YIELD RESPONSE TO NITROGEN AND BORON APPLICATIONS IN SOYBEAN

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CERTIFICATE

This is to certify that the thesis entitled "YIELD RESPONSE TO NITROGEN AND BORON APPLICATIONS IN SOYBEAN" submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in AGRONOMY, embodies the result of a piece of bona-fide research work carried out by KAZI SALMAN KAZOL, REGISTRATION NO. 10-03805 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2016

Dhaka, Bangladesh

Prof. Dr. H.M.M. Tariq Hossain

Supervisor

Dedicated To

My Beloved Parents

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YIELD RESPONSE TO NITROGEN AND BORON APPLICATIONS IN SOYBEAN

ABSTRACT

An experiment was carried out at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2015 to December 2015 to study the yield response to nitrogen and boron applications in soybean. Four nitrogen (N) levels (0, 15, 30 and 45 kg/ha) and four boron (B) levels (0, 0.825, 1.65 and 2.5 kg/ha) were considered as factors for the experiment. There were 16 treatment combinations. The experiment was laid out in a split plot design with three replications. Data were collected on different growth, yield and yield contributing parameters of soybean. Results revealed that 30 kg N/ha and 1.65 kg B/ha as an individual effect and also in combinations, gave the best yield responses in soybean. Individually 30 kg N/ha gave the highest pod length (3.56 cm), number of seed/pod (2.73), 1000 seed weight (109.58 g), seed yield (1249.17 kg/ha), stover yield (1661.17 kg/ha) and harvest index (45.43%) and 1.65 kg B/ha gave the highest pod length (3.46 cm), number of seed/pod (2.67), 1000 seed weight (100.25 g), seed yield (1116.67 kg/ha), stover yield (1508.25 kg/ha) and harvest index (42.70%). Combination of 30 kg N/ha with 1.65 kg B/ha gave the highest number of pods/plant (48.13), pod length (3.68 cm), number of seeds/pod (2.87), 1000 seed weight (120.10 g), seed yield (1453.33 kg/ha), stover yield (1768 kg/ha) and the highest harvest index (45.23%) where control treatment showed lowest performance.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

Soybean (*Glycine max* L.) is one of the most important oil seed legume crops of the world. It belongs to the family Leguminosae, sub-family Papilionaceae. It is considered as an important economic food legume cultivated worldwide because of its higher nutritional and industrial values. Soybean is a good source of protein, unsaturated fatty acids, minerals like Ca and P including vitamin A, vitamin B, vitamin C and vitamin D which can meet-up different nutritional need of human and animals. Soybean seed is referred to the protein hope of the future because of its high nutritive value containing about 42-45% protein (Rahman, 2001). Different kinds of soya products like soyadal, soyamilk, soyacurd and soyaflour are becoming familiar foods to the people in Bangladesh. Soybean plants can be used as fodder and forage. Its forage and oilcake are excellent nutritive foods for livestock and poultry.

It builds up the soil fertility by fixing a large amount of atmospheric nitrogen through the root nodules and also through leaf fall on the ground at maturity. The nodulated soybean plants can fix 94 kg nitrogen in a hectare in one season (Satter, 2001). The plants are classified as oil seed rather than pulse by Food and Agriculture Organization (FAO, 2003). Although soybeans are native to Southeast Asia, 55% of production is in the United States. Other leading producers of soybeans are Argentina, Brazil, China and India. It contains 20% edible oil, 35% carbohydrate, 40% protein, 10 % moisture, 4 % mineral and 5 % ash. In view of the nutritional value of soybean, it is perhaps the best of all other pulses (Kim, 1995).

Therefore, this is one of the reasons that Asian Vegetable Research and Development Centre (AVRDC) selected this crop for intensive research. In developed countries soybean is used either in the split form or to make curry spiced with chilies, is consumed with rice. It is also used in making sweetmeats after grinding into flour. Soybean contains some anti-nutritional factors such as trypsin inhibitors, haemoglutamins, saponins, flatulents, raffinose etc.

Soybean was introduced in Bangladesh many years ago but its cultivation as well as yield of soybean is not satisfactory compared to developed countries. Soybean was introduced in Bangladesh around 1942, but its cultivation did not expand satisfactorily. Its organized cultivation started in the late seventies. In recent years, Mennonite Central Committee (MCC), Crop Diversification Program (CDP), Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), Bangladesh Council of Scientific and Industrial Research (BCSIR), Bangladesh Institute of Nuclear Agriculture (BINA) and other NGO's are trying to expand its cultivation. The statistical information regarding soybean acreage and production in Bangladesh is 41,388 hectare and 65,158 metric ton. The annual production of soybean in Bangladesh is negligible compared to its huge demand. Despite suitable climatic and edaphic conditions the yield of soybean in the world is about 3.0 t ha^{-1} while that in Bangladesh is only 1.4 t ha^{-1} (BBS, 2012).

The practice of intensive cropping with modern varieties causes a marked depletion of inherent nutrient reserve in soils of Bangladesh. Consequently, in addition to N, P and K deficiencies, some other nutrients such as B, Zn and Mo deficiencies are being observed in many parts of the country. As such different micronutrient fertilizers are required in different amounts for producing crops. Supplying N to the soybean plant during the time of peak seed demand, may possibly prevent premature senescence, and boost seed yields.

Boron is reported to influence seed and nodule formation of legumes and oil synthesis (Malewar *et al.,* 2001). Therefore, the experiment was undertaken with the objectives below:

1. To determine the effect of N on soybean seed yield,
2. To determine the effect of B on soybean seed yield and
3. To determine the interactive effect of both the nutrients on growth and seed yield of soybean.

CHAPTER II

REVIEW OF LITERATURE

Soybean is considered to be a very important leguminous oil seed crop in the world. Much attention has been received by a large number of researchers on various aspects of soybean production, processing and utilization. Since review of literature forms a bridge between the past and present research works related to problem, which helps an investigator to draw a satisfactory conclusion, an effort was thus made to present some research works related to the present study in this section.

2.1 Effect of nitrogen applications for response to reproductive stage of soybean

Wingeyer *et al*. (2014) conducted an experiment on nitrogen fertilization and supplemental irrigation during soybean (*Glycine max* (L.) Merr.) reproductive stages have gained interest to increase soybean yields. We assessed the effect of N fertilizer (0 and 60 kg N ha^{-1}) applied at the beginning of bloom (R1) and full pod (R4) combined with rain-fed (NIrr) and irrigated (Irr) conditions during reproductive stages on crop growth and yield in the southeast of Buenos Aires Province, Argentina. At the beginning of seed filling (R5), aboveground biomass and plant N accumulation were unaffected by the addition of N fertilizer. Average soybean yields were 4.24 and 3.39 Mg ha^{-1} for Irr and NIrr treatments, respectively, and were not affected by N fertilization. Our results suggest addition of N fertilizer during soybean reproductive stages was not an effective management practice to increase yields of irrigated or rain-fed soybean plants.

Wilson *et al*. (2014) conducted a field study with soybean cultivars released from 1923 to 2008 in maturity group (MG) II and MG III was conducted in multiple environments with a non-limiting supply of fertilizer N to examine the main effects and interactions of N supply and release year on seed yield and seed quality. Supplemental N totaled 560 kg N ha^{-1} with 40% applied at planting and 60% applied at V5. Seed yield increased with release year in MG

II (17.2 kg ha^{-1} yr^{-1}). Application of N to MG II cultivars increased seed protein by 10 to 19.5 g kg^{-1} across all release years, but seed yield and seed oil was not affected. Seed yield gains of MG III cultivars fertilized with N was 27.4 kg ha^{-1} yr^{-1}, which was 20% better than unfertilized (22.8 kg ha^{-1} yr^{-1}). Application of N to MG III cultivars increased seed mass (11%) across release years with no changes in seed protein and oil. The limited supply of N increased seed protein across all release years in MG II cultivars, and the N supply from the soil and biological N fixation was insufficient to maximize seed yield in modern, MG III cultivars in the tested environments

Ahmed and Ali (2013) reported that legume crops are not only used as human diet but also enriched soil fertility through biological nitrogen fixation. Micronutrients are imperative module of soil fertility and they manipulate crop productivity. An experiment was conducted to evaluate their effect on soybean productivity. Treatments comprised of control, *Rhizobium* inoculation alone and along with two levels (2 and 4 kg ha^{-1}) of micronutrients. The performance of *Rhizobium* alone was superior over uninoculated control in all parameters. The results showed that increasing rate of micronutrients along with *Rhizobium* inoculation significantly increased mungbean productivity. *Rhizobium* inoculation along with Mo @ 2 kg ha^{-1} increased plant height, root length, 100-seed weight, nodule number $plant^{-1}$ and nitrogen content in seed by 59, 67, 72, 162 and 8%, respectively, over uninoculated control whereas highest number of pods $plant^{-1}$ and seed yield was obtained along with Zn @ 4 kg ha^{-1}. Number of nodules $plant^{-1}$ was positively correlated with %N in seed and seed yield. It was concluded that micronutrients application along with *Rhizobium* inoculation enhanced mungbean productivity.

Umeh *et al.* (2011) was carried a research to determine the effect of different types and rates of nitrogen (N) fertilizer on growth and yield response of soybean varieties under Umudike ecological conditions, Abia State, Nigeria.

Pot experiment was conducted in 2008 outside the green house of Michael Okpara University of Agriculture, Umudike. The response of two varieties of soybean (Tropical *Glycine Max*-TGX 1440 and TGX 1740) to three different nitrogen fertilizer types (NPK 15 15 15, NPK 20 10 10 and Urea) at four different rates (0, 30, 60 and 90kgN/ha) were evaluated. It was observed that plant height, number of branches, number of seed, dry matter weight and dry pod weight differed significantly at ($P < 0.05$) in both varieties using different fertilizer types and at different fertilizer rates. TGX 1440 using NPK 15 15 15 at the rate of 60kg N ha^{-1} gave the highest plant height than using NPK 20 10 10 and Urea and at other rates (0,30 and 90kg N ha^{-1}) in the same variety and in TGX 1740. Also increased application of nitrogen fertilizer rate increased plant height, dry matter weight, dry pod weight and pod length as in TGX 1440 using NPK 15 15 15 and NPK 20 10 10 but decreased pod number per plant.

Boroomandan *et al*. (2009) conducted an experiment on soybean (var. Williams) as a split-plot based on randomized complete blocks design with three replications. Nitrogen starter fertilizer treatments were arranged in three rates (0, 40, 80 kg ha^{-1} as main plots and plant density as sub plots arranged with three levels (15, 30, 45 plant m^{-2}. Based on similarity treatments and experimental designs, the results of analysis of combined variance and mean comparisons showed significant (528.4 kg ha^{-1} yield increase as density increased from 30 to 45 plant m^{-2} and nitrogen starter fertilizer increased from 0 to 40 kg ha^{-1} in two years. Seed protein was unaffected by plant densities, but nitrogen application changed it. This experiment showed density of 45 plant m-2 and application of nitrogen starter fertilizer 40 kg ha^{-1} are optimum and increase seed yield under condition of our experiment

Mrkovacki *et al*. (2008) conducted an experiment to study the effects of different nitrogen rates (0, 30, 60, 90 kg N ha^{-1}) on the soybean cultivar Proteinka, inoculated with the NS–Nitragin microbial fertilizer. Trials were set up at BačkiPetrovac on a soil with no previous history of soybean cultivation. At flowering, the largest mass and length of the aboveground plant parts were recorded in the treatment with 60 kg N ha^{-1}, while the largest nodule number, mass and N content were obtained with 30 kg N ha^{-1}.

Osborne and Riedell (2006) conducted a field experiment using a split-plot design with three replications. Whole plots were tillage [no-tillage (NT) and conventional tillage (CT)] with starter fertilizer rate as the split plot treatments. Nitrogen was band applied at planting as urea (UR), at rates to supply 0, 16, 32 and 64 kg N ha^{-1}. Analysis of the experiment showed an average yield increase of 16.4% and 12.2% for the 32 kg N ha^{-1} rate, compared to the no N treatment in CT and N, with no difference in seed N or oil concentration. This research demonstrates that applying N as starter has the potential to increase soybean yield but this may or may not translate into improved seed quality in the unique environments of the northern of Iran.

Taylor *et al*. (2005) conducted a field study to determine the optimum economic rate of N that would stimulate early dry matter accumulation, and thus yield, in late-planted soybean. The effects of three planting dates (mid-June, late-June, and mid-July), two MG VIII cultivars (Kuell and Prichard), and five N rates (0, 25, 50, 75, and 100 kg haha^{-1}) were studied for 2 year at three Alabama locations (Fairhope, Shorter, and Crossville). Nitrogen application of 60 to 70 kg ha^{-1} maximized yield and R_1 dry matter accumulation. However, N reduced nodule number and mass, but had no effect on R1 plant height, mature plant height, or seed quality, protein and oil content. Yield was reduced linearly by later planting, but there was no interaction between N rate and planting date for yield. At current prices for N and soybean, we concluded that N can be a viable input for double-cropped soybean at an optimal economic rate of 59 kg ha^{-1}.

Jamal *et al*. (2005) conducted a field experiment to assess the growth characteristics, seed and oil yield of two cultivars of soybean (*Glysin max* L.) Merr.) cv. PK-416 (V_1) and cv. PK-1024 (V_2) in relation to sulphur and nitrogen nutrition. Six combinations (T_1-T_6) of two levels of sulphur (0 and 40 kg ha^{-1}) and two levels of nitrogen (23.5 and 43.5 kg ha^{-1}) were applied to the two soybean cultivars as nutrients. Maximum response was observed with treatment T_6 (having 40 kg S and 43.5 kg N ha^{-1}). Seed and Oil yields were increased 90 and 102% in V_1, and 104 and 123% in V_2, respectively as compared to the control i.e. T_1 (having 0 kg S and 23.5 kg N ha^{-1}). Positive responses of S and N interaction on leaf area index, leaf area duration, and crop growth rate and biomass production were also observed.

