	37.75 jk
N_2B_1	19.19 ij	2.39 hij	0.66 hij	39.78 hi
N_2B_2	20.67 gh	2.49 fg	0.72 fg	41.55 fgh
N_2B_3	21.51 efg	2.54 def	0.76 def	43.11 def
N_2B_4	21.00 fg	2.52 ef	0.74 ef	42.63 efg
N_3B_1	19.82 hi	2.45 gh	0.69 gh	40.87 gh
N_3B_2	22.41 cde	2.59 cd	0.80 cd	44.75 cd
N_3B_3	24.43 a	2.72 a	0.95 a	50.12 a
N_3B_4	23.78 ab	2.68 ab	0.91 ab	48.81 ab
N_4B_1	19.55 hij	2.43 ghi	0.68 ghi	40.35 hi
N_4B_2	21.95 def	2.56 cde	0.78 cde	43.67 cde
N_4B_3	23.55 abc	2.66 ab	0.87 b	47.94 b
N_4B_4	22.75 bcd	2.62 bc	0.82 c	45.39 c
$LSD_{(0.05)}$	**1.24**	**0.06**	**0.04**	**2.00**
CV(%)	**3.58**	**1.53**	**3.32**	**2.80**

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

Notes:

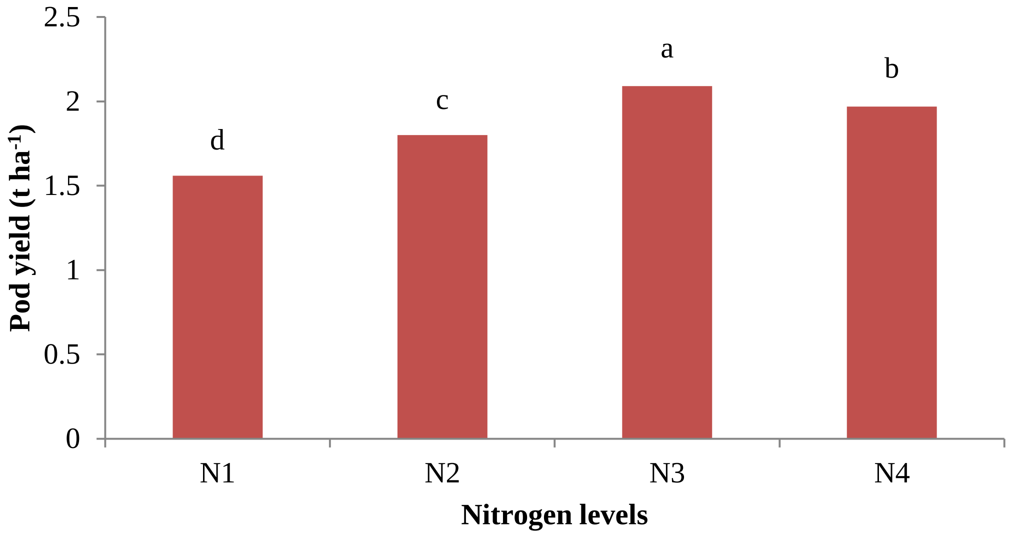
N_1= 0 kg urea ha^{-1}
N_2= 25 kg urea ha^{-1}
N_3= 30 kg urea ha^{-1}
N_4= 35 kg urea ha^{-1}

B_1= control (no boric acid)
B_2= 0.1% boric acid as foliar application
B_3= 0.2% boric acid as foliar application
B_4= 0.3% boric acid as foliar application

4.8 Pod yield

4.8.1 Effect of nitrogen level

Significant variation on pod yield (t ha^{-1}) of groundnut was observed due to effect of different nitrogen levels (Figure 15). From the experiment result revealed that the maximum pod yield (2.09 t ha^{-1}) was obtained from N_3 treatment while the minimum pod yield (1.56 t ha^{-1}) was obtained from N_1 treatment. The result of the experiment was also in coincided by Mondal *et al.* (2020) who reported that fertilizing with 100% of the recommended dose of nitrogen combined with rhizobium inoculant and polythene mulch significantly enhanced peanut plant growth, yield and yield-attributing traits, while resulting in the maximum fertilizer (i.e., nitrogen, phosphorus and potassium) uptake by different plant parts. Tekulu *et al.* (2020) reported that Average pod yield increased by 85.4% for a combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} fertilizers compared to the control plots. Plots fertilized with the highest combined rates of N and P have attained lower grain yield compared to the combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}. Hasan *et al.* (2019) revealed that Vegetative growth and yield of the plant was better at $N_{30}P_{60}$ Kg ha^{-1} than the all other treatments. Kumar *et al.* (2014) also reported that The treatment receiving N/P fertilizer ratio of 0.50 (30 kg N, 60 kg P_2O_5, 25 kg K_2O ha^{-1}) produced significantly higher dry pod yield (3310 kg ha^{-1}), number of filled pods $plant^{-1}$ (17.47), total number of pods $plant^{-1}$ (18.80) and 100-kernel weight (38.50 g). Further, the same treatment recorded significantly higher uptake (147.04 kg N, 23.30 kg P_2O_5, 118.48 kg K_2O, 10.93 kg S ha^{-1}) as compared to all other N/P fertilizer ratios. Hossain and Hamid (2007) reported that application of N and P fertilizer exerted significant effects on root development, photosynthesis, yield contributing characters and pod yield of the crop. Plant receiving 60 kg N and 39 kg P ha^{-1} had larger root system, greater photosynthetic rate and better yield contributing characters that resulted in the maximum pod yield which, however, was not significantly different from $N_{60}P_{26}$ treatment.



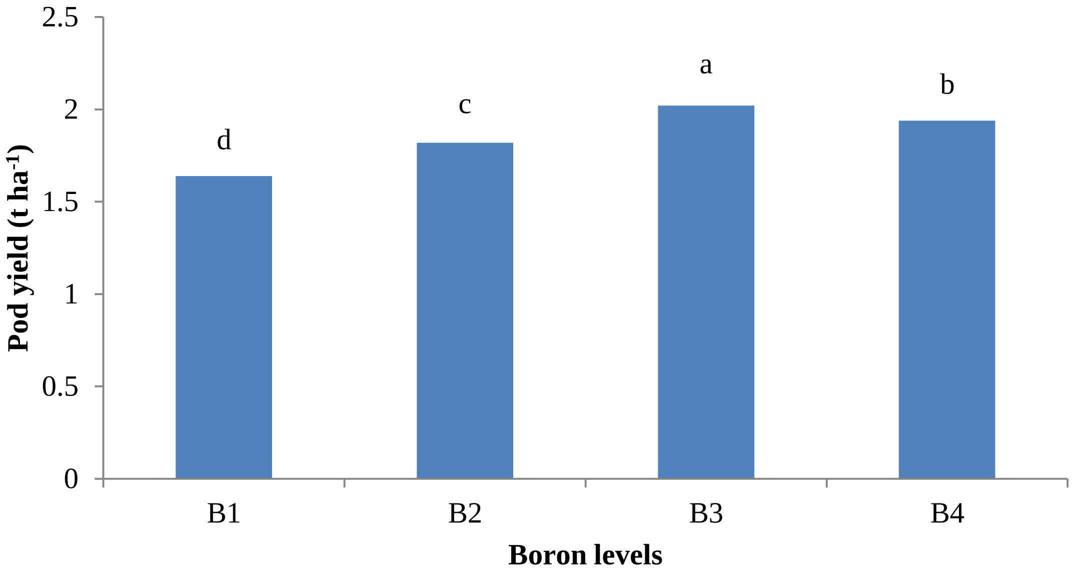
The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 15. Effect of nitrogen level on pod yield hectare^{-1} of groundnut ($LSD_{0.05}$= 0.06).