Barker and Sawyer (2005) conducted a study to determine the impact of N fertilizer applied to the soil at the beginning pod growth stage on soybean yield and seed quality. Additional objectives were to study alternative N fertilizer and application practices that might enhance soybean use of applied N. A field study was conducted at five locations in Iowa during 1999 and 2000. Nitrogen treatments were urea and polymer-coated urea broadcast and subsurface band placed between the rows at 45 and 90 kg N ha^{-1} and a no-N control. The study showed few, small, and inconsistent effects of N material, placement, and rate on seed yield and quality components at individual sites or when combined across individual sites. There were no significant effects on seed yield, with only a 39 kg ha^{-1} increase from applied N. Seed protein, oil, and fiber concentrations were the same with or without N application. Aboveground plant dry matter (DM) at the R6 growth stage was greater with the higher N rate, but plant DM with N application was lower than the no-N control. Nitrogen concentration in plant DM was significantly increased with applied N. In conclusion, N application increased N concentration in R6 soybean plants, but N rate and alternative application practices had no positive effect on plant DM, seed N concentration and removal, seed yield, or seed quality components. It was concluded that growers should not consider fertilizer N applied to soil during early reproductive stages as a method to increase soybean yield or seed quality. Gutiérrez-Boem *et al*. (2004) conducted two field experiments to determine the effects of a late season N fertilization on leaf senescence and fall, seed yield and its components, and residual soil nitrate, and to evaluate the potential risk of groundwater contamination. Two rates of nitrogen (50 and 100 kg N ha^{-1}) were applied at the R_3 and R_5 development stages. Nitrogen fertilization, either at R_3 or R_5, increased soil nitrate availability during the seed-filling period. Seed yield, seed number and protein content were not affected by N fertilization. The addition of 100 kg N ha^{-1} produced a small delay of 1–2 days in the leaf fall, and slightly increased seed size (3.6%). Our results suggest that increasing soil N availability during the seed-filling period is not an effective way to delay leaf senescence or to increase seed growth and yield of soybean. Nitrogen fertilization increased the level of residual nitrate in the top soil at one site (the one with lowest seed yield), increasing the risk of nitrate leaching during subsequent fallow.

Soomru *et al.* (2005) observed that the soybean plants inoculated by *Bradyrhizobium japonicum*and PSB with low level of P gave higher dry matter, nodulation, N content and seed yield $plant^{-1}$ compared to the uninoculated plants. Inoculation of soybean seeds with *Bradyrhizobium japonicum*culture gave significantly taller plants with more nodules, pods per plants, seeds per pod and seed weight than untreated seeds.

Paudal and Prasad (2005) carried out a greenhouse experiment to evaluate the effectiveness of *Bradyrhizobium japonicum*on soybean and observed that *Bradyrhizobium japonicum* inoculation increased the number of nodules, shoot length of plant and total chlorophyll content in fresh leaves of soybean plant.

Chang *et al.* (2005) conducted an experiment in Tandojam, Pakistan in 2004 to investigate the effect of *Bradyrhizobium japonicum* inoculation on N accumulation in soybean at various parts (roots, nodules, stems, pods, leaves and seeds) and growth stages (budding, flowering, podding and maturity). Uninoculated plants served as the control. A higher nodulation N content was recorded in inoculated plants compared to uninoculated ones.

Agha *et al.* (2004) conducted a field experiment to Tandojam, Pakistan. The effects of N fertilizer rates (0, 50 and 75 kg ha^{-1}) singly or in combination with the seed inoculation of *Bradyrhizobium japonicum*on the yield components of soybean. The application of N and inoculation of *Bradyrhizobium japonicum* significantly enhanced seed yield and yield components. The highest number of pods $plant^{-1}$, number of seeds pod^{-1}, seed weight $plant^{-1}$, number of nodules $plant^{-1}$ and seed yield were obtained higher with 50 kg N ha^{-1}+ inoculation of *Bradyrhizobium japonicum.*

Egamberdiyeva *et al.* (2004) carried out a field experiment to see the effect of inoculation with *Bradyrhizobium japonicum* S2492 on soybean growth, nodulation and yield in N deficient soil of Uzbekistan. The results revealed positive effects on growth, nodule number and yields of soybean after inoculation with *Bradyrhizobiumjaponicum*S2492.

El-Desouky and Atawia (1998) conducted two field experiments in Aswam, Egypt during 1999 and 2000 to assess the effect of single or mixed inoculations with *Bradyrhizobium japonicum* alone or with selected Rhizobacterial strains on field grown soybean (cv. Clark) and the effect of inoculant application on the nodulation, growth and yield of soybean. Results showed that nodulation and vegetative growth were greatly promoted by inoculation with *Bradyrhizobium japonicum* alone compared with uninoculated control.

Gan *et al*. (2002) conducted a field experiment was conducted to study the effects of N application as urea at various stages during the vegetative and reproductive phases on crop biomass, N_2 fixation and yield of two soybean genotypes, Luyuebao and Jufeng. Starter N at 25 kg ha^{-1} resulted in minimum biomass and pod yield while starter N at 75 $kgha^{-1}$ had no significant effect and N top dressing, at either the R1 or R_5 stage, resulted in increased biomass and pod yield. Maximum biomass and pod yield were obtained when a top dressing of 50 kg ha^{-1} was applied at the flowering stage. The effects of top dressing on the capacity to fix N_2 were complex. Any topdressing reduced nodulation and P fix, but increased biomass, so that total N_2 fixed increased for top dressing at the flowering or pod filling stage. Common farmer's practice of applying 75 kg N ha^{-1} at the V_4 stage, resulted in a significant reduction in N_2 fixation. To evaluate the application of N fertilization at various stages of development on growth, nodulation and N_2 fixation in more detail, an experiment in nutrient solution with or without 20 ml $MnNO_3^-$was conducted with genotype Tidar. The N-free treatment gave the lowest biomass and total N accumulation, as in the field experiment. A continuous nitrate supply resulted in the highest biomass, associated with an increase in total leaf area per plant, maximum individual leaf area, branches and node number per plant, shoot/root ratio and leaf area ratio, compared to the N-free treatment. R_1 was the most responsive stage for nitrate supply as well as for interruption of the nitrate supply. Since the results from the field experiment were in agreement with those from the experiment in nutrient solution in a greenhouse, the latter can be used to predict crop performance in the field.

Experiments were conducted to determine the effect of (i) application rate and reproductive stage timing of N or B on soybean seed yield and (ii) cultivar, row spacing, or planting date on the response of soybean to R_3-stage N and B applications. Nitrogen was applied to the soil at 0, 14, 28, 56, 84, 112, or 168 kg ha^{-1}, or B was applied to the foliage at 0, 0.14, 0.28, or 0.56 kg ha^{-1} to either R3- or R5-stage soybean in the rate and timing experiments. Treatments for the cultivar, row-spacing, and planting-date experiments included 0 + 0, 56 + 0, 0 + 0.28, and 56 + 0.28 kg ha^{-1} N + B, respectively. In yield environments ranging from 2400 to 5300 kg ha^{-1}, application of N or B did not increase seed yield at any rate or application stage, nor did cultivar, row spacing, or planting date alter this lack of response. Analysis of leaf tissue taken at the R_2 soybean development stage and before nutrient application indicated that N and B concentrations were above the minimum level required by soybean for maximum yields not limited by N or B. Lack of response to supplemental N or B suggested that N supplied via fixation and soil organic matter mineralization and native levels of B in soils are adequate for high yields in the Mid-Atlantic Coastal Plain soybean production region (Freeborn *et al*., 2001).

Okereke *et al.* (2000) conducted two field experiments at Akwa, Nigeria to assess the competitiveness of foreign *Bradyrhizobium* in influencing the promiscuous soybean cultivar (TGX 536-021). Seeds were inoculated with antibiotic mutants of the *bradyrhizobia* strains before sowing. Nodule number significantly increased and showed great variability in 84 days after sowing the probability due to differences in the ability of inoculant *bradyrhizobia* to form nodules with the soybean cultivars TGX 536-021.

Podder *et al.* (1999) carried out a field experiment at Old Brahmaputra Flood plain soil to evaluate the effect of seed inoculation with 8 *bradyrhizobial* strains on shoot length of soybean. They reported that, significantly higher shoot length produced in the inoculated treatments than the uninoculated control.

Islam *et al.* (1999) reported that significantly lowest number of nodules were observed in uninoculated and the highest in inoculated treatments. All the *Bradyrhizobium* inoculation treatments performed better in nodulation, dry matter and straw yield of soybean.

Starling *et al*. (1998) conducted an experiment to determine the interactive effects of growth habit (determinate and indeterminate stem termination types) and starter N (0 and 50 kg ha^{-1}) on soybean growth and yield when planted following corn in a double-crop system. Three Maturity Group VIII soybean genotypes [the near-isolines Au86-2397I (Dt1Dt1, indeterminate) and Au86-2397D (dt1dt1, determinate) and a determinate check cultivar, Cook] were planted in late July in seven Alabama environments during 1995 and 1996. Starter N increased R_1 dry matter for both Au86-2397D and Au86-2397I by 0.50 Mg ha^{-1}. Au86-2397I had 1 cm greater average plant height at the R_1 developmental stage and 14 cm greater height at R_8 than Au86-2397D. Au86-2397I yielded 0.16 Mg ha^{-1} more than its determinate near-isoline. Application of starter N decreased the number of nodules per root, but increased plant N concentration and dry matter yield. Seed yield was increased on average by 0.15 Mg ha^{-1} with addition of starter N. In this study, an indeterminate genotype soybean coupled with application of starter N promoted greater soybean growth and yield in a late-planted, double-cropped system.

Wesley *et al*. (1998) conducted at eight sites over a 2-yr period on irrigated soybean to evaluate effects of N rates (0, 20, 40 lb. /acre) and sources (urea-ammonium nitrate solution [UAN], ammonium nitrate, urea, urea + N-[n-butyl] thiophosphorictriamide [NBPT]) on leaf N concentrations, seed yield, and seed protein, and oil concentrations. The NBPT used is a commercially available urease inhibitor. Most N was broadcast but UAN was applied over the top of the canopy through flat-fan nozzles. All applications were made at the R3 growth stage. Nitrogen concentrations in leaf samples taken 2 to 3 weeks after N application were unaffected by N fertilization. Soybean yields were increased significantly by late-season N application at six of eight sites; the average increase was 6.9 bu/acre or 11.8 %. Both of the nonresponsive sites had yields averaging under 50 bu/acre, whereas responsive sites yielded 56 bu/acre or more. Soybean plants at all locations were well nodulated. In most cases, 20 lb. N/acre provided positive responses. Late-season N fertilization increased seed protein and oil concentrations at some sites, but overall combined analysis indicated no significant effects. Nitrogen sources performed similarly. Application of UAN resulted in leaf burn, which probably reduced yields at the 40 lb. N/acre rate. However, this would not be a problem for producers applying UAN through irrigation systems where the UAN would be much more diluted. Even when well nodulated, soybean with high yield potential may not be able to take in enough N to achieve maximum yield of high quality seed. Public and private soil test labs and crop consultants may have to reevaluate N recommendations for soybean with high yield potential. Supplemental N application at the R_3 growth stage can provide positive economic returns for producers growing irrigated soybean with high yield potential.

Krishna *et al*. (1995) grew irrigated soybean (cv. MACS 58) on a Vertisol at Bapatla (Andhra Pradesh) during the post rainy season N was applied at 30 and 60 kg ha^{-1}. N application increased the dry matter production by 13% over control. No significant difference was observed between 30 and 60 kg N ha^{-1}. The experimental soil was low in available N (220 kg N ha^{-1}), medium in available P (40 kg $P_20_5$$ha^{-1}$) and high in available K (572 kg K_20 ha^{-1}).

Jadhav *et al*. (1994) observed that on Vertisols of Pune (Maharastra) in soybean (cv MACS 13), the leaf area produced was slow up to 42 days after sowing (DAS); it increased rapidly thereafter and about 84 per cent of leaf area $plant^{-1}$was attained at 56 DAS. The dry matter accumulation was also slow during initial stages (up to 28 DAS), thereafter, it progressively increased and 30% of dry matter plant" accumulated by 56 DAS. Application of 60 and 90 kg N ha^{-1} significantly increased plant leaf area at all stages of crop growth as compared to control and 30 kg N ha^{-1}. The application of 30 kg N ha^{-1} also produced significantly more leaf area plant" than control. Crop treated with N @ 60 and 90 kg ha^{-1} accumulated significantly more dry matter in leaves, stem, branches and pods and, therefore, produced more total dry matter than control and 30 kg N ha^{-1}. The crop was grown during rainy season and soil was low in available N (140 kg ha^{-1}), medium in available PIO_2 (22 kg ha^{-1}) and high in available K_20 (413 kg ha^{-1}).

Rahman *et al*. (1982) studied the response of applied N to soybean (cv. Davis). They found that N applied @ 100 kg ha^{-1} increased plant growth but drastically reduced the nodule number and nodule weight. The combined application of inoculum + urea (25 kg N ha^{-1}) showed good performance with respect to number of nodules and their dry weight.

Kang (1975) stated that in the former bean yields with IARI and CB 1809 inoculants were better than with Nitrogen-S. In the field experiment, inoculation alone was inadequate to supply the nitrogen need of the crop, 30 kg N/ha being needed with inoculation, and 60 kg N/ha without inoculation, for maximum yield. Higher nitrogen application, combined with inoculation, increased dry matter, N-uptake, bean yield, pod number, bean weight and nitrogen content of seed. Oil content of the seeds decreased with inoculation and nitrogen application.

Gowda and Kaul (1998) carried out a field trial in Egypt to study the effects on soybeans with or without seed inoculation with *Bradyrhizobium japonicum* and found that soybean yield increased with inoculation over uninoculated control.

Mitra *et al.* (1998) conducted a pot experiment where inoculation of soybean seed with *Bradyrhizobium japonicum* was done. Seed inoculation increased root nodulation and biomass yield.

Dubey *et al.* (1997) conducted a field experiment on seed inoculation with different strains of *Bradyrhizobium japonicum* and reported that plant height and seed yield significantly increased over control.

Vera *et al.* (2002) inoculated Gujrat soybean-I seeds with *Bradyrhizobium* and obtained the yield of 1293 kg ha^{-1} against the lower yield of 1197 kg $ha^{-1}$from with no inoculation.

Haque (1996) observed that the inoculation of soybean seeds with *Bradyrhizobium japonicum* gave the highest seed yield of the crop.

Hasan *et al*. (2007) conducted two field experiments with soybean at BAU farm and found that *Bradyrhizohium* inoculation produced marked effect on growth and yield of soybean.