4.8.2 Effect of foliar boron level

Foliar boron levels exerted significant variation on pod yield (t ha^{-1}) of groundnut under this experiment (Figure 16). From the experiment result showed that the maximum pod yield of groundnut was obtained from B_3 (2.02 t ha^{-1}) treatment. On the other hand, the minimum pod yield of groundnut was obtained from B_1 (1.64 t ha^{-1}) treatment. The finding of the experiment was coincided with the findings of Mekdad (2019) who reported that among the three foliar spray with boron levels (B_0: tap water, B_1: 100 ppm and B_2: 150 ppm) on peanut the experimental results indicated that yield components, yield and its quality of peanut were positively ($P \leq 0.01$) affected by foliar boron application (B_2). Correlation analysis appeared appearance of highly significant with r values between oil and pod yields. Quamruzzaman *et al.* (2016) revealed that pod yield and germination were markedly increased with the application of boron. Kabir *et al.* (2013) also reported that the fertilizer level for P, Ca and B should be 50 kg ha^{-1}, 110 kg ha^{-1} and 2.5 kg ha^{-1}, respectively for obtaining the highest yield of groundnut under this particular soil. Singh *et al*. (2008) reported that foliar application (0.1% aqueous solution) of borosol, chemiebor and solubor showed similar response in increasing the pod yield by 7-39, 6-32, and 6-35%, respectively.



The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 16. Effect of foliar boron level on pod yield hectare^{-1} of groundnut ($LSD_{0.05}$= 0.06).

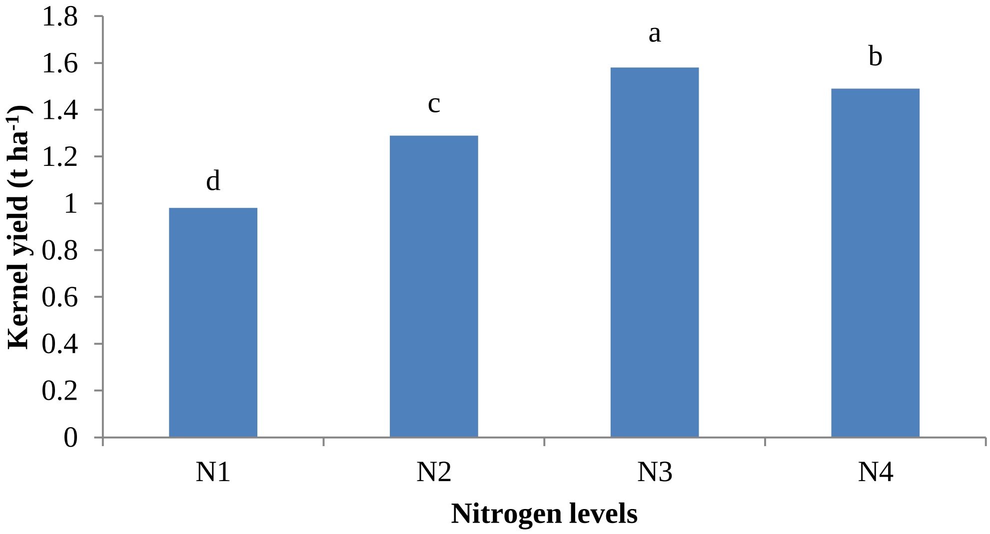
4.8.3 Combined effect of nitrogen and foliar boron level

Combined effect of nitrogen and foliar boron levels showed significant difference on pod yield of groundnut under the present study (Table 5 Appendix IX). Result from the experiment revealed that the maximum pod yield of groundnut (2.37 t ha^{-1}) was obtained from N_3B_3 treatment combination which was statistically as par with N_3B_4 (2.29 t ha^{-1}) treatment combination. On the other hand, the minimum pod yield of groundnut (1.49 t ha^{-1}) was obtained from N_1B_1 treatment combination which were statistically similar with N_1B_2 (1.55 t ha^{-1}) and N_1B_4 (1.58 t ha^{-1}) treatment combinations.

4.9 Kernel yield

4.9.1 Effect of nitrogen level

Significant variation on kernel yield (t ha^{-1}) of groundnut was observed due to effect of different nitrogen levels (Figure 17). From the experiment result revealed that the maximum kernel yield (1.58 t ha^{-1}) was obtained from N_3 treatment while the minimum kernel yield (0.98 t ha^{-1}) was obtained from N_1 treatment. The result of the experiment was also in coincided by Mondal *et al.* (2020) who reported that fertilizing with 100% of the recommended dose of nitrogen combined with rhizobium inoculant and polythene mulch significantly enhanced peanut plant growth, yield and yield-attributing traits, while resulting in the maximum fertilizer (i.e., nitrogen, phosphorus and potassium) uptake by different plant parts. Hasan *et al.* (2019) revealed that vegetative growth and yield of the plant was better at $N_{30}P_{60}$ kg ha^{-1} than the all other treatments. Tekulu *et al.* (2020) reported that average seed yield increased by 85.4% for a combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} fertilizers compared to the control plots. Plots fertilized with the highest combined rates of N and P have attained lower grain yield compared to the combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}.



The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

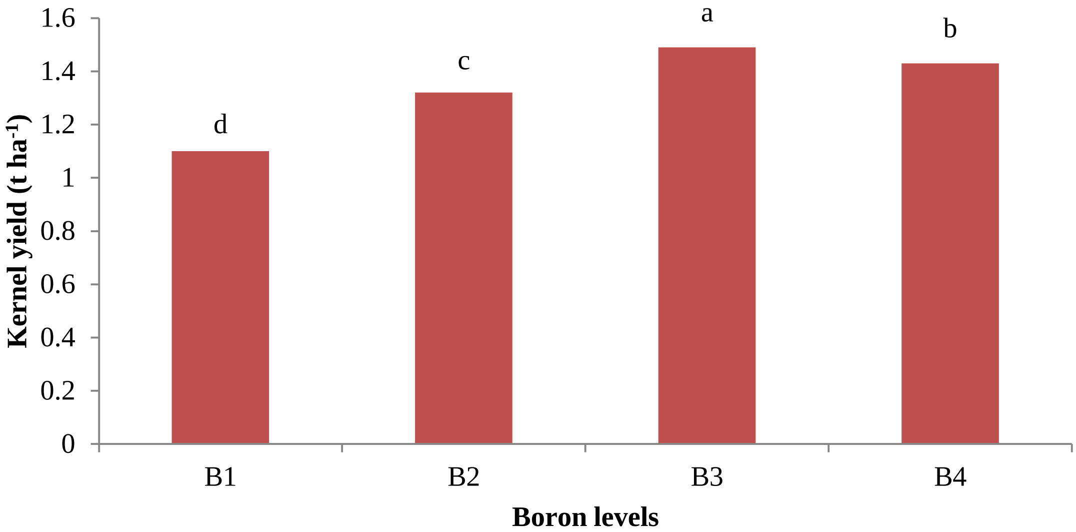
N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 17. Effect of nitrogen level on kernel yield hectare^{-1} of groundnut ($LSD_{0.05}$= 0.05).

4.9.2 Effect of foliar boron level

Foliar boron levels exerted significant variation on kernel yield (t ha^{-1}) of groundnut under this experiment (Figure 18). From the experiment result showed that the maximum kernel yield of groundnut was obtained from B_3 (1.49 t ha^{-1}) treatment. On the other hand, the minimum kernel yield of groundnut was obtained from B_1 (1.10 t ha^{-1}) treatment. The finding of the experiment was coincided with the findings of

Mekdad (2019) who reported that among the three foliar spray with boron levels (B_0: tap water, B_1: 100 ppm and B_2: 150 ppm) on peanut the experimental results indicated that yield components, yield and its quality of peanut were positively ($P \leq 0.01$) affected by foliar boron application (B_2). Kabir *et al.* (2013) also reported that the fertilizer level for P, Ca and B should be 50 kg ha^{-1}, 110 kg ha^{-1} and 2.5 kg ha^{-1}, respectively for obtaining the highest yield of groundnut under this particular soil.



The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 18. Effect of foliar boron level on kernel yield hectare^{-1} of groundnut ($LSD_{0.05}$= 0.04).

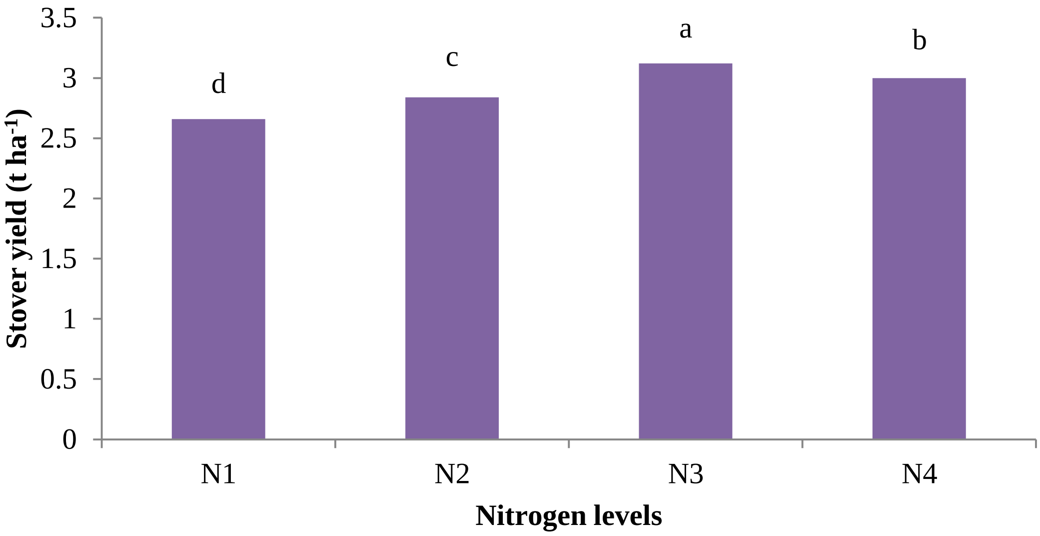
4.9.3 Combined effect of nitrogen and foliar boron level

Combined effect of nitrogen and foliar boron levels showed significant difference on kernel yield of groundnut under the present study (Table 5 Appendix IX). Result from the experiment revealed that the maximum kernel yield of groundnut (1.81 t ha^{-1}) was obtained from N_3B_3 treatment combination which was statistically as par with N_3B_4 (1.74 t ha^{-1}) treatment combination. On the other hand, the minimum kernel yield of groundnut (0.92 t ha^{-1}) was obtained from N_1B_1 treatment combination which was statistically similar with N_1B_2 (0.97 t ha^{-1}) treatment combination.

4.10 Stover yield

4.10.1 Effect of nitrogen level

Significant variation was revealed on stover yield of groundnut due to the effect of different nitrogen levels (Figure 19). From the experiment result revealed that the maximum stover yield (3.12 t ha^{-1}) was obtained from N_3 treatment while the minimum stover yield (2.66 t ha^{-1}) was obtained from N_1 treatment. Similar trends also observed by El-Habbasha *et al.* (2013) who reported that increasing N levels from 30 to 40 kg N fed^{-1} significantly increased number of pods plant^{-1}, weight of pods plant^{-1}, weight of seeds plant^{-1}, 100-seed weight, pod yield fed^{-1}, seed yield fed^{-1} and straw yield fed^{-1}.



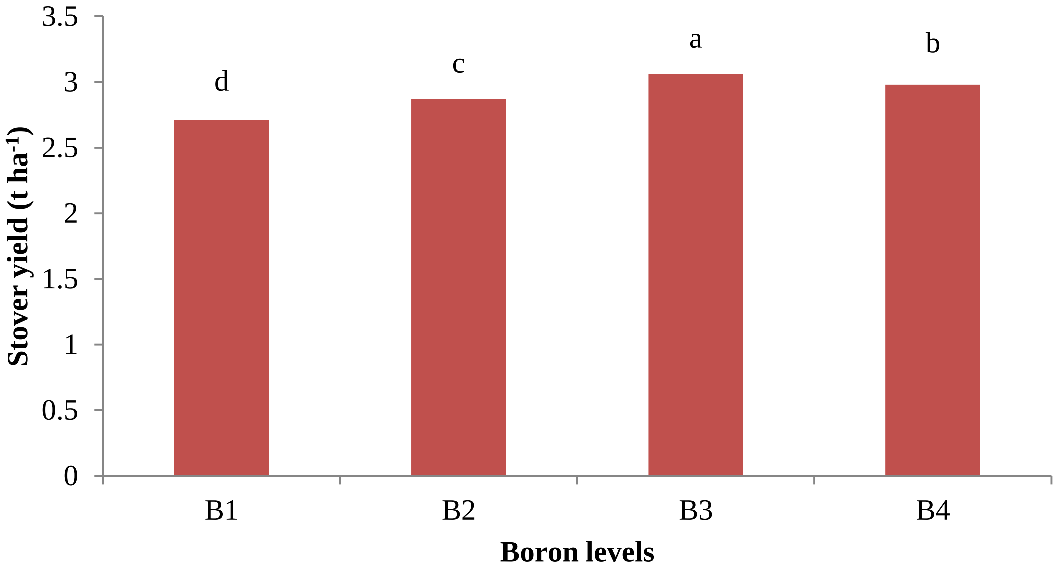
The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 19. Effect of nitrogen level on stover yield hectare^{-1} of groundnut ($LSD_{0.05}$= 0.04).

4.10.2 Effect of foliar boron level

Significant variation was observed on stover yield (t ha^{-1}) of groundnut due to the foliar boron levels under this experiment (Figure 20). From the experiment result showed that the maximum stover yield of groundnut (3.06 t ha^{-1}) was obtained from B_3 treatment. On the other hand, the minimum stover yield of groundnut was obtained from B_1 (2.71 t ha^{-1}) treatment. The finding of the experiment was coincided with the findings of Kabir *et al.* (2013) who reported that fertilizer doses of B 2.5 kg ha^{-1} increases pod yield, biological yield, straw yield and harvest index.