Panwar *et al.* (1998) conducted an experiment to study the effect of N concentration of cultural solution, *Bradyrhizobium* inoculation and plant density on the growth and yield of soybean cultivars. They observed that *Bradyrhizobium* inoculation increased the stem length of soybean.

Uslu *et al.* (1997) conducted a field trial where soybean that were inoculated with *Bradyrhizobium japonicum*, or not inoculated. They found that nodules per plant were increased by inoculation.

Thanausont and Vilhay (1996) observed in a pot experiment that *Bradyrhizohium* inoculant increased nodulation and N_2-fixation of soybean.

Ranjit and Pal (2004) reported that soybean seed inoculated with *Bradyrhizobium* had significant effects on nodulation and nodule distribution along with roots.

Rodrigues *et al*. (1994) conducted a field experiment on Soybean (cv. Sansory) inoculated with *Bradyrhizobium japonicum* and Mo application @ 270 g Mo ha^{-1} and reported increased nodulation.

Soybean demand for nitrogen (N) can exceed 2.5 kg N bu^{-1} for optimum seed yield. Utilization of the majority of this N occurs during seed development, and it is at this time that the soybean begins to remobilize tissue N for translocation to the seed. Nitrogen sources for the soybean include mineralization, soil organic matter, symbiotically fixed N, and N incorporated into plant tissue. Under certain soil, climatic, and yield conditions, N supply may limit soybean seed production. However, N applications made before reproductive growth stages are reported to decrease *Bradyrhizobia* activity, exhibited by reduced growth of nodules and lower N fixation, thus further increasing the difference between N supply and demand (Yoneyama, *et al.*, 1985; Bhangoo and Albritton, 1976; Ham *et al.*, 1975; Yoshida, 1979).

Laboratory research has demonstrated that as N applications increase, nodule fresh weight and haemoglob in content of nodules decreases when compared to a control, denoting a lowered amount of N fixation (Harper and Cooper, 1971).

Field studies to measure soybean response to applied N have been conducted by several researchers. Pre plant applied N at 134 kg ha^{-1} on a silt loam soil in Nebraska to irrigated soybeans did not consistently alter yield (Slater, *et al.*, 2001). Similarly, on a silty clay loam in Illinois N applications from 0 to 900 kg ha^{-1} yr^{-1} elicited no yield effect, except for slight yield reductions at the higher N rates (Welch *et al.*, 1973).

Two sites in Michigan generated variable results. On a Zilwaukee clay no yield response was reported at an N rate of 134 kg ha^{-1}, while on a sandy loam yield increases averaged 460 kg ha^{-1} over the control plots (Wankhade *et al*., 1998).

One solution for overcoming this situation of supplying needed N for plant growth without impeding the development of *Bradyrhizobium*is foliar N applications during reproductive stages of plant growth. Yield increases from foliar fertilization using fertilizer grade urea applied at rates of 45, 90, and 135 kg ha^{-1} at R_4 (Fehr and Caviness, 1977) were reported (Xiong and Liu, 1993).

Increases over the control yield of 2640 kg ha^{-1} for the two years averaged 123, 160, and 243 kg ha^{-1} for the three treatments, respectively. In a series of experiments conducted at eight sites over a 2-year period on irrigated soybean, applications of N at 22 and 44 kg ha^{-1} increased yield at six of the eight sites for an average increase of 464 kg ha^{-1} or 11.8% (Wesley *et al.*, 1998). Yields at the two unresponsive sites were less than 3360 kg ha^{-1} and the authors suggested that responses from N might only be realized under high yield potentials.

Similarly, greenhouse and field studies by Yoshida (1979) reported yield increases with N applications. The greenhouse study utilized five N rates from 15 to 150 ppm NO_3^-N in complete hydroponic solutions and a control containing no N. Total seed yield increased from the control of 0.9 g to 81.6 g per pot with 50 ppm N, while the highest N rate, 150 ppm, yielded 76.7 g per pot. In the field study, N applications from 30 to 90 kg ha^{-1} applied from seedling emergence to R_1 increased yields by 720 kg ha^{-1}, averaged across all treatments. Yield benefits of up to 148 kg ha^{-1} over the control of 2856 kg ha^{-1} have been reported in Kentucky. In this work, liquid UAN (28% N) was dribbled beside the rows between the R_2 to R_3 development stages at rates of 29 kg ha^{-1} and 36 kg ha^{-1} in 1996 and 1997, respectively.

Supplemental N has been thought to be beneficial only in years of adequate moisture (Keyser and Li, 1992) or under irrigation at high yield potentials (Wesley *et al.,* 1998).

An experiments have demonstrated that supplemental N will increase yields in plants under drought stress. When water stress occurs during the critical time of seed filling, carbon and N can be remobilized from plant leaf tissue and translocate to the seeds, resulting in faster declines in photosynthetic rates (Dwivedi *et al.,* 1996). This leads to premature leaf senescence, and lowered yields through reduced seed size and seed number.

Observed yield increases in Arkansas on a silt loam soil occurred where non-irrigated soybeans received a broadcast N application rate of 224 kg ha^{-1} at V_6 and an additional 112 kg ha^{-1} N application at R_2. Yield for non-irrigated soybeans without N application was 2373 kg ha^{-1}, while yield for the non-irrigated soybeans with N applications was 2798 kg ha^{-1}. The yield for the irrigated soybeans which received no N application was 2728 kg ha^{-1}, and the difference between the non-irrigated soybeans receiving N and the irrigated soybeans not receiving N were not significantly different (Purcell and King, 1996). These researchers concluded that the application of N fertilizer alleviated the N deficit due to poor N fixation by *Bradyrhizobium* caused by low soil moisture.

In an additional greenhouse experiment, Purcell and King (1996) also observed that through supplemental N fertilization, the effects of drought were partially reversed when compared to plants which received full water and no additional N, since the N application compensated for the low N fixation of the *Bradyrhizobium.* Supplemental late season N applications offer the potential benefits of increasing yield under optimum moisture conditions as well as during times of inadequate moisture.

2.2 Effect of boron application for response of soybean

An experiment was conducted by Pandey and Gupta (2013) to study the effect of foliar application of boron (B) on reproductive biology and seed quality of black gram *(Vigna mungo*). Black gram *(V. mungo* L. var. DPU-88-31) was grown under controlled sand culture condition at deficient and sufficient B levels. After 32 days of sowing B deficient plants were sprayed with three concentrations of B (0.05%, 0.1 % and 0.2% borax) at three different stages of reproductive development. Foliar spray at all the three concentrations and at all stages increased the yield parameters like number of pods, pod size and number of seeds formed Plant^{-1}.Foliar B application also improved the seed yield of black gram. Foliar B application improved the seed quality in terms of storage seed proteins (albumin, globulin, glutenin and prolamin) and carbohydrates (sugars and starch) in black gram.

Quddus *et al.* (2011) studied to evaluate the effect of zinc and boron on the yield and yield contributing characters of mungbean (*Vigna radiata L.* Wilczek) and to find out the optimum dose of Zn and B for yield maximization. There were four levels of zinc (0, 0.75, 1.5, and 3.0 kg ha^{-1}) and boron (0, 0.5, 1.0, and 2 kg ha^{-1}) along with a blanket dose of N, P, Kand S were 20, 25, 35 and 20 kg ha^{-1}. Results showed that the combination of Zn (1.5 kg ha^{-1}) and B (1.0 kg ha^{-1}) produced significantly higher yield (3058 kg ha^{-1})

Crak *et al.* (2006) carried out a field experiment to examine the effect of soil and foliar application of B (66.14% B_2O_3) at different rates (0, 0.5, 1, 1.5 and 2 kg ha^{-1}) on plant height, first pod height, Pod $plant^{-1}$, boron content of seed, germination rate, 1000-seed weight, oil, protein and yield of 'A 3935' soybean during 2002-2003 at the experimental area of Turkey. Increasing B rate applied either as soil or foliar improved yield (40%), first pod height (17%), B content of seed (42%), germination rate (11%) and 1000-seed weight (5%) of soybean. For maximum yield, 1.09 kg ha^{-1} of B was recommended.

Liu Peng *et al.* (2005) carried out an experiment with three cultivars (Zhechum no. 3, Zhechum no. 2 and 3811) of soybean at four growth stages. The lowest yield (2173 kg ha^{-1}) and (1573 kg ha^{-1}) were found in control (Zn_0B_0) combination. The combined application of zinc and boron were observed superior to their single application in both the years. Therefore, the combination of Zn1.5 & B1.0 kg ha^{-1} might be considered as suitable dose for mungbean cultivation in Bangladesh. But from regression analysis, the optimum treatment combination was Zn1.87 & B1.24 kg ha^{-1} supply of Mo and/or B sufficiently increased the absorption of Mo and B by soybean. High supply of B decreased B absorption but increased B content. The absorption of B was the highest in all the treatment at early stage and the B content was lower than single B supply at maturity stage. The B absorbed by soybean mainly accumulated in leaf.

Mohanti *et al.* (2004) carried out a field experiment during kharif 2000 at Raipur, India to evaluate the effects of different levels of S (0, 10, 20 and 30 kg ha^{-1}) and B (0 and 0.002% at pre-flowering or/and pre-podding) on soybean cv Js-335. The highest plant height, number of pod and seed yield was recorded in the combined application of S and B fertilizer.

Sarkar (2002) carried out a field experiment to evaluate the nodulation, yield and quality of Bangladesh soybean-4 as influenced by S and B application. The experiment comprised five levels of both S and B viz. 0, 10, 20, 30 and 50 kg S ha^{-1} and 0, 0.5, 1.0, 2.0 and 4.0 kg B ha^{-1}. The highest biological yield and most of the yield attributes were obtain for the treatment combination of 30kg S and l.0 kg B ha^{-1}.

Boron helps root system development, fruit and seed formation of plant. Plant height, root length, total dry matter production and seed yield of soybean were higher at 50 than 100 ppm B (Hemantaranjan *et al.*, 2000).

Reinboti and Blevins (1995) carried out an experiment with application of B separately 5 times during reproductive growth did not affect soybean yield. But foliar application of B increased the plant height and nodulation of the soybean.

Rodrigues *et al.* (1994) reported that boron deficiency preventing completion of growth cycle. When boron was applied at different levels than the plant growth increased but without micronutrient (B) completely stunted the plant growth.

Panwar *et al.* (1998) reported that chickpeas seed yield was reduced by 4.4% and 61% after the application of 0.8 and 2.0 mg B kg^{-1}soil, respectively. Straw yield was less affected by high B but dry matter yield in chickpea was increased by 0.2% foliar application of boron.

Xiong and Liu (1993) conducted a pot experiment in B deficient calcareous soil and showed that B decreased protein content of the rape seeds. Both deficiency (< 0.33 mgL^{-1}) and excess (> 0.33 mgL^{-1}) of B deteriorated the quality of sesame seeds by lowering the protein and starch contents. Protein content of sunflower was decreased by B (Tamac *et al.*, 1997).

Boron is a micronutrient because of concentration levels in plant tissue, not because of importance in plant growth. Boron's widespread role within the plant includes cellwall synthesis, sugar transport, cell division, differentiation, membrane functioning, root elongation, and regulation of plant hormone levels (Marschner, 1995; Romheld and Marschner, 1991; Pilbeam and Kirkby, 1983).

Boron is one of the most commonly deficient micronutrients in agriculture, with reports of deficiencies in 132 crops and in 80countries (Shorrocks, 1997). These deficiencies typically result from boron leaching occurring in humid areas with coarse textured soils (Mortvedt and Woodruff, 1993;Marschner, 1995; Welch, *et al.,* 1991).

Gascho and McPherson (1997) reported yield benefits from foliar B applications over the control yield on an irrigated Bonifay sand in Georgia. The application of 0.28 kg Bha^{-1} at soybean development stage as defined by Fehr and Caviness (1977) generated yields averaging 353 kg ha^{-1} higher than the control yield of 3247 kg ha^{-1}, averaged over five cultivars at the same site. In this study, three out of five cultivars showed significant response to B applications at any rate, leading the authors to believe that yield response to B may depend on cultivar. Other researchers from Georgia report that B mixed with diflubenzuron [1-(4-chlorophenyl) 3-(2, 6-difluorobenzoyl) urea] insecticide applied to R_2or R_3 increased yield by an average of 23% at four sites (Hudson and Clarke, 1997).

The yield level for the untreated check averaged 2580 kg ha^{-1} while the B+diflubenzuron treated plots applied at R_2 to R_3 yielded 3185 kg ha^{-1}. Similarly, on a loamy sand, two split B applications at ½ the treatment rate, the first applied at R_1 and the second seven days later, increased yields by 4% for rates up to 1.12 kg ha^{-1} (Touchton and Boswell,1975).

Direct infusions of soybean plants growing on a Mexico silt loam soil with supplemental B using H_3BO_3 as the source have caused an 84.8% increase in the total number of branch pods per plant as well as an increase of 17.6 % in total seed weight per plant (Schon and Blevins, 1987). Seed yield in this experiment corresponded to 4170 $kgha^{-1}$ for B injected plants and 3540 kg ha^{-1} for the control plants. During this experiment, the yield increase was due to an increase in the number of pods per plant.

On the same Mexico silt loam soil in Missouri utilizing the same soybean cultivar, two foliar applications of B at $R_1$and R_2 increased the number of pods per branch (Schon and Blevins, 1990).

In another experiment, six split applications from R_1 through R8 increased both the number of pods per branch and the number of branches per plant (Schon and Blevins, 1990). Similarly, two foliar applications at R_4 and R_5 caused a yield increase of 356 kg ha^{-1} on a Mexico silt loam in Missouri (Reinbott and Blevins, 1995).

Soil applied B rates of 2.8 kg ha^{-1}in a silty clay loam produced soybean yield increases of 11% and 13%, respectively, in the first two years with no effect in the third year after application respectively (Reinbott and Blevins, 1995). These increases corresponded to yields of 1931 kg ha^{-1}and 1934 kg ha^{-1}compared to the control yield of1736 kg ha^{-1}and 1687 kg ha^{-1}for years one and two, respectively. In these studies, soil applied B increased pods per branch by 17% and number of pods per plant by 39%. A late planting date in the third year possibly contributed to the lack of response.