The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 20. Effect of foliar boron level on stover yield $hectare^{-1}$ of groundnut ($LSD_{0.05}$= 0.06).

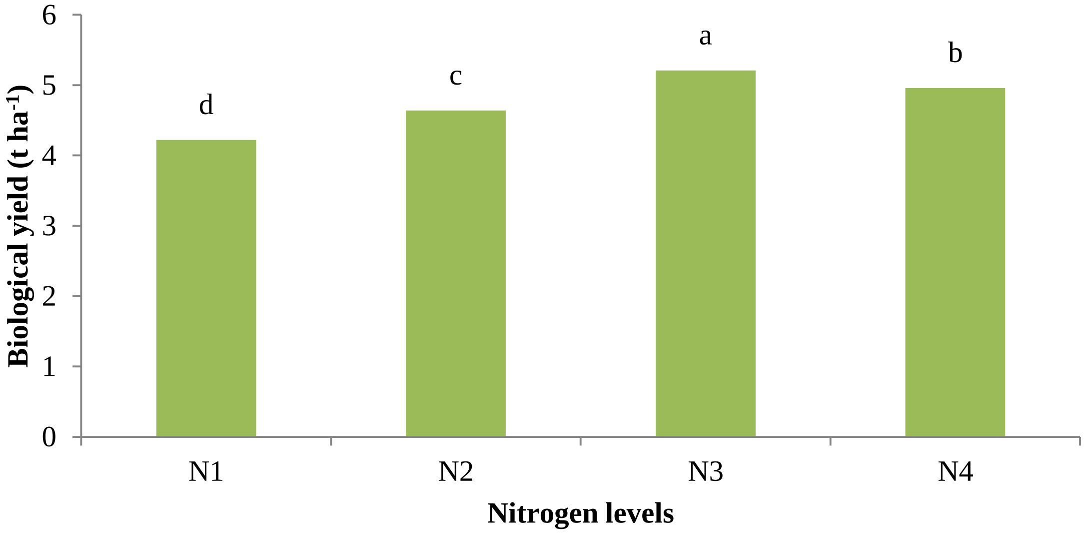
4.10.3 Combined effect of nitrogen and foliar boron level

Combined effect of nitrogen and foliar boron levels showed significant difference on stover yield of groundnut under the present study (Table 5 and Appendix IX). Result from the experiment indicated that the maximum stover yield (3.38 t ha^{-1}) was obtained from N_3B_3 treatment combination which was statistically as par with N_3B_4 (3.32 t ha^{-1}) treatment combination. On the other hand, the minimum stover yield (2.63 t ha^{-1}) was obtained from N_1B_1 treatment combination which was statistically similar with N_1B_2, N_1B_3 N_1B_4, N_2B_1 and N_4B_1 treatment combinations.

4.11 Biological yield

4.11.1 Effect of nitrogen level

Groundnut exerted significant influence on biological yield due to effect of different nitrogen levels (Figure 21). From the experiment result revealed that the maximum biological yield (5.21 t ha^{-1}) was obtained from N_3 treatment. On the other hand, the minimum biological yield (4.22 t ha^{-1}) was achieved from N_1 treatment. The result of the experiment was in coincided with the findings of Bharathi *et al.* (2021) who reported that nitrogen fertilizer along with Rhizobium and PSB increase the pod yield, biological yield and harvest index of groundnut. Mondal *et al.* (2020) reported that fertilizing with 100% of the recommended dose of nitrogen combined with rhizobium inoculant and polythene mulch significantly enhanced peanut plant growth, yield and yield-attributing traits, while resulting in the maximum fertilizer (i.e., nitrogen, phosphorus and potassium) uptake by different plant parts.



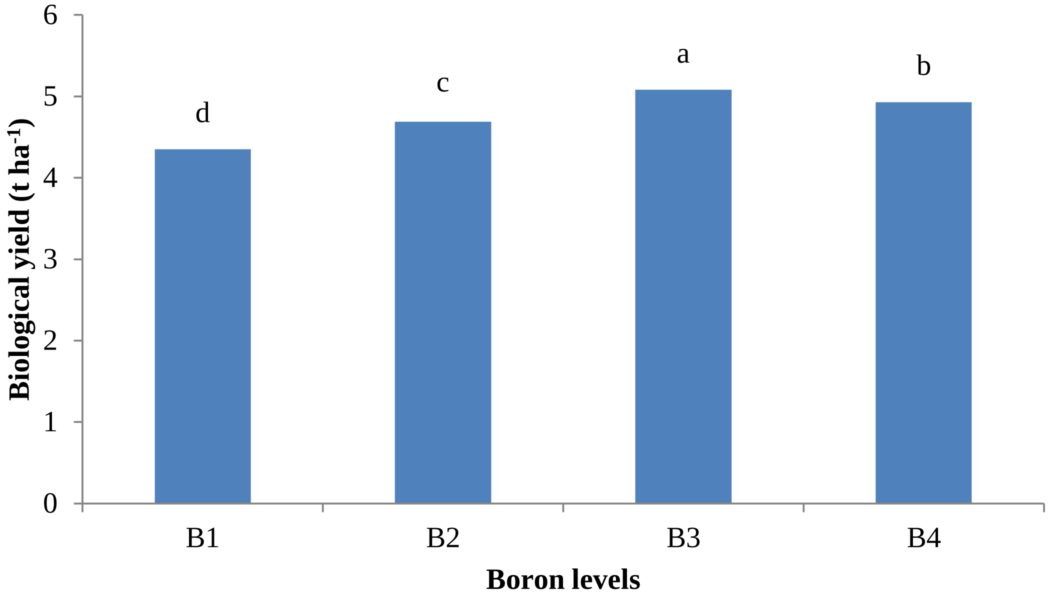
The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 21. Effect of nitrogen level on biological yield hectare^{-1} of groundnut ($LSD_{0.05}$= 0.14).

4.11.2 Effect of foliar boron level

Significant effect on biological yield was observed due to different foliar boron levels under the present study (Figure 22). From the experiment result showed that the maximum biological yield of groundnut was observed in B_3 (5.08 t ha^{-1}) treatment. On the other hand, the minimum biological yield of groundnut was obtained from B_1 (4.35 t ha^{-1}) treatment. Similar result also found by Kabir *et al.* (2013) who reported that the combined dose of P_2, Ca_1 and B_2 produced the highest values for almost all the growth, yield and yield contributing parameters. Thus, it can be concluded that the fertilizer level for P, Ca and B should be 50 kg ha^{-1}, 110 kg ha^{-1} and 2.5 kg ha^{-1}, respectively for obtaining the highest yield of groundnut under this particular soil.



The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 22. Effect of foliar boron level on biological yield hectare^{-1} of groundnut ($LSD_{0.05}$= 0.14).

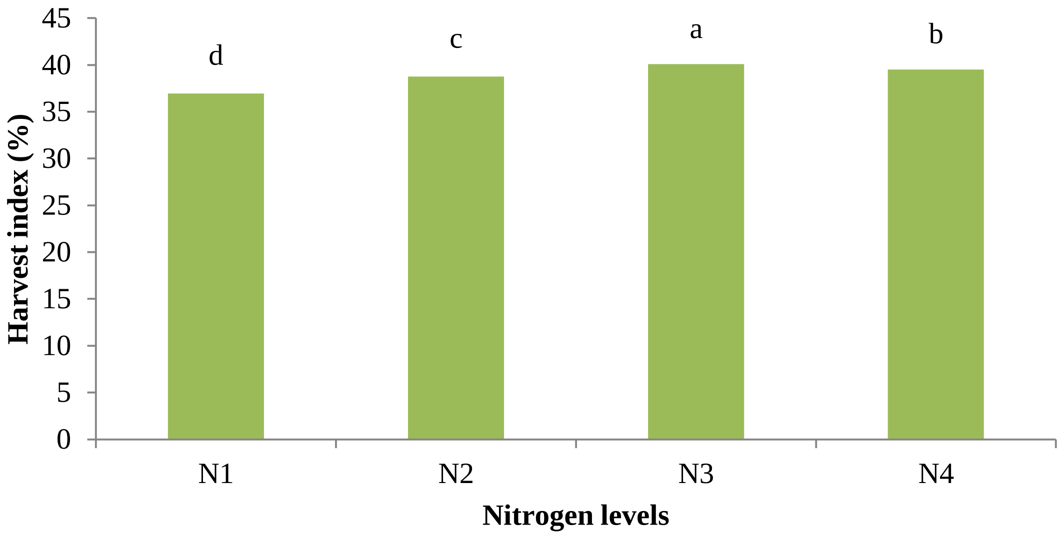
4.11.3 Combined effect of nitrogen and foliar boron level

Combined effect of nitrogen and foliar boron levels showed significant difference on biological yield (t ha^{-1}) of groundnut under the study (Table 5 and Appendix IX). Result revealed that the maximum biological yield of groundnut (5.75 t ha^{-1}) was achieved from N_3B_3 treatment combination which was statistically similar to N_3B_4 (5.61 t ha^{-1}). On the other hand, the minimum biological yield (4.12 t ha^{-1}) was observed in N_1B_1 treatment combination which was statistically similar with N_1B_2, N_1B_3 N_1B_4 and N_2B_1 treatment combinations.

4.12 Harvest index

4.12.1 Effect of nitrogen level

Harvest index (%) of groundnut showed significant influences due to effect of different nitrogen levels (Figure 23). Result from the experiment noted that the maximum harvest index (40.09%) was obtained from N_3 treatment. On the other hand, the minimum harvest index (36.95%) was observed in N_1 treatment. Similar result was also observed by Bharathi *et al.* (2021) who reported that the maximum results showed in growth and yield attributing characters *viz.*, plant length (102.19 cm), dry weight (45.78 g), no. of nodules plant^{-1} (157.78), no. of pods plant^{-1} (28.80), no. of kernels pod^{-1} (2.07), seed index (47.06), seed yield (2655.58 kg ha^{-1}), haulm yield (3587.20 kg ha^{-1}), harvest index (42.31%) were recorded significantly higher in T_9 (20 kg N ha^{-1} + Rhizobium + PSB). Tekulu *et al.* (2020) reported that the highest N harvest index was obtained for control treatments and for plots treated with combined application of 15 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}.



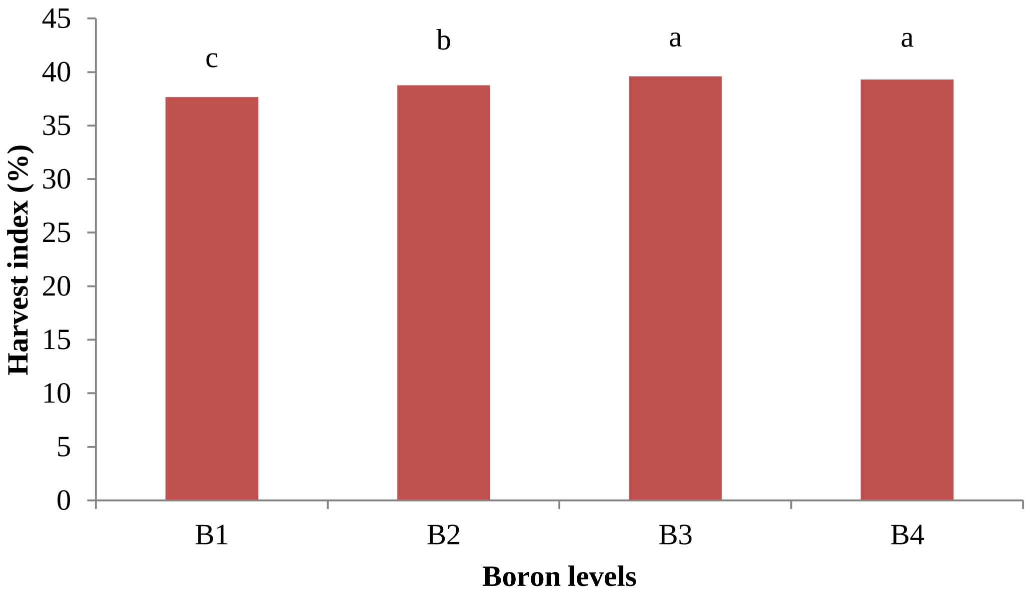
The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

N_1= 0 kg urea ha^{-1}, N_2= 25 kg urea ha^{-1}, N_3= 30 kg urea ha^{-1} and N_4= 35 kg urea ha^{-1}

Figure 23. Effect of nitrogen level on harvest index of groundnut ($LSD_{0.05}$= 0.31).

4.12.2 Effect of foliar boron level

Significant effect on harvest index (%) of groundnut was observed due to foliar boron levels under the study (Figure 24). From the experiment result showed that the maximum harvest index of groundnut was obtained from B_3 (39.61%) treatment which was statistically similar with B_4 (39.30%) treatment. On the other hand, the minimum harvest index of groundnut was obtained from B_1 (37.67%) treatment. Similar result was also found by Kabir *et al.* (2013) who reported that the combined dose of P_2, Ca_1 and B_2 produced the highest values for almost all the growth, yield (pod yield, straw yield, biological yield and harvest index) and yield contributing parameters. Thus, it can be concluded that the fertilizer level for P, Ca and B should be 50 kg ha^{-1}, 110 kg ha^{-1} and 2.5 kg ha^{-1}, respectively for obtaining the highest yield of groundnut under this particular soil.



The similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

B_1= control, B_2= 0.1% boric acid, B_3= 0.2% boric acid and B_4= 0.3% boric acid

Figure 24. Effect of foliar boron levels on harvest index of groundnut ($LSD_{0.05}$= 0.34).

4.12.3 Combined effect of nitrogen and foliar boron level

Different nitrogen levels along with different foliar boron application marked significant difference on harvest index (%) of groundnut (Table 5 and Appendix IX). Result revealed that the maximum harvest index of groundnut (41.12%) was obtained from N_3B_3 treatment combination which was statistically similar with N_3B_4 (40.81%) treatment combination. On the other hand, the minimum harvest index of groundnut (36.16%) was obtained from N_1B_1 treatment combination which was statistically dissimilar with the other treatment combination under the study.