Broadcast applications of B at 0.28 to 1.12 kg ha^{-1}at three sites in Georgia generated variable results, but soybean yield was increased by 4% on a coastal plain soil (loamy sand) with low soil test B levels (0.14 ppm hot-water-soluble B) (Touchton and Boswell, 1975).

Research in Arkansas on a silt loam soil reported yield increases up to 538 kg ha^{-1}overthe control yield of 2861 kg ha^{-1}to soil applied B during early flowering at a rate of 3 kgha^{-1}(Al-Molla, 1985). At another site on a silt loam soil, Al-Molla (1985) reported a yield increase of 569 kg ha^{-1}over the control yield of 2257 kg ha^{-1}with a B application of4 kg ha^{-1}made to the soil at early flowering.

In contrast to these positive yield responses, soil applied B on a silt loam in Missouriat rates of 0.0, 0.28, 0.56, and 1.12 kg ha^{-1}generated no significant differences in yield or yield components (Schon and Blevins, 1990). No yield effect was also observed on a silt-loam in Missouri with split foliar applications of B at rates of either 0.56 or 1.12 kg ha^{-1}applied at R_2 and R_3 (Reinbott and Blevins, 1995).

No significant yield effects were observed with soil applied B at rates up to 1.12 kg ha^{-1}in a sandy loam in Georgia, and yield reductions of 10% were observed at one site when a B rate of 2.24 kg ha^{-1}was utilized (Touchton and

Boswell, 1975).These variable results demonstrate the need for further research on B applications to soybeans. Application timing, rate, and conditions necessary for a yield response have not yet been fully determined.

Foliar application of B deposits where needed, alleviating leaching concerns in coarse textured soils, allows application rates of approximately 50% less than soil applied rates, and enables the producer to apply B at the critical plant growth stages (Martens and Westermann, 1991; Mortvedt and Woodruff, 1993). Additionally, levels of B accepted to be adequate may actually be insufficient as higher yields are obtained. The objective of this experiment was to determine the effects on soybean yield of B applications at four rates and two growth stages on sandy Coastal Plain soils of the Mid-Atlantic soybean-growing region under high-yielding irrigated conditions.

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, intercultural operations, data collection and statistical analyses.

3.1 Location

The field experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2015 to December 2015. Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone "AEZ-28" of Madhupur Tract (BBS, 2012). The location of the experimental site has been shown in Appendix I.

3.2 Soil

The soil of the research field is slightly acidic with low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done from Soil Resources Development Institute (SRDI), Dhaka. The experimental plot was also high land and the soil of the experimental site is clay loam with a pH of 5.45-5.61. The physicochemical properties and nutrient status of soil of the experimental plots are given in Appendix II.

3.3 Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 2000). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The detailed meteorological data in respect of air temperature, relative humidity, total rainfall and soil temperature recorded by the Weather Station of Bangladesh, Sher-e-Bangla Nagar, Dhaka during the period of study have been presented in Appendix II.

3.4 Seed collection

Bangladesh Agricultural Research Institute (BARI) released BARI Soybean-6 in 2012. BARI Soybean-6 was used as plant material for the present study. Seeds were collected from the BARI, Joydebpur, Gazipur. Germination test of seed was done in the laboratory before sowing and germination was found to be 97%.

3.5 Treatments

The experiment consisted of two factors as mentioned below:

Factor A: Levels of Nitrogen- 4

1. N_0 = 0 kg N/ha
2. N_1 = 15 kg N/ha
3. N_2 = 30 kg N/ha
4. N_3 = 45 kg N/ha

Factor B: Levels of Boron- 4

1. B_0 = 0 kg B/ha
2. B_1 = 0.825 kg B/ha
3. B_2 = 1.65 kg B/ha
4. B_3 = 2.5 kg B/ha

3.6 Design and layout

The experiment was laid out in a split plot design with three replications. The size of the individual plot was 2m × 2m and total numbers of plots were 48. There were 16 treatment combinations. Each block was divided into 16 unit plots. Different levels of nitrogen were placed in main plot and levels of boron were placed in sub plot. Field experiment was done on October 07, 2015 with interplant spacing of 0.50 m and inter block spacing of 1.00 m. The layout of the study has been presented in Figure 1.

3.6.1 Layout of the experiment field

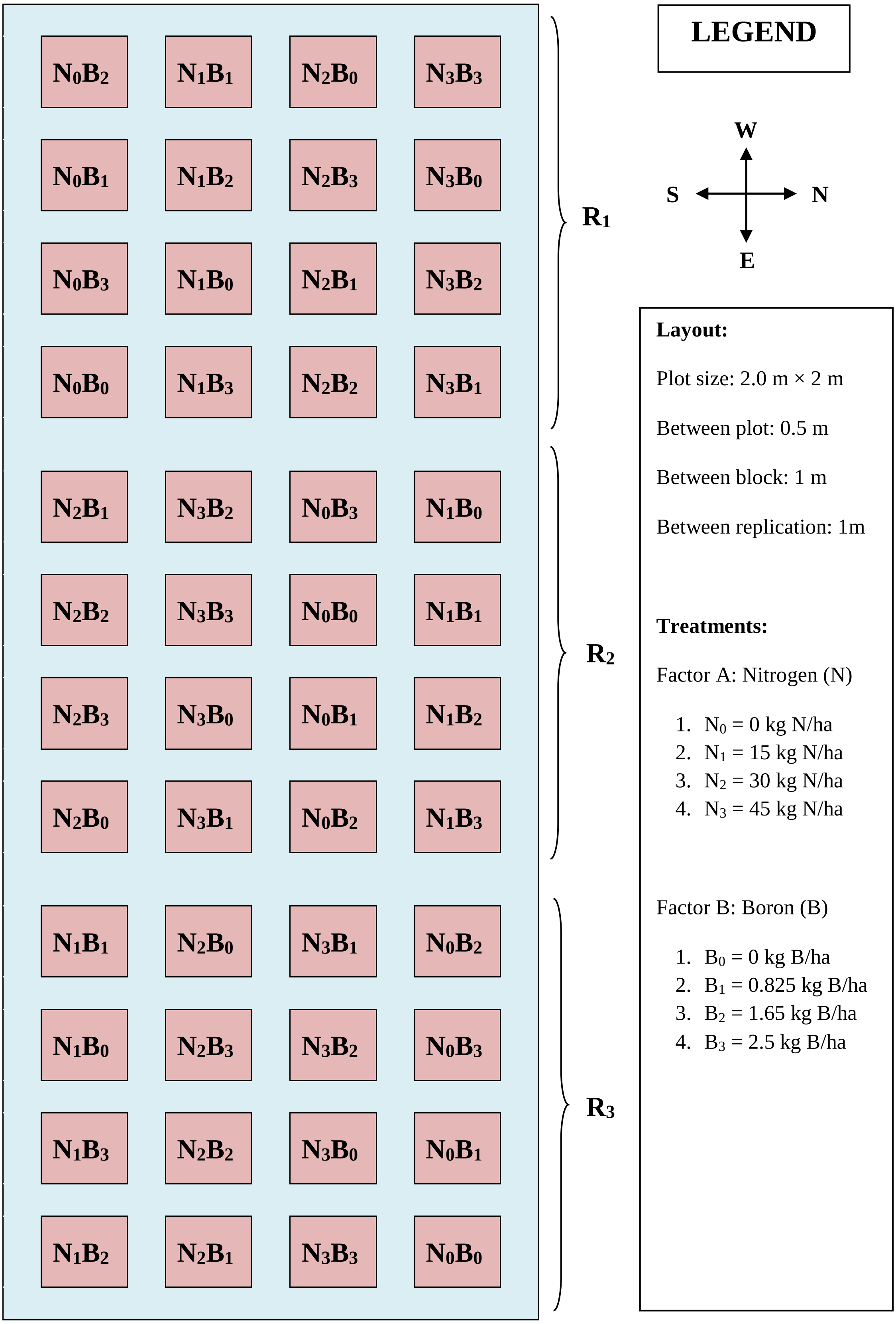

Fig. 1. Layout of experiment field

3.7 Land preparation

The land of the experimental field was first opened on October 01, 2015 with a power tiller. Then it was exposed to the sunshine for 5 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of the crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field. The soil was treated with insecticides at the time of final ploughing. Furadan 5G was applied @ 8 kg ha^{-1} to protect young plants from the attack of mole cricket, ants, and cutworms.

3.8 Fertilizer application

All the fertilizers except nitrogen and boron were applied according to BARI recommendation. Nitrogen and boron fertilizers were applied as per treatments in each plot. The BARI recommended doses of TSP, MoP, and gypsum are given below:

Fertilizers	Dose (ha^{-1})	Quantity ($plot^{-1}$)
Urea	As per treatment	As per treatment
TSP	175 kg	70 g
MoP	120 kg	48 g
Gypsum	115 kg	46 g
Boric acid	As per treatment	As per treatment

Source: BARI (2006)

Total TSP, MoP and gypsum were applied as basal dose. Nitrogen and boron were applied as per treatment at two installments. Half of total required nitrogen and boron were applied as urea and boric acid as basal dose and rest amount were applied at reproductive stage (flowering stage).

3.8.1 Fertilizer application procedure in the experiment field as per treatment

3.8.1.1 Nitrogen

1) **N_0 = 0 kg N/ha (0 kg urea/ha):** No nitrogen was applied to the experiment plot.
2) **N_1 = 15 kg N/ha (33 kg urea/ha):** Nitrogen was applied to the experiment plot as urea. Total urea was required 33 kg per ha. 16.5 kg/ha urea was applied as basal dose and rest amount (16.5 kg/ha) was applied at flowering stage.
3) **N_2 = 30 kg N/ha (66 kg urea/ha):** Nitrogen was applied to the experiment plot as urea. Total urea was required 66 kg per ha. 33 kg/ha urea was applied as basal dose and rest amount (33 kg/ha) was applied at flowering stage.
4) **N_3 = 45 kg N/ha (98 kg urea/ha):** Nitrogen was applied to the experiment plot as urea. Total urea was required 98 kg per ha. 49 kg/ha urea was applied as basal dose and rest amount (49 kg/ha) was applied at flowering stage.

3.8.1.2 Boron

1) **B_0 = 0 kg B/ha (0 kg boric acid per ha):** No boron was applied to the experiment plot.
2) **B_1 = 0.825 kg B/ha (5 kg boric acid per ha):** Boron was applied to the experiment plot as boric acid. Total boric acid was required 5 kg per ha. Boric acid @ 2.5 kg/ha was applied as basal dose and rest amount (2.5 kg/ha) was applied at flowering stage.
3) **B_2 = 1.65 kg B/ha (10 kg boric acid per ha):** Boron was applied to the experiment plot as boric acid. Total boric acid was required 10 kg per ha. Boric acid @ 5 kg/ha was applied as basal dose and rest amount (5 kg/ha) was applied at flowering stage.
4) **B_3 = 2.5 kg B/ha (15 kg boric acid per ha):** Boron was applied to the experiment plot as boric acid. Total boric acid was required 15 kg per

ha. Boric acid @ 7.5 kg/ha was applied as basal dose and rest amount (7.5 kg/ha) was applied at flowering stage.

3.9 Seed treatment

Seeds were treated with Vitavex-200 @ 0.25% before sowing to prevent seeds from the attack of soil borne disease.

3.10 Seed sowing

Seeds were sown on October 07, 2015 continuously in 30 cm apart rows opened by hand hoe. After sowing, the seeds were covered with soil and slightly pressed by hands.

3.11 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.11.1 Thinning

Emergence of seedlings was completed within 10 days after sowing. Over crowded seedlings were thinned out for two times. First thinning was done after 20 days of sowing which was done to remove unhealthy and lineless seedlings. The second thinning was done 10 days after first thinning.

3.11.2 Weeding

First weeding was done at 15 DAS and second one at 35 DAS along with thinning to keep the plots free from weeds and to keep the soil loose and aerated with optimum plant population.

3.11.3 Irrigation

The first irrigation was done at 20 DAS. Second irrigation was provided at 55 DAS. Proper drainage facility was also provided for draining out excess water.

3.11.4 Disease and pest management

The experimental crop was infested by hairy caterpillars (*Diacrisia oblique*) and cutworm at early growth stage, which were controlled by applying Sumithion 50 EC @1.0 L ha^{-1}. Hand picking of infested leaves was also done as a control measure. Diseased or off type plants were uprooted as and when required but these were not recorded.

3.12 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants, which were vigorous and luxuriant.

3.13. Sampling

Five plants were collected randomly from each plot. These 5 plants were used for recording yield component data.

3.14 Harvest and post-harvest operations

The crop was harvested on 27 December 2015 when the crop was properly matured. One meter area was harvested for yield data and it was converted to t ha^{-1}. The harvested plants were tied into bundles and carried to the threshing floor. The crops were sun dried by spreading on the threshing floor. The seeds were separated from the plants by hand stick and thereafter were cleaned, dried and weighed. The weights of the dry straw were also taken from the same demarcated area and were also converted to t ha^{-1}.

3.15 Collection of data

3.15.1 Crop growth parameters

a. Plant height (cm) at 30, 50, 70 DAS and at harvest.
b. Number of leaves /plant at 30, 50, 70 DAS and at harvest.
c. Number of branches /plant at 30, 50, 70 DAS and at harvest.

3.15.2 Yield contributing characters

a. Number of pods/plant at 50, 55, 60, 65 and 70 DAS
b. Pod length (cm) at harvest
c. Number of seeds/pod at harvest
d. Weight of 1000 seeds (g)

3.15.3 Yield and harvest index

a. Seed yield (t/ha)
b. Straw yield (t/ha)
c. Harvest index (%)

3.16 Procedure of recording growth data

3.16.1 Plant height (cm)

The height of the soybean plants was recorded from 30 days after sowing (DAS) at 20 days interval up to 70 DAS and at harvest. The plant height was counted as beginning from the ground level up to tip of the top leaf. The average height of five plants randomly selected was considered as the height of the plant for each plot.

3.16.2 Number of leaves/ plant

Total number of leaves/plant was taken from 30 DAS at 20 days interval up to 70 DAS and at harvest. The average number of leaves/plant of five plants was considered as the number of leaves plant^{-1} for each plot.

3.16.3 Number of branches/plant

Total number of branches/plant was taken from 30 DAS at 20 days interval up to 70 DAS. The average number of branches/plant of five plants was considered as the number of branches plant^{-1} for each plot.

3.17 Procedure of collecting data on yield and yield components

For assessing yield parameters data were collected from 5 randomly selected plants from each of the plots. For measuring seed and straw yield, an area of 1.0 m^2 from center of each plot was harvested.

3.17.1 Number of pods/plant

The number of pods/plant was recorded from randomly selected 5 plants of each plot. Data was recorded at harvest time. Mean data was expressed in number. Number of pods/plant was measured by hand counting at 5 days interval from 50 DAS to 70 DAS.

3.17.2 Pod length (cm)

The length of pod was measured by using a meter scale. The measurement was taken from the base to tip of the pod. Average length of pod was taken from five randomly selected pods from randomly selected plants of each plot. Data was recorded at harvest time. Mean data was expressed in centimeter (cm).

3.17.3 Number of seeds/pod

Data on the number of seeds/pod was counted. Five plants were randomly selected and the average data were collected from inner rows of each plot except harvest area during the time of harvesting.

3.17.4 Weight of 1000 seeds (g)

One thousand cleaned dried seeds were randomly collected from the seed stock of each plot and were sun dried properly. These dried seeds were weighed using an electric balance and the weight was expressed in gram.

3.17.5 Seed and straw yield (t ha^{-1})

An area of central 1.0 m^2 was harvested from each plot for yield measurement. The crop of each plot was bundled separately, tagged properly and brought to the threshing floor. The bundles were dried in an open sun, threshed and then seeds were cleaned. The seeds and straw weights for each plot were recorded.

3.17.6 Biological yield (t ha^{-1})

Biological yield was calculated by using the following formula:

Biological yield= Seed yield + Straw yield

3.17.7 Harvest index (%)

Harvest index is the relationship between seed yield and biological yield. It was calculated by using the following formula:

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

3.18 Statistical analysis

The recorded data were subjected to statistical analysis. Analysis of variance was done following two factor split plot design with the help of computer program MSTAT-C. The mean differences among the treatments were adjusted by Duncan’s Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The research work was accomplished to investigate the soybean yield response to nitrogen and boron application at basal and reproductive stage. Some of the data have been presented and expressed in table(s) and others in figures for easy discussion, comparison and understanding. The results of each parameter have been discussed and possible interpretations where ever necessary have been given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

Plant height of soybean varied significantly due to different levels of nitrogen treatments at different days after sowing (Appendix IV and Fig. 2). At different growth stages numerically the longest plant (14.48, 54.00, 62.17 and 64.52 cm at 30, 50, 70 DAS and at harvest, respectively) was obtained from N_3 (45 kg N/ha) followed by N_2 (30 kg N/ha). Similarly, the shortest plant (12.70, 40.96, 44.21 and 47.04 cm at 30, 50, 70 DAS and at harvest, respectively) was recorded from control treatment, N_0 (0 kg N/ha) followed by N_1 (15 kg N/ha). Umeh *et al.* (2011) reported that 60 kg N ha^{-1} gave the highest plant height. Results revealed that plant height increased with increasing N levels irrespective of growing period up to at harvest. Similar results was also found by Starling *et al*. (1998) and they observed that 50 kg ha^{-1} gave greater average plant height than control.

Plant height of soybean also varied significantly due to different levels of boron treatments at different days after sowing (Appendix IV and Fig. 3). Results revealed that at different growth stages the longest plant (14.03, 50.21, 58.42 and 59.54 cm at 30, 50, 70 DAS and at harvest, respectively) was obtained from B_3 (2.5 kg B/ha) followed by B_2 (1.65 kg B/ha) at all growth stages. Likewise, the shortest plant (13.22, 44.25, 52.17 and 53.15 cm at 30, 50, 70 DAS and at harvest, respectively) was recorded from control treatment,

B_0 (0 kg B/ha) followed by B_1 (0.825 kg B/ha). The results obtained by Crak *et al.* (2006), Mohanti *et al.* (2004) and Hemantaranjan *et al*. (2000) supported the present findings.

Interaction effect of different levels of nitrogen and boron application in terms of plant height also exposed significant variation at different days after sowing (Appendix IV and Table 1). Results indicated that numerically the highest plant height (14.87, 56.00, 65.33 and 68.00 cm at 30, 50, 70 DAS and at harvest respectively) was recorded from N_3B_3 treatment combination which was statistically similar to N_3B_2 followed by N_2B_3 treatment combination. Correspondingly, the lowest plant height (12.40, 37.33, 46.17 and 43.08 cm at 30, 50, 70 DAS and at harvest respectively) was recorded from N_0B_0 treatment combination followed by N_0B_1 and N_0B_2. The treatment combination of N_3B_1, N_3B_0, N_2B_2 and N_2B_1 also gave comparatively higher plant height but significantly different from all other treatment combinations.

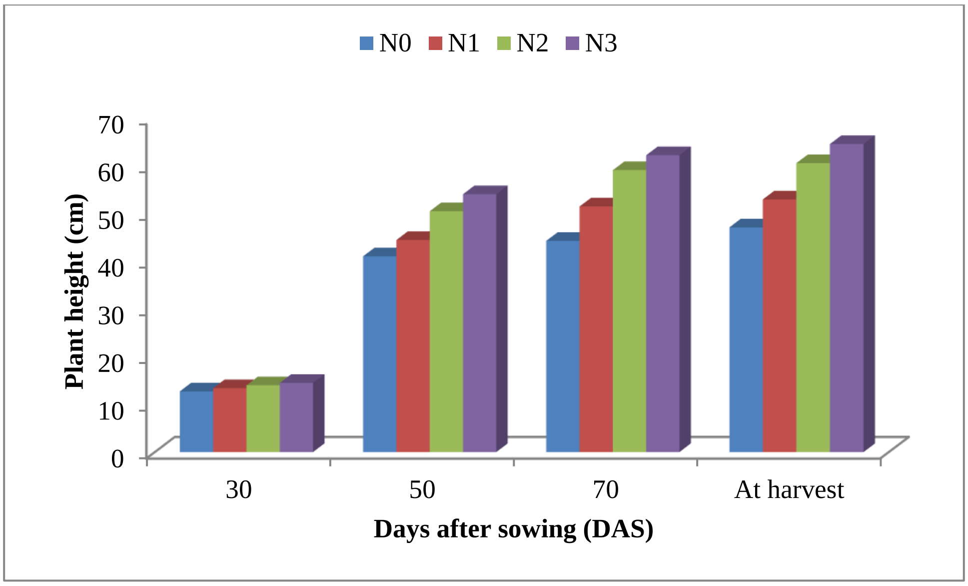

Fig.2. Response to nitrogen application on plant height of Soybean (SE = 0.099, 1.939, 1.783 and 3.133 at 30, 50, 70 DAS and at harvest, respectively)

N_0 = 0 kg N/ha, N_1 = 15 kg N/ha, N_2 = 30 kg N/ha, N_3 = 45 kg N/ha

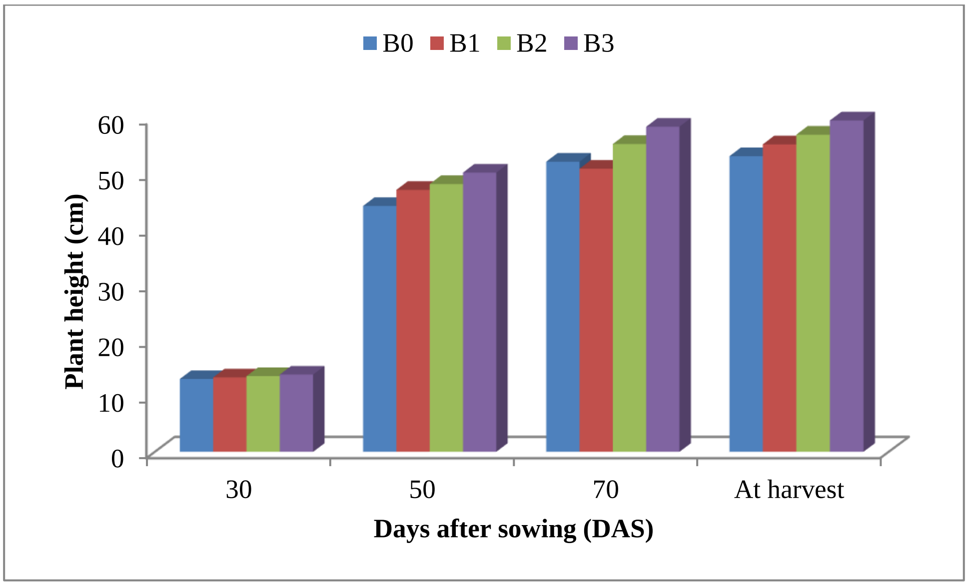

Fig. 3. Response to boron application on plant height of Soybean (SE = 0.552,1.646,1.85 and 1.3950 at 30, 50, 70 DAS and at harvest, respectively)

B_0 = 0 kg B/ha, B_1 = 0.825 kg B/ha, B_2 = 1.65 kg B/ha, B_3 = 2.5 kg B/ha

Table 1. Response to nitrogen and boron application on plant height of Soybean

Treatments	Plant height (cm) at			
	30 DAS	50 DAS	70 DAS	At harvest
N_0B_0	12.40 i	37.33 g	46.17 g	43.08 i
N_0B_1	12.53 hi	41.33 f	37.00 h	47.33 h
N_0B_2	12.60 hi	42.00 ef	44.33 g	47.67 h
N_0B_3	13.27 g	43.17 ef	49.33 f	50.08 g
N_1B_0	12.80 h	42.17 ef	44.83 g	50.92 g
N_1B_1	13.33 g	43.33 ef	49.83 f	51.17 g
N_1B_2	13.53 fg	44.00 e	53.00 e	51.65 g
N_1B_3	13.80 ef	48.00 d	58.00 cd	57.83 ef
N_2B_0	13.60 fg	46.33 d	57.33 d	57.25 f
N_2B_1	13.87 ef	50.50 c	58.33 cd	60.08 de
N_2B_2	14.00 de	50.67 c	58.67 cd	60.67 d
N_2B_3	14.40 bc	54.17 ab	61.83 b	64.00 bc
N_3B_0	14.07 cde	51.17 c	60.33 bc	61.33 d
N_3B_1	14.33 bcd	53.33 b	58.50 cd	62.50 cd
N_3B_2	14.67 ab	55.50 ab	64.50 a	66.25 ab
N_3B_3	14.87 a	56.00 a	65.33 a	68.00 a
SE	0.3105	3.2937	3.7007	2.7899
CV(%)	14.82	12.03	11.82	8.59

N_0 = 0 kg N/ha
N_1 = 15 kg N/ha
N_2 = 30 kg N/ha
N_3 = 45 kg N/ha

B_0 = 0 kg B/ha
B_1 = 0.825 kg B/ha
B_2 = 1.65 kg B/ha
B_3 = 2.5 kg B/ha

4.1.2 Number of leaves/plant

Number of leaves/plant of soybean varied significantly due to different levels of nitrogen treatments at different days after sowing (Figure 4 and Appendix V). At different growth stages, the highest number of leaves/plant (5.27, 16.67, 22.29 and 23.25 at 30, 50, 70 DAS and at harvest, respectively) was obtained from N_3 (45 kg N/ha) followed by N_2 (30 kg N/ha). Similarly, the lowest number of leaves/plant (3.20, 10.04, 19.08 and 16.50 at 30, 50, 70 DAS and at harvest, respectively) was recorded from control treatment, N_0 (0 kg N/ha).

Number of leaves/plant of soybean also varied significantly due to different levels of boron treatments at different days after sowing (Figure 5 and Appendix V). Results revealed that at different growth stages the highest number of leaves/plant (4.62, 14.04, 21.21 and 21.42 at 30, 50, 70 DAS and at harvest, respectively) was obtained from B_3 (2.5 kg B/ha) which was closely followed by B_2 (1.65 kg B/ha) at all growth stages. Likewise, the lowest number of leaves/plant (3.74, 11.75, 20.67 and 19.00 at 30, 50, 70 DAS and at harvest, respectively) was recorded from control treatment, B_0 (0 kg B/ha) followed by B_1 (0.825 kg B/ha).

Interaction effect of different levels of nitrogen and boron application in terms of number of leaves/plant also exposed significant variation at different days after sowing (Appendix V and Table 2). Results signified that the highest number of leaves/plant (5.58, 17.67, 24.33 and 24.00 at 30, 50, 70 DAS and at harvest, respectively) was recorded from N_3B_3 treatment combination which was statistically identical withN_3B_2 and closely followed by N_3B_1 treatment combination. Correspondingly, the lowest number of leaves/plant (2.90, 9.17, 21.83 and 14.83 at 30, 50, 70 DAS and at harvest, respectively) was recorded from N_0B_0 treatment combination which was statistically similar with N_0B_1 followed by N_0B_2 and N_0B_3. The treatment combination of N_2B_1, N_2B_2, and N_2B_3 also gave comparatively higher number of leaves/plant but significantly different from all other treatment combinations.