Table 5. Combined effect of nitrogen and foliar boron levels on pod yield, kernel yield, stover yield, biological yield and harvest index of groundnut

Treatment Combinations	Pod yield (t ha^{-1})	Kernel yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
N_1B_1	1.49 l	0.92 k	2.63 h	4.12 k	36.16 k
N_1B_2	1.55 kl	0.97 jk	2.65 gh	4.20 jk	36.90 j
N_1B_3	1.62 ijk	1.04 ij	2.69 gh	4.31 ijk	37.58 hi
N_1B_4	1.58 jkl	1.00 j	2.67 gh	4.25 ijk	37.17 ij
N_2B_1	1.65 ijk	1.11 hi	2.71 fgh	4.36 h-k	37.84 h
N_2B_2	1.79 fgh	1.27 f	2.81 ef	4.60 fgh	38.91 ef
N_2B_3	1.91 def	1.41 e	2.96 cd	4.87 def	39.22 de
N_2B_4	1.85 efg	1.35 e	2.88 de	4.73 efg	39.11 ef
N_3B_1	1.73 ghi	1.21 fg	2.76 fg	4.49 ghi	38.53 fg
N_3B_2	2.00 cd	1.54 d	3.02 c	5.02 d	39.84 cd
N_3B_3	2.37 a	1.81 a	3.38 a	5.75 a	41.12 a
N_3B_4	2.29 ab	1.74 ab	3.32 ab	5.61 ab	40.81 ab
N_4B_1	1.69 hij	1.16 gh	2.74 fgh	4.43 hij	38.14 gh
N_4B_2	1.94 cde	1.49 d	2.98 cd	4.92 de	39.43 de
N_4B_3	2.18 b	1.69 bc	3.21 b	5.39 bc	40.44 bc
N_4B_4	2.05 c	1.62 c	3.06 c	5.11 cd	40.11 c
$LSD_{(0.05)}$	**0.12**	**0.07**	**0.12**	**0.28**	**0.67**
CV(%)	**4.04**	**3.25**	**2.60**	**3.50**	**1.04**

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

Notes:

N_1= 0 kg urea ha^{-1}
N_2= 25 kg urea ha^{-1}
N_3= 30 kg urea ha^{-1}
N_4= 35 kg urea ha^{-1}

B_1= control (no boric acid)
B_2= 0.1% boric acid as foliar application
B_3= 0.2% boric acid as foliar application
B_4= 0.3% boric acid as foliar application

CHAPTER V

SUMMARY AND CONCLUSION

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SUMMARY AND CONCLUSION

The experiment was carried out at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during April 2021 to August 2021 to study the effect of different levels of nitrogen and foliar boron on growth and yield of groundnut. The experiment consisted of two factors. Factor A: Nitrogen (4 levels) *viz.*, N_1: 0 kg urea ha^{-1} (control), N_2: 25 kg urea ha^{-1}, N_3: 30 kg urea ha^{-1} and N_4: 35 kg urea ha^{-1}, and factor B: Foliar boron (4 levels) *viz.*, B_1: Control, B_2: 0.1% boric acid (5 kg boric acid ha^{-1}), B_3: 0.2% boric acid (10 kg boric acid ha^{-1}) and B_4: 0.3% boric acid (15 kg boric acid ha^{-1}). The experiment was laid out in Split-plot design with three replications. There were 16 treatment combinations. The total numbers of unit plots were 48. The size of unit plot was 4.00 m^2 (2.00 m × 2.00 m). Nitrogen was placed along the main plot and foliar application of boron was placed along the sub plot. The groundnut seeds were sown in lines maintaining a line to line distance of 30 cm and plant to plant distance of 15 cm having 2 seeds hole^{-1}. The data on different growth, yield contributing parameters and yield of groundnut were recorded and statistically analyzed.

Different growth and yield contributing parameters were significantly influenced by different nitrogen levels. Results revealed that the longest plant (15.34, 22.93, 32.34, 42.29 and 46.22 cm at 25, 50, 75, 100 DAS and at harvest, respectively), number of leaves plant^{-1} (14.92, 30.00, 38.00, 42.83 and 45.67 at 25, 50, 75, 100 DAS and at harvest, respectively), number of branches plant^{-1} (3.42, 6.08, 7.42, 8.00 and 8.58 at 25, 50, 75, 100 DAS and at harvest, respectively), number of pods plant^{-1} (22.61), pod length (2.61 cm), 100 seeds weight (46.14 g), pod yield plot^{-1} (0.84 kg), pod yield (2.09 t ha^{-1}), kernel yield (1.58 t ha^{-1}), stover yield (3.12 t ha^{-1}), biological yield (5.21 t ha^{-1}) and harvest index (40.09%) were obtained from N_3 treatment. On the other hand, the shortest plant (13.00, 18.19, 25.09, 31.52 and 35.87 cm at 25, 50, 75, 100 DAS and at harvest, respectively), number of leaves plant^{-1} (11.50, 21.67, 28.08, 32.00 and 33.83 at 25, 50, 75, 100 DAS and at harvest, respectively), number of branches plant^{-1} (2.25, 4.75, 6.00, 6.41 and 6.75 at 25, 50, 75, 100 DAS and at harvest, respectively), number of pods plant^{-1} (17.62), pod length (2.32 cm), 100 seeds weight of groundnut (37.52 g), pod yield plot^{-1} (0.62 kg), pod yield (1.56 t ha^{-1}), kernel yield (0.98 t ha^{-1}), stover yield (2.66 t ha^{-1}), biological yield (4.22 t ha^{-1}) and harvest index (36.95%) were observed in N_1 treatment.

Growth, yield and yield contributing parameters were significantly influenced by different foliar boron levels. In case of foliar boron level, results revealed that the longest plant (15.04, 22.28, 31.46, 40.94 and 44.69 cm at 25, 50, 75, 100 DAS and at harvest, respectively), number of leaves $plant^{-1}$ (14.42, 28.58, 36.67, 41.50 and 43.67 at 25, 50, 75, 100 DAS and at harvest, respectively), number of branches $plant^{-1}$ (3.25, 6.00, 7.33, 7.84 and 8.25 at 25, 50, 75, 100 DAS and at harvest, respectively), number of pods $plant^{-1}$ (21.99), pod length (2.57 cm), 100 seeds weight of groundnut (45.00 g), pod yield $plot^{-1}$ (0.81 kg), pod yield (2.02 t ha^{-1}), kernel yield (1.49 t ha^{-1}), stover yield (3.06 t ha^{-1}), biological yield (5.08 t ha^{-1}) and harvest index (39.61%) were obtained from B_3 treatment. On the other hand, the shortest plant (13.40, 19.56, 26.12, 34.03 and 38.00 cm at 25, 50, 75, 100 DAS and at harvest, respectively), number of leaves $plant^{-1}$ (12.25, 23.83, 29.25, 33.67 and 36.17 at 25, 50, 75, 100 DAS and at harvest, respectively), number of branches $plant^{-1}$ (2.50, 5.08, 6.34, 6.67 and 7.17 at 25, 50, 75, 100 DAS and at harvest, respectively), number of pods $plant^{-1}$ (18.84), pod length (2.39 cm), 100 seeds weight of groundnut (39.36 g), pod yield $plot^{-1}$ (0.65 kg), pod yield (1.64 t ha^{-1}), kernel yield (1.10 t ha^{-1}), stover yield (2.71 t ha^{-1}), biological yield (4.35 t ha^{-1}) and harvest index (37.67%) were observed in B_1 treatment.