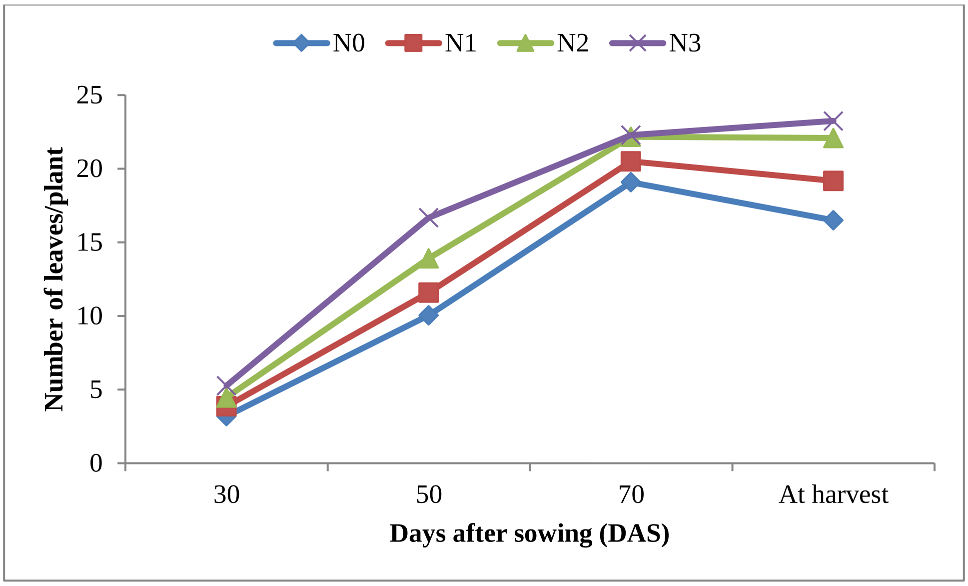

Fig. 4. Response to nitrogen application on number of leaves/plant of Soybean (SE = 0.138, 0.269, 0.317 and 0.276 at 30, 50, 70 DAS and at harvest, respectively)

N_0 = 0 kg N/ha, N_1 = 15 kg N/ha, N_2 = 30 kg N/ha, N_3 = 45 kg N/ha

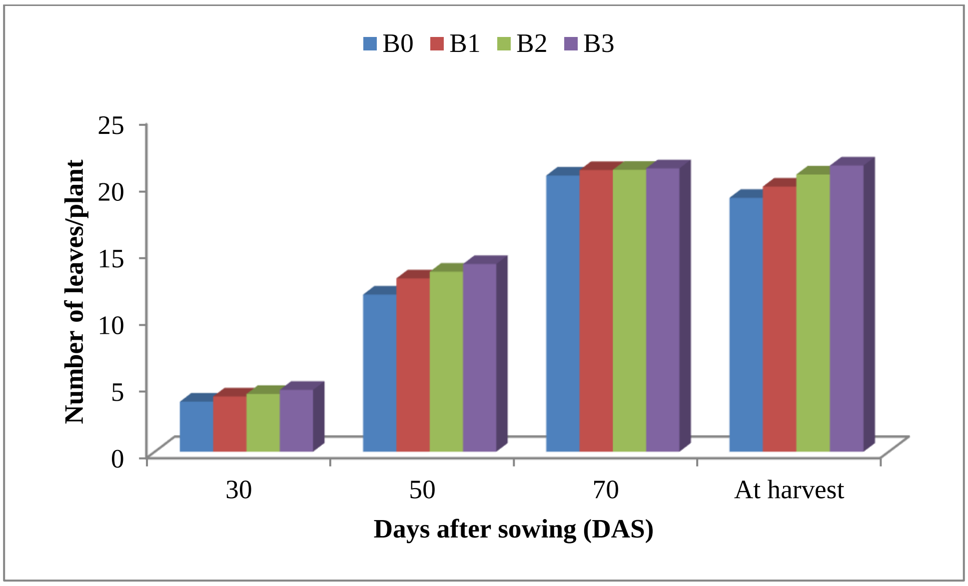

Fig. 5. Response to boron application on number of leaves/plant of Soybean (SE = 0.083, 0.275, 0.326 and 0.290 at 30, 50, 70 DAS and at harvest, respectively)

B_0 = 0 kg B/ha, B_1 = 0.825 kg B/ha, B_2 = 1.65 kg B/ha, B_3 = 2.5 kg B/ha

Table 2. Response to nitrogen and boron application on number of leaves/plant of Soybean

Treatments	Number of leaves/plant at			
	30 DAS	50 DAS	70 DAS	At harvest
N_0B_0	2.90 h	9.17 h	21.83 cd	14.83 g
N_0B_1	3.03 h	9.83 gh	20.83 d	16.17 fg
N_0B_2	3.10 gh	10.17 fgh	23.50 ab	17.33 f
N_0B_3	3.77 efg	11.00 fg	21.83 cd	17.67 ef
N_1B_0	3.30 fgh	10.50 fgh	22.17 bcd	17.50 ef
N_1B_1	3.83 ef	11.33 fg	22.17 bcd	18.00 ef
N_1B_2	4.03 de	11.67 ef	16.33 e	19.33 de
N_1B_3	4.30 cde	12.83 de	17.33 e	21.83 bc
N_2B_0	4.17 cde	12.83 de	17.17 e	21.00 cd
N_2B_1	4.30 cde	13.50 cd	17.50 e	22.00 abc
N_2B_2	4.57 cd	14.33 bc	20.33 d	22.33 abc
N_2B_3	4.83 bc	15.00 b	21.33 d	23.00 abc
N_3B_0	4.57 cd	14.50 bc	21.33 d	22.67 abc
N_3B_1	5.37 ab	17.17 a	24.00 ab	23.17 ab
N_3B_2	5.57 a	17.33 a	24.17 a	23.57 a
N_3B_3	5.58 a	17.67 a	24.33 a	24.00 a
SE	0.175	0.534	0.782	0.634
CV(%)	8.25	10.44	9.36	11.72

N_0 = 0 kg N/ha
N_1 = 15 kg N/ha
N_2 = 30 kg N/ha
N_3 = 45 kg N/ha

B_0 = 0 kg B/ha
B_1 = 0.825 kg B/ha
B_2 = 1.65 kg B/ha
B_3 = 2.5 kg B/ha

4.1.3 Number of branches/plant

Significant influence was found on number of branches/plant of soybean due to different levels of nitrogen treatments at different days after sowing (Figure 6 and Appendix VI). Results confirmed that the highest number of branches/plant (2.68, 2.88, 5.25 and 7.00 at 30, 50, 70 DAS and at harvest, respectively) was obtained from N_3 (45 kg N/ha) followed by N_2 (30 kg N/ha). Similarly, the lowest number of branches/plant (0.38, 0.67, 2.46 and 3.08 at 30, 50, 70 DAS and at harvest respectively) was recorded from control treatment, N_0 (0 kg N/ha). Similar results was found by Umeh *et al*. (2011) and Gan *et al.* (2002).

Number of branches/plant of soybean also significantly influenced by different levels of boron treatments at different days after sowing (Figure 7 and Appendix VI). Results exposed that the highest number of branches/plant (1.96, 2.00, 4.42 and 6.04 at 30, 50, 70 DAS and at harvest, respectively) was obtained from B_3 (2.5 kg B/ha) which was statistically same at 50 and 70 DAS with B_2 (1.65 kg B/ha). Likewise, the lowest number of branches/plant (0.96, 1.08, 3.46 and 4.42 at 30, 50, 70 DAS and at harvest, respectively) was recorded from control treatment, B_0 (0 kg B/ha) followed by B_1 (0.825 kg B/ha). Supported findings was also found by Schon and Blevins (1987).

Interaction effect of different levels of nitrogen and boron application on number of branches/plant also showed significant variation at different days after sowing (Appendix VI and Table. 3). Results signified that the highest number of branches/plant (3.20, 3.50, 5.83 and 7.83 at 30, 50, 70 DAS and at harvest, respectively) was recorded from N_3B_3 treatment combination which was statistically similar with N_3B_2 followed by N_2B_3 treatment combination. Correspondingly, the lowest number of branches/plant (0.00, 0.50, 2.17 and 2.67 at 30, 50, 70 DAS and at harvest, respectively) was recorded from N_0B_0 treatment combination which was statistically similar with N_0B_1 and N_0B_2 followed by N_0B_3, N_1B_0 and N_1B_1.

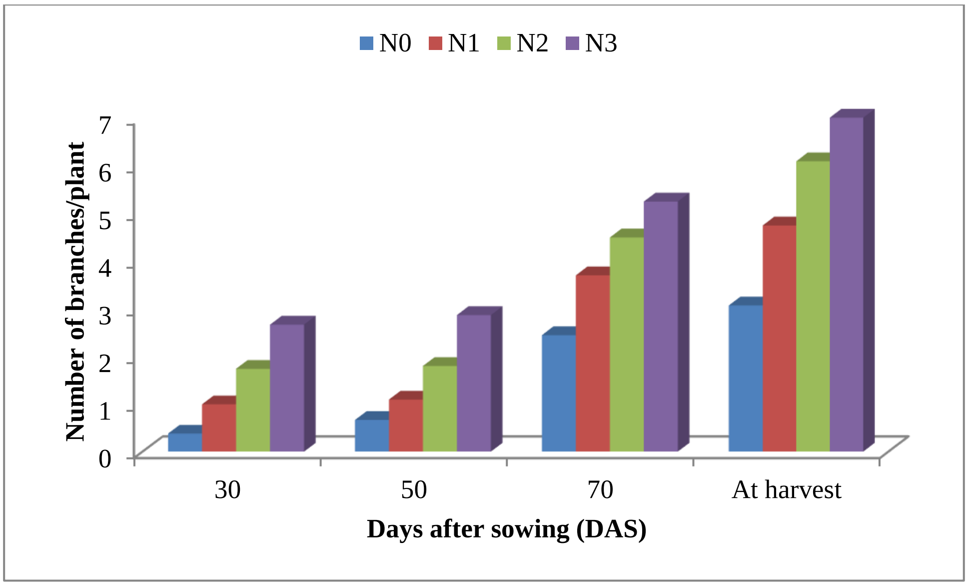

Fig. 6. Response to nitrogen application on number of branches/plant of Soybean (SE = 0.072, 0.092, 0.164 and 0.188 at 30, 50, 70 DAS and at harvest respectively)

N_0 = 0 kg N/ha, N_1 = 15 kg N/ha, N_2 = 30 kg N/ha, N_3 = 45 kg N/ha

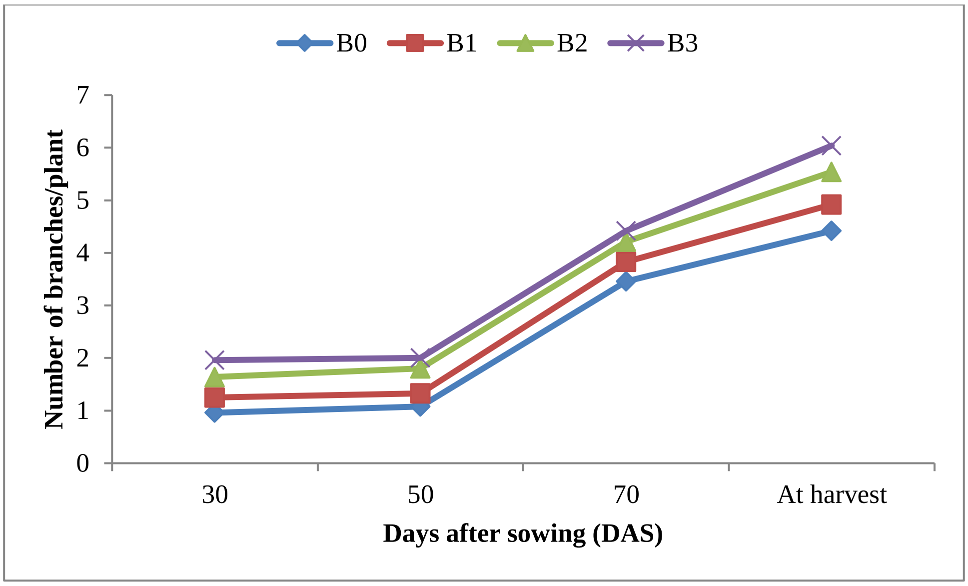

Fig. 7. Response to boron application on number of branches/plant of Soybean (SE = 0.078, 0.102, 0.170 and 0.207 at 30, 50, 70 DAS and at harvest respectively)

B_0 = 0 kg B/ha, B_1 = 0.825 kg B/ha, B_2 = 1.65 kg B/ha, B_3 = 2.5 kg B/ha

Table 3. Response to nitrogen and boron application on number of branches/plant of Soybean

Treatments	Number of branches/plant at			
	30 DAS	50 DAS	70 DAS	At harvest
N_0B_0	0.00 g	0.50 g	2.17 h	2.67 h
N_0B_1	0.00 g	0.67 g	2.33 h	2.83 h
N_0B_2	0.67 f	0.73 g	2.33 h	2.83 h
N_0B_3	0.83 ef	0.87 fg	3.00 g	4.00 g
N_1B_0	0.67 f	0.73 g	2.67 gh	3.17 h
N_1B_1	0.83 f	0.87 fg	3.83 f	4.83 f
N_1B_2	1.17 de	1.27 ef	4.17 ef	5.33 ef
N_1B_3	1.33 d	1.33 de	4.17 ef	5.67 c-e
N_2B_0	1.17 de	1.33 de	4.17 ef	5.50 e
N_2B_1	1.50 d	1.67 cd	4.33 d-f	5.67 de
N_2B_2	1.50 d	1.67 cd	4.50 c-e	6.17 cd
N_2B_3	2.83 b	2.87 ab	5.00 bc	7.00 b
N_3B_0	2.00 c	2.00 bc	4.83 cd	6.33 c
N_3B_1	2.67 b	2.83 ab	4.83 cd	6.33 c
N_3B_2	2.83 b	2.87 ab	5.50 ab	7.50 ab
N_3B_3	3.20 a	3.50 a	5.83 a	7.83 a
SE	0.162	0.208	0.355	0.458
CV(%)	7.44	9.39	11.24	10.49

N_0 = 0 kg N/ha B_0 = 0 kg B/ha
N_1 = 15 kg N/ha B_1 = 0.825 kg B/ha
N_2 = 30 kg N/ha B_2 = 1.65 kg B/ha
N_3 = 45 kg N/ha B_3 = 2.5 kg B/ha

4.1.5 Number of pods/plant

Significant variation was observed for number of pods/plant of soybean due to different levels of nitrogen treatments at different days after sowing (Figure 10 and Appendix VIII). Results indicated that the highest number of pods/plant (22.08, 27.92, 33.42, 38.87 and 42.90 at 50, 55, 60, 65 and 70 DAS, respectively) was obtained from N_2 (30 kg N/ha) which was statistically identical with N_3 (45 kg N/ha) at all growth stages followed by N_1 (15 kg N/ha). Similarly, the lowest number of pods /plant (6.42, 8.33, 10.08, 13.61 and 21.68 at 50, 55, 60, 65 and 70 DAS, respectively) was recorded from control treatment, N_0 (0 kg N/ha). The result obtained from the present study was in conformity with the findings of Ahmad and Ali (2013), *Umeh et al*. (2011) and Soomru *et al.* (2005).

Significant influence was also found by different levels of boron treatments at different days after sowing in terms of number of pods/plant of soybean (Figure 11 and Appendix VIII). Results revealed that the highest number of pods/plant (18.08, 24.25, 28.59, 33.02 and 36.78 at 50, 55, 60, 65 and 70 DAS, respectively) was obtained from B_2 (1.65 kg B/ha) which was closely followed by B_3 (2.5 kg B/ha) at all cropping stages. Likewise, the lowest number of pods/plant (11.08, 13.92, 18.92, 23.64 and 30.47 at 50, 55, 60, 65 and 70 DAS, respectively) was recorded from control treatment, B_0 (0 kg B/ha) followed by B_1 (0.825 kg B/ha). Supported results were also found by Pandey and Gupta (2013).

Number of pods/plant was significantly influenced by interaction effect of different levels of nitrogen and boron application at different days after sowing (Appendix VIII and Table .5). Results signified that the highest number of pods/plant (29.90, 35.33, 40.00, 44.93 and 48.13 at 50, 55, 60, 65 and 70 DAS, respectively) was recorded from N_2B_2 treatment combination which was statistically similarl with N_2B_1 and N_3B_1 at 55, 60 and 65 DAS followed by $N_3B_2$and N_2B_3 treatment combination. Likewise, the lowest number of pods/plant (3.67, 5.00, 6.00, 10.90 and 19.67 at 50, 55, 60, 65 and 70 DAS, respectively) was recorded from N_0B_0 treatment combination which was statistically similar with N_0B_1 and N_0B_2 at 65 and 70 DAS followed by N_0B_3 and N_1B_0.

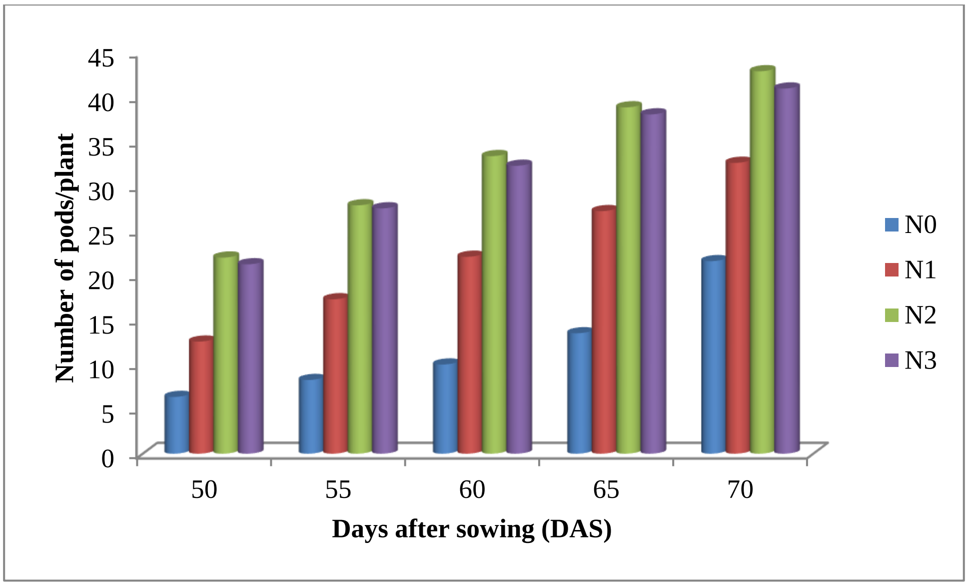

Fig. 8. Response to nitrogen application on number of pods/plant of Soybean (SE = 0.377, 0.628, 1.252, 1.385 and 1.378 at 50, 55, 60, 65 and 70 DAS respectively)

N_0 = 0 kg N/ha, N_1 = 15 kg N/ha, N_2 = 30 kg N/ha, N_3 = 45 kg N/ha

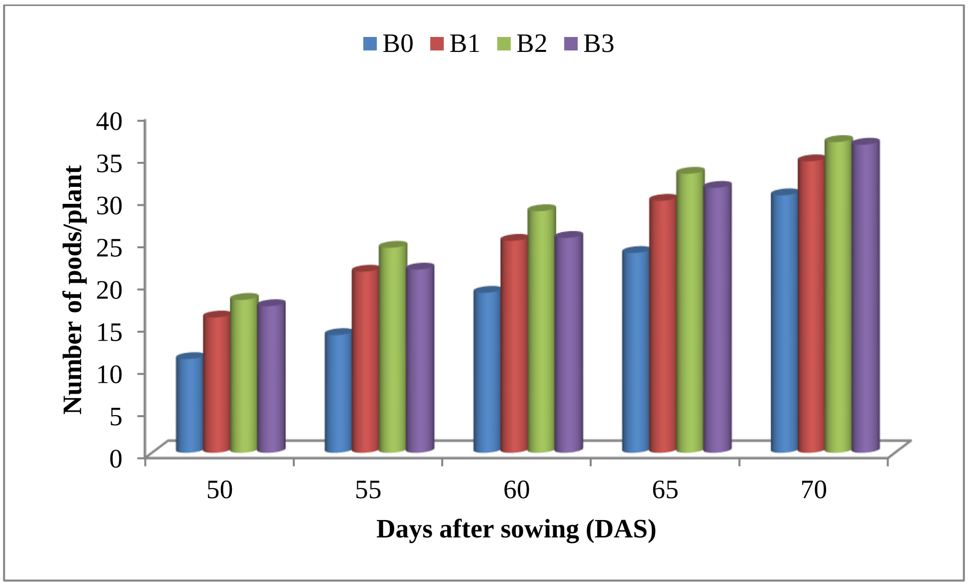

Fig. 9. Response to boron application on number of pods/plant of Soybean (SE = 0.388, 0.467, 0.621, 1.247 and 1.385 at 50, 55, 60, 65 and 70 DAS respectively)

B_0 = 0 kg B/ha, B_1 = 0.825 kg B/ha, B_2 = 1.65 kg B/ha, B_3 = 2.5 kg B/ha

Table .4 Response to nitrogen and boron application on number of pods/plant of Soybean

Treatments	Number of pods/plant at				
	50 DAS	55 DAS	60 DAS	65 DAS	70 DAS
N_0B_0	3.67 i	5.00 g	6.00 h	10.90 h	19.67 h
N_0B_1	5.33 i	7.00 fg	9.00 g	11.50 h	19.93 h
N_0B_2	6.00 hi	8.00 f	9.33 g	11.77 h	20.73 h
N_0B_3	10.67g	13.33 e	16.00 e	20.27 g	26.40 g
N_1B_0	8.00 h	9.00 f	13.33 f	17.90 g	25.88 g
N_1B_1	14.67f	21.00 c	26.67 c	33.20 d	35.40 de
N_1B_2	10.67 g	16.00 d	20.33 d	24.00 f	32.60 f
N_1B_3	17.33 e	23.67 b	28.33 bc	33.97 d	36.80 de
N_2B_0	12.33 g	16.00 d	26.33 c	28.40 e	34.07 ef
N_2B_1	26.00 b	34.33 a	39.00 a	43.50 a	44.67 bc
N_2B_2	29.00 a	35.33 a	40.00 a	44.93 a	48.13 a
N_2B_3	18.00 e	24.67 b	28.33 bc	35.47 cd	37.00 d
N_3B_0	20.33 d	25.67 b	30.00 b	37.37 bc	42.27 c
N_3B_1	26.33 b	34.67 a	39.67 a	43.87 a	47.13 ab
N_3B_2	23.67 c	26.33 b	30.67 b	38.57 b	44.40 bc
N_3B_3	18.00 de	25.00 b	29.00 bc	35.67 cd	37.80 d
SE	0.794	1.016	1.342	2.558	2.667
CV(%)	8.59	11.25	7.33	10.42	13.37

N_0 = 0 kg N/ha　　B_0 = 0 kg B/ha
N_1 = 15 kg N/ha　　B_1 = 0.825 kg B/ha
N_2 = 30 kg N/ha　　B_2 = 1.65 kg B/ha
N_3 = 45 kg N/ha　　B_3 = 2.5 kg B/ha

4.2 Yield contributing parameters

4.2.1 Pod length

Significant variation was observed on pod length of soybean due to different levels of nitrogen treatments (Table 6 and Appendix IX). Results indicated that the highest pod length (3.56 cm) was obtained from N_2 (30 kg N/ha) which was statistically Similar with N_3 (45 kg N/ha) followed by N_1 (15 kg N/ha). Similarly, the lowest pod length (3.25 cm) was recorded from control treatment, N_0 (0 kg N/ha). Similar results was also observed by Ahmad and Ali (2013).

Significant influence was also found by different levels of boron treatments in terms of pod length of soybean (Table 7 and Appendix IX). Results revealed that the highest pod length (3.46 cm) was obtained from B_2 (1.65 kg B/ha) which was statistically identical with B_1 (0.825 kg B/ha) and B_3 (2.5 kg B/ha) ($LSD_{0.05}$ = 0.101). Likewise, the lowest pod length (3.34 cm) was recorded from control treatment, B_0 (0 kg B/ha). The attained result from the present study was similar with the findings of Pandey and Gupta (2013).

Pod length was significantly influenced by interaction effect of different levels of nitrogen and boron application (Table 8 and Appendix IX). Results signified that the highest pod length (3.68 cm) was recorded from N_2B_2 treatment combination which was statistically similar with N_2B_1 and N_3B_1 followed by N_3B_0, N_3B_2 and N_3B_3 treatment combination. Likewise, the lowest pod length (3.20 cm) was recorded from N_0B_0 treatment combination which was statistically similar with N_0B_1, N_0B_2 and N_1B_0 followed by N_0B_3, N_1B_1 and N_1B_2.

4.2.2 Number of seeds/pod

In terms of number of seeds/pod of soybean, significant variation was observed due to different levels of nitrogen treatments (Table 6 and Appendix IX). Results revealed that the highest number of seeds/pod (2.73) was obtained from N_2 (30 kg N/ha) which was statistically similar with N_3 (45 kg N/ha). Similarly, the lowest number of seed/pod (2.47) was recorded from control treatment, N_0 (0 kg N/ha). The result obtained from the present study was similar with the findings of Agha *et al.* (2004).

Significant influence was also found by different levels of boron treatments for number of seed/pod of soybean (Table 7 and Appendix IX). Results showed that the highest number of seeds/pod (2.67) was obtained from B_2 (1.65 kg B/ha) which was statistically similar with B_1 (0.825 kg B/ha) and B_3 (2.5 kg B/ha). Likewise, the lowest number of seeds/pod (2.55) was recorded from control treatment, B_0 (0 kg B/ha). The achieved result from the present study was similar with the findings of Pandey and Gupta (2013).

Number of seeds/pod was significantly influenced by interaction effect of different levels of nitrogen and boron application (Table 8 and Appendix IX). Results signified that the highest number of seed/pod (2.87) was recorded from N_2B_2 treatment combination in comparison with N_2B_1, N_3B_0, N_3B_1, N_3B_2 and N_3B_3 treatment combination. Likewise, the lowest number of seeds/pod (2.40) was recorded from N_0B_0 treatment combination which was statistically similar with N_0B_1, N_0B_2 and N_1B_0 followed by N_0B_3, and N_1B_2.

4.2.3 Weight of 1000 seeds(g)

Weight of 1000 seeds of soybean was significantly varied with different levels of nitrogen treatments (Table 6 and Appendix IX). Results revealed that the highest 1000 seed weight (109.58 g) was obtained from N_2 (30 kg N/ha) followed by N_3 (45 kg N/ha). Similarly, the lowest 1000 seed weight (72.00 g) was recorded from control treatment, N_0 (0 kg N/ha) and the second lowest by N_1 (15 kg N/ha).

Significant influence was also found by different levels of boron treatments for 1000 seed weight of soybean (Table 7 and Appendix IX). Results showed that the highest 1000 seed weight (100.25 g) was obtained from B_2 (1.65 kg B/ha) which was statistically similar with B_1 (0.825 kg B/ha). Likewise, the lowest 1000 seed weight (80.92 g) was recorded from control treatment, B_0 (0 kg

B/ha) followed by B_3 (2.5 kg B/ha). Supported findings was also observed by Crak *et al.* (2006).

Weight of 1000 seeds was significantly influenced by interaction effect of different levels of nitrogen and boron application (Table 8 and Appendix IX). Results signified that the highest 1000 seed weight (120.10 g) was recorded from N_2B_2 treatment combination which was statistically identical with N_3B_1 and statistically similar with N_3B_2. Accordingly, the lowest 1000 seed weight (61.00) was recorded from N_0B_0 treatment combination which was statistically similar with N_0B_1 followed by N_0B_2, N_0B_3, N_1B_0, N_1B_2 and N_2B_0.

Table 5. Response to nitrogen application on yield contributing parameters of Soybean

Treatments	Yield contributing parameters		
	Pod length (cm)	Number of seeds/pod	1000 seed weight (g)
N_0	3.25c	2.47c	72.00d
N_1	3.35b	2.60b	88.42c
N_2	3.56 a	2.73 a	109.58 a
N_3	3.53 a	2.72 a	103.42 b
SE	0.071	0.063	2.348
CV(%)	4.76	5.27	7.21

N_0 = 0 kg N/ha, N_1 = 15 kg N/ha, N_2 = 30 kg N/ha, N_3 = 45 kg N/ha

Table 6 Response to boron application on yield contributing parameters of Soybean.

Treatments	Yield contributing parameters		
	Pod length (cm)	Number of seeds/pod	1000 seed weight (g)
B_0	3.34 b	2.55 b	80.92c
B_1	3.45 a	2.65 a	98.42a
B_2	3.46 a	2.67 a	100.25 a
B_3	3.45 a	2.65 a	93.83b
SE	0.084	0.071	2.338
CV(%)	5.87	6.39	8.12

B_0 = 0 kg B/ha, B_1 = 0.825 kg B/ha, B_2 = 1.65 kg B/ha, B_3 = 2.5 kg B/ha

Table 7. Response to nitrogen and boron application on yield contributing parameters of Soybean.