Combined effect of different levels of nitrogen and foliar boron showed significant influence on growth, yield contributing characters and yield of groundnut. Results revealed that the longest plant (16.92, 24.53, 35.25, 45.81 and 50.71 cm at 25, 50, 75, 100 DAS and at harvest, respectively), number of leaves $plant^{-1}$ (16.33, 33.33, 42.67, 47.00 and 50.33 at 25, 50, 75, 100 DAS and at harvest, respectively), number of branches $plant^{-1}$ (4.00, 6.67, 8.00, 8.67 and 9.00 at 25, 50, 75, 100 DAS and at harvest, respectively), number of pods $plant^{-1}$ (24.43), pod length (2.72 cm), 100 seeds weight of groundnut (50.12 g), pod yield $plot^{-1}$ (0.95 kg), pod yield (2.37 t ha^{-1}), kernel yield (1.81 t ha^{-1}), stover yield (3.38 t ha^{-1}), biological yield (5.75 t ha^{-1}) and harvest index (41.12%) were obtained from N_3B_3 treatment combinations. On the other hand, the shortest plant (12.68, 17.37, 23.68, 29.15 and 34.15 cm at 25, 50, 75, 100 DAS and at harvest, respectively), number of leaves $plant^{-1}$ (11.00, 20.00, 27.33, 30.67 and 32.33 at 25, 50, 75, 100 DAS and at harvest, respectively), number of branches $plant^{-1}$ (2.00, 4.33, 5.67, 6.00 and 6.33 at 25, 50, 75, 100 DAS and at harvest, respectively), number of pods plant^{-1} (16.81), pod length (2.28 cm), 100 seeds weight of groundnut (36.45 g), pod yield plot^{-1} (0.59 kg), pod yield (1.49 t ha^{-1}), kernel yield (0.92 t ha^{-1}), stover yield (2.63 t ha^{-1}), biological yield (4.12 t ha^{-1}) and harvest index (36.16%) were observed from N_1B_1 treatment combinations.

The results in this research indicated that the plants performed better in respect of pod yield (2.37 t ha^{-1}) and kernel yield (1.81 t ha^{-1}) in N_3B_3 treatment combination than others. Therefore, it can be concluded from the above study that the treatment combinations of N_3B_3 (groundnut growing on 30 kg urea ha^{-1} with foliar boron levels @0.2%) was found to be most suitable combination for the potential pod yield and kernel yield of groundnut.

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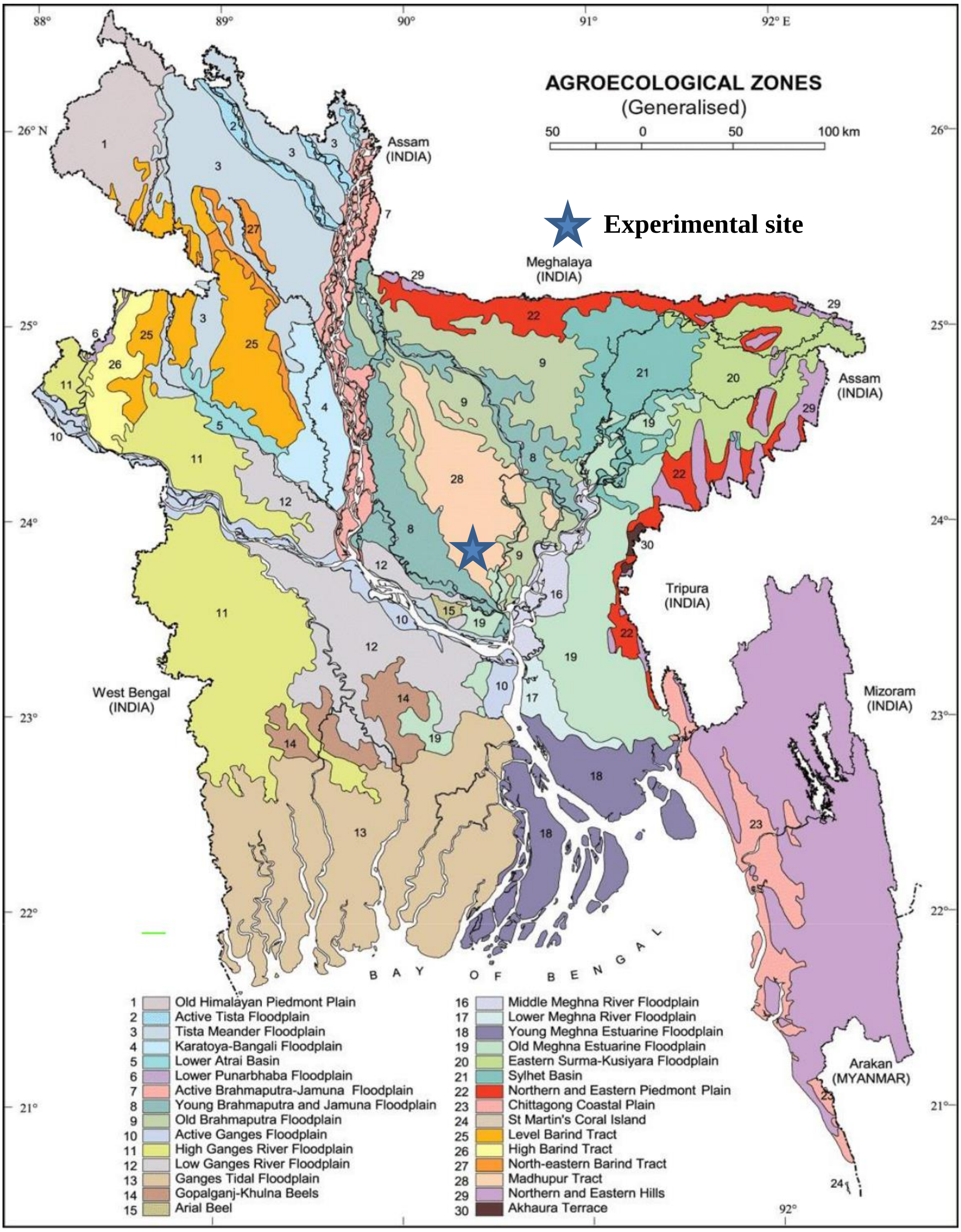
APPENDICES

APPENDICES

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



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

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University, 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
pH	6.2
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

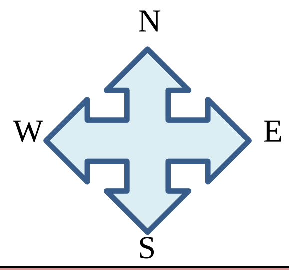
Source: Soil Resource Development Institute (SRDI)

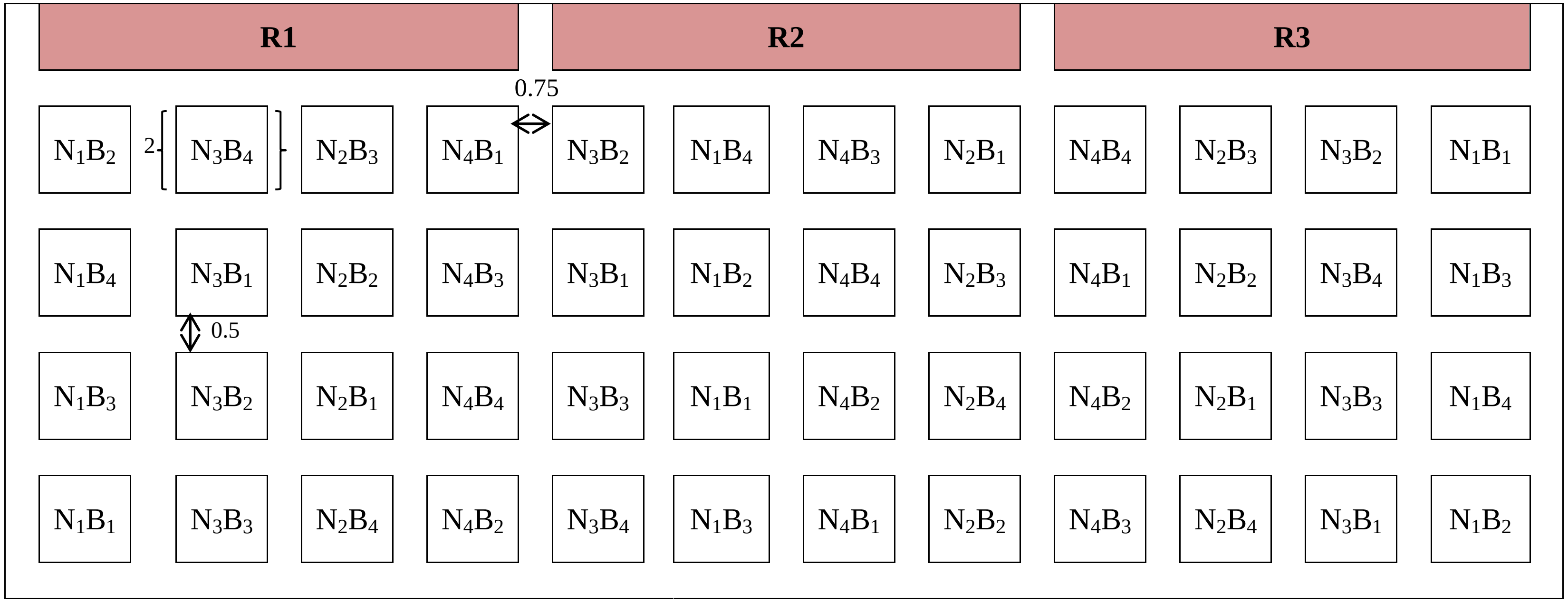
Appendix III. Monthly records of air temperature, relative humidity and total rainfall during the period from April 2021 to August 2021

Year	**Month**	**Air temperature (℃)**		**Relative humidity (%)**	**Total rainfall (mm)**
		Maximum	**Minimum**		
2021	April	36.6	21.4	65	86
	May	35.8	24.6	72	92
	June	32.4	25.7	80	86
	July	32.6	26.8	81	114
	August	32.2	26.5	80	106

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207

Appendix IV. Layout of the experimental plot





Length of plot: 2.00 m, **Width of plot:** 2.00 m

Replication to replication distance: 0.75 m

Plot to plot distance: 0.5 m,

Unit plot size: 2.00 m × 2.00 m (4.00 m^2)

Appendix V. Mean square values of plant length at different days after sowing of groundnut growing under the experiment

Sources of variation	Degrees of freedom	Mean square values of plant length at				
		25 DAS	50 DAS	75 DAS	100 DAS	Harvest
Replication	2	2.2726	9.1378	19.493	49.000	0.729
Factor A	3	12.3664**	51.9424**	125.976**	283.527**	247.855**
Error	6	0.1577	0.1287	0.155	1.000	1.298
Factor B	3	5.7893**	16.5630**	66.967**	108.932**	100.428**
A × B	9	0.7037*	0.6615*	4.045**	4.227**	6.842**
Error	24	0.2360	0.2761	0.355	1.000	1.778

* significant at 5% level of significance

** significant at 1% level of significance

Appendix VI. Mean square values of number of leaves plant^{-1} at different days after sowing of groundnut growing during experimentation

Sources of variation	Degrees of freedom	Mean square values of number of leaves plant^{-1} at				
		25 DAS	50 DAS	75 DAS	100 DAS	Harvest
Replication	2	13.3590	58.141	45.563	57.608	79.438
Factor A	3	26.9149**	162.425**	249.312**	277.192**	329.758**
Error	6	0.4594	0.307	0.144	0.758	0.394
Factor B	3	10.6310**	52.497**	125.693**	144.156**	131.680**
A × B	9	0.6651*	3.002**	16.646**	10.670**	10.254**
Error	24	0.2457	0.516	0.582	0.986	0.928

* significant at 5% level of significance

** significant at 1% level of significance

Appendix VII. Mean square values of number of branches plant^{-1} at different days after sowing of groundnut growing during experimentation

Sources of variation	Degrees of freedom	Mean square values of number of branches plant^{-1} at				
		25 DAS	50 DAS	75 DAS	100 DAS	Harvest
Replication	2	0.5513	0.5776	0.8372	1.0353	1.1395
Factor A	3	3.4316**	4.4620**	4.8018**	5.8479**	7.6616**
Error	6	0.0087	0.0071	0.0061	0.0743	0.0615
Factor B	3	1.3455**	1.9292**	2.0657**	3.0212**	2.9555**
A × B	9	0.1514**	0.0831**	0.0587**	0.1131*	0.1650**
Error	24	0.0059	0.0141	0.0169	0.0408	0.0424

* significant at 5% level of significance

** significant at 1% level of significance

Appendix VIII. Mean square values of number of pods plant^{-1}, length of pod, pod yield plot^{-1} and weight of 100 seeds of groundnut at harvest

Sources of variation	Degrees of freedom	Mean square values of			
		Number of pods plant^{-1}	Length of pod	Pod yield plot^{-1}	Weight of 100-seed
Replication	2	45.7333	0.00407	0.0256	121.000
Factor A	3	58.7720**	0.196821**	0.1062**	167.9200**
Error	6	0.2108	0.00161	0.0004	0.6670
Factor B	3	22.2212**	0.07787**	0.0511**	71.6810**
A × B	9	1.2558*	0.00444**	0.0055**	7.0170**
Error	24	0.5497	0.00146	0.0006	1.4170

* significant at 5% level of significance

** significant at 1% level of significance

Appendix IX. Mean square values of pod yield, kernel yield, stover yield, biological yield and harvest index of groundnut at harvest

Sources of variation	Degrees of freedom	Mean square values of				
		Pod yield	Kernel yield	Stover yield	Biological yield	Harvest index
Replication	2	0.00226	0.0256	0.00006	0.04951	0.4661
Factor A	3	0.64382**	0.8334**	0.47612**	2.22525**	22.5082**
Error	6	0.00336	0.0022	0.00229	0.02099	0.0990
Factor B	3	0.32932**	0.3493**	0.27862**	1.21340**	8.7550**
A × B	9	0.03415**	0.0306**	0.04002**	0.14758**	0.2998*
Error	24	0.00563	0.0019	0.00568	0.02772	0.1620

* significant at 5% level of significance

** significant at 1% level of significance