Treatments	Yield contributing parameters		
	Pod length (cm)	Number of seeds/pod	1000 seed weight (g)
N_0B_0	3.20 f	2.40 f	61.00 e
N_0B_1	3.22 f	2.47 ef	65.00 e
N_0B_2	3.22 f	2.47 ef	81.00 d
N_0B_3	3.37 e	2.53 de	81.00 d
N_1B_0	3.23 f	2.47 ef	81.00 d
N_1B_1	3.38 e	2.67 bc	94.67 c
N_1B_2	3.37 e	2.60 cd	82.33 d
N_1B_3	3.43 de	2.67 bc	95.67 c
N_2B_0	3.37 e	2.60 cd	81.33 d
N_2B_1	3.59 ab	2.73 b	114.00 b
N_2B_2	3.68 a	2.87 a	120.10 a
N_2B_3	3.47 cde	2.67 bc	98.33 c
N_3B_0	3.54 bc	2.73 b	100.30 c
N_3B_1	3.60 ab	2.73 b	120.00 a
N_3B_2	3.57 bc	2.73 b	117.00 ab
N_3B_3	3.51 bcd	2.73 b	100.00 c
SE	0.166	0.152	4.655
CV(%)	5.87	6.39	8.12

N_0 = 0 kg N/ha	B_0 = 0 kg B/ha
N_1 = 15 kg N/ha	B_1 = 0.825 kg B/ha
N_2 = 30 kg N/ha	B_2 = 1.65 kg B/ha
N_3 = 45 kg N/ha	B_3 = 2.5 kg B/ha

4.3 Yield parameters

4.3.1 Seed yield

Seed yield/ha of soybean was significantly influenced by different levels of nitrogen treatments (Table 9 and Appendix X). Results revealed that the highest seed yield (1249.17 kg/ha) was obtained from N_2 (30 kg N/ha) followed by N_3 (45 kg N/ha). Similarly, the lowest seed yield (714.17 kg/ha) was recorded from control treatment, N_0 (0 kg N/ha) followed by N_1 (15 kg N/ha). The result obtained from the present study was in conformity with the findings of Wingeyer *et al.* (2014), Wilson *et al.* (2014) and Umeh *et al.* (2011).

Significant influence was also found by different levels of boron treatments for seed yield of soybean (10 and Appendix X). Results showed that the highest seed yield (1116.67 kg/ha) was obtained from B_2 (1.65 kg B/ha) followed by B_3 (2.5 kg B/ha) and B_1 (0.825 kg B/ha). Likewise, the lowest seed yield (810.83 kg/ha) was recorded from control treatment, B_0 (0 kg B/ha). The obtained yield from the present study was similar with the findings of Pandey and Gupta (2013) and Quddus *et al.* (2011).

Interaction effect of different levels of nitrogen and boron application had significantly influence on seed yield soybean (Table 11 and Appendix X). Results signified that the highest seed yield (1453.33 kg/ha) was recorded from N_2B_2 treatment combination where the 2^{nd} and 3^{rd} highest seed yield 1443.33 kg/ha and 1280 kg/ha respectively were achieved from N_2B_1 and N_2B_3 respectively. Accordingly, the lowest seed yield (540 kg/ha) was recorded from N_0B_0 treatment combination followed by 2^{nd} and 3^{rd} lowest seed yield (653.33 kg/ha and 683.33 kg/ha respectively) were obtained from N_0B_1 and N_0B_2 respectively.

4.3.2 Stover yield

Stover yield/ha of soybean was significantly influenced by different levels of nitrogen treatments (Table 9 and Appendix X). Results revealed that the highest stover yield (1661.17 kg/ha) was obtained from N_2 (30 kg N/ha)followed by N_3 (45 kg N/ha) and N_1 (15 kg N/ha). On the other hand, the lowest stover yield (1055.75 kg/ha) was recorded from control treatment, N_0 (0 kg N/ha).

Significant influence was also found by different levels of boron treatments for stover yield of soybean (Table 10 and Appendix X). Results showed that the highest Stover yield (1508.25 kg/ha) was obtained from B_2 (1.65 kg B/ha) followed by B_3 (2.5 kg B/ha) and B_1 (0.825 kg B/ha). Similarly, the lowest stover yield (1152.42 kg/ha) was recorded from control treatment, B_0 (0 kg B/ha).

Interaction effect of different levels of nitrogen and boron application had significantly influence on stover yield of soybean (Table 11 and Appendix X). Results signified that the highest stover yield (1768 kg/ha) was recorded from N_2B_2 treatment combination which was statistically similar with N_2B_1 followed by N_3B_1 and N_3B_2. Consequently, the lowest stover yield (880 kg/ha) was recorded from N_0B_0 treatment combination followed by N_0B_1 and N_1B_0.

4.3.3 Harvest index

Harvest index was significantly influenced by different levels of nitrogen treatments (Table 9 and Appendix X). Results revealed that the highest harvest index (45.43%) was obtained from N_2 (30 kg N/ha) where the lowest harvest index (40.38%) was recorded from control treatment, N_0 (0 kg N/ha) followed by N_1 (15 kg N/ha) and N_3 (45 kg N/ha).

Significant influence was not found by different levels of boron treatments for harvest index of soybean (Table 10 and Appendix X). But results showed that the highest harvest index (42.70%) was obtained from B_2 (1.65 kg B/ha) where the lowest harvest index (42.31%) was recorded from control treatment, B_0 (0 kg B/ha).

Interaction effect of different levels of nitrogen and boron application had significant influence on harvest index of soybean (Table 11 and Appendix X). Results signified that the highest harvest index (45.23%) was recorded from N_2B_2 treatment combination was statistically similar with N_2B_1 followed by N_2B_3. Accordingly, the lowest harvest index (38.52%) was recorded from N_0B_0 treatment combination followed by N_0B_2, N_1B_3 and N_2B_0.

Table 8. Response to nitrogen application on yield and harvest index of Soybean.

Treatments	Seed Yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
N_0	714.17 d	1055.75 d	40.38 c
N_1	835.00 c	1212.42 c	41.53 b
N_2	1249.17 a	1661.17 a	45.43 a
N_3	1213.33 b	1561.83 b	42.83 b
SE	18.644	22.389	2.658
CV(%)	10.76	13.38	7.43

N_0 = 0 kg N/ha, N_1 = 15 kg N/ha, N_2 = 30 kg N/ha, N_3 = 45 kg N/ha

Table 09. Response to boron application on yield and harvest index of Soybean.

Treatment	Seed Yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
B_0	810.83 d	1152.42 d	42.31
B_1	1016.67 c	1403.33 c	42.50
B_2	1116.67 a	1508.25 a	42.70
B_3	1067.50 b	1427.17 b	42.67
SE	19.384	21.637	NS
CV(%)	11.35	14.83	8.38

B_0 = 0 kg B/ha, B_1 = 0.825 kg B/ha, B_2 = 1.65 kg B/ha, B_3 = 2.5 kg B/ha

Table 10. Response to nitrogen and boron application on yield parameters of Soybean.

Treatments	Seed Yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
N_0B_0	540.00 p	880.00 m	38.52 k
N_0B_1	653.33 o	974.00 l	40.22 h
N_0B_2	683.33 n	1060.00 k	39.28 i
N_0B_3	980.00 i	1309.00 h	43.50 d
N_1B_0	703.33 m	983.00 l	42.17 e
N_1B_1	920.00 j	1246.67 i	43.57 cd
N_1B_2	716.67 l	1093.33 j	41.29 g
N_1B_3	1000.00 h	1526.67 g	39.09 ij
N_2B_0	820.00 k	1306.67 h	39.11 in
N_2B_1	1443.33 b	1762.00 a	44.92 a
N_2B_2	1453.33 a	1768.00 a	45.23 a
N_2B_3	1280.00 c	1644.00 e	43.80 b
N_3B_0	1180.00 g	1673.33 d	42.32 e
N_3B_1	1253.33 d	1726.00 b	41.96 ef
N_3B_2	1213.33 e	1692.00 c	43.45 d
N_3B_3	1206.67 f	1553.33 f	43.60 cd
SE	36.114	42.859	4.267
CV(%)	11.35	14.83	8.38

N_0 = 0 kg N/ha　　B_0 = 0 kg B/ha
N_1 = 15 kg N/ha　　B_1 = 0.825 kg B/ha
N_2 = 30 kg N/ha　　B_2 = 1.65 kg B/ha
N_3 = 45 kg N/ha　　B_3 = 2.5 kg B/ha

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2015 to December 2015 to study the yield response to nitrogen and boron application in soybean. Under the present investigation, four (4) nitrogen (N) levels *viz*., (i) N_0 = 0 kg N/ha, (ii) N_1 = 15 kg N/ha, (iii) N_2 = 30 kg N/ha and (iv) N_3 = 45 kg N/ha and four (4) levels of boron (B) *viz*., (i) B_0 = 0 kg B/ha, (ii) B_1 = 0.825kg B/ha, (iii) B_2 = 1.65 kg B/ha and (iv) B_3 = 2.5 kg B/ha were used. The experiment was laid out in a split plot design with three replications. The size of the individual plot was 2m × 2m and total numbers of plots were 48. There were 16 treatment combinations. Data were collected on growth, yield and yield contributing parameters with 5 days interval and at harvest.

The study revealed that doses of N and B significantly affected growth and yield of soybean. In case of N effect, it was found that the highest plant height (14.48, 54.00, 62.17 and 64.52 cm at 30, 50, 70 DAS and at harvest, respectively), number of leaves/plant (5.27, 16.67, 22.29 and 23.25 at 30, 50, 70 DAS and at harvest, respectively) and number of branches/plant (2.68, 2.88, 5.25 and7.00 at 30, 50, 70 DAS and at harvest, respectively) were obtained from N_3 (45 kg N/ha) and number of pods/plant (22.08, 27.92, 33.42, 38.87 and 42.90 at 30, 35, 40, 45 and 50 DAS, respectively) were obtained from N_2 (30 kg N/ha) where the lowest plant height (12.70, 40.96, 44.21 and 47.04 cm at 30, 50, 70 DAS and at harvest respectively), number of leaves/plant (3.20, 10.04, 19.08 and 16.50 at 30, 50, 70 DAS and at harvest, respectively), number of branches/plant (0.38, 0.67, 2.46 and 3.08 at 30, 50, 70 DAS and at harvest, respectively), number of pods/plant (6.42, 8.33, 10.08, 13.61 and 21.68 at 50, 55, 60, 65 and 70 DAS, respectively) were recorded from control treatment, N_0 (0 kg N/ha). Moreover, the highest pod length (3.56 cm), number of seeds/pod (2.73), 1000 seed weight (109.58 g), seed yield (1249.17 kg/ha), stover yield (1661.17 kg/ha) and harvest index (45.43%) were obtained from N_2 (30 kg

N/ha) but the lowest pod length (3.25 cm), lowest number of seeds/pod (2.47), lowest 1000 seed weight (72.00 g), lowest seed yield (714.17 kg/ha), lowest stover yield (1055.75 kg/ha) and the lowest harvest index (40.38%) were recorded from control treatment, N_0 (0 kg N/ha).

In case of different doses of boron application to the soil, the highest plant height (14.03, 50.21, 58.42 and 59.54 cm at 30, 50, 70 DAS and at harvest, respectively), number of leaves/plant (4.62, 14.04, 21.21 and 21.42 at 30, 50, 70 DAS and at harvest, respectively), number of branches/plant (1.96, 2.00, 4.42 and 6.04 at 30, 50, 70 DAS and at harvest, respectively) were obtained from B_3 (2.5 kg B/ha) but the highest number of pods/plant (18.08, 24.25, 28.59, 33.02 and 36.78 at 30, 35, 40, 45 and 50 DAS, respectively), pod length (3.46 cm), number of seeds/pod (2.67), 1000 seed weight (100.25 g), seed yield (1116.67 kg/ha), stover yield (1508.25 kg/ha) and harvest index (42.70%) were obtained from B_2 (1.65 kg B/ha) where the lowest plant height (13.22, 44.25, 52.17 and 53.15 cm at 30, 50, 70 DAS and at harvest, respectively), number of leaves/plant (3.74, 11.75, 20.67 and 19.00 at 30, 50, 70 DAS and at harvest, respectively), number of branches/plant (0.96, 1.08, 3.46 and 4.42 at 30, 50, 70 DAS and at harvest respectively), number of pods/plant (11.08, 13.92, 18.92, 23.64 and 30.47 at 50, 55, 60, 65 and 70 DAS, respectively), pod length (3.34 cm), number of seeds/pod (2.55), 1000 seed weight (80.92 g), seed yield (810.83 kg/ha), stover yield (1152.42 kg/ha) and harvest index (42.31%) were recorded from control treatment, B_0 (0 kg B/ha)

In terms of interaction effect of N and B, results showed that the highest plant height (14.87, 56.00, 65.33 and 68.00 cm at 30, 50, 70 DAS and at harvest, respectively), number of leaves/plant (5.58, 17.67, 24.33 and 24.00 at 30, 50, 70 DAS and at harvest, respectively) and number of branches/plant (3.20, 3.50, 5.83 and 7.83 at 30, 50, 70 DAS and at harvest, respectively) were recorded from N_3B_3 and the highest number of pods/plant (29.90, 35.33, 40.00, 44.93 and 48.13 at 50, 55, 60, 65 and 70 DAS, respectively) was recorded from N_2B_2.

Moreover, the highest pod length (3.68 cm), number of seeds/pod (2.87), 1000 seed weight (120.10 g), seed yield (1453.33 kg/ha), stover yield (1768 kg/ha) and the highest harvest index (45.23%) were also recorded from N_2B_2. Similarly, the lowest plant height (12.40, 37.33, 46.17 and 43.08 cm at 30, 50, 70 DAS and at harvest, respectively), number of leaves/plant (2.90, 9.17, 21.83 and 14.83 at 30, 50, 70 DAS and at harvest, respectively), number of branches/plant (0.00, 0.50, 2.17 and 2.67 at 30, 50, 70 DAS and at harvest respectively) and the lowest number of pods/plant (3.67, 5.00, 6.00, 10.90 and 19.67 at 30, 35, 40, 45 and 50 DAS respectively) were recorded from N_0B_0. The lowest pod length (3.20 cm), number of seed/pod (2.40), 1000 seed weight (61.00), seed yield (540 kg/ha), stover yield (880 kg/ha) and lowest harvest index (38.52%) were also recorded from N_0B_0.

However on the basis of the findings, the following conclusion could be made:

Among the levels of nitrogen 30 kg N/ha resulted highest seed yield (1249.17 kg/ha) and among the levels of boron 1.65 kg/ha of ‘B’ attributed to highest seed yield (1116.67 kg/ha) of soybean. Combination of 30 kg N with 1.65 kg B per ha attributed to highest seed yield (1453.33 kg/ha) and this combination could be practiced for yield optimization in soil of our study in Bangladesh.

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APPENDICES

Appendix l: Experimental site showing in the map under the present study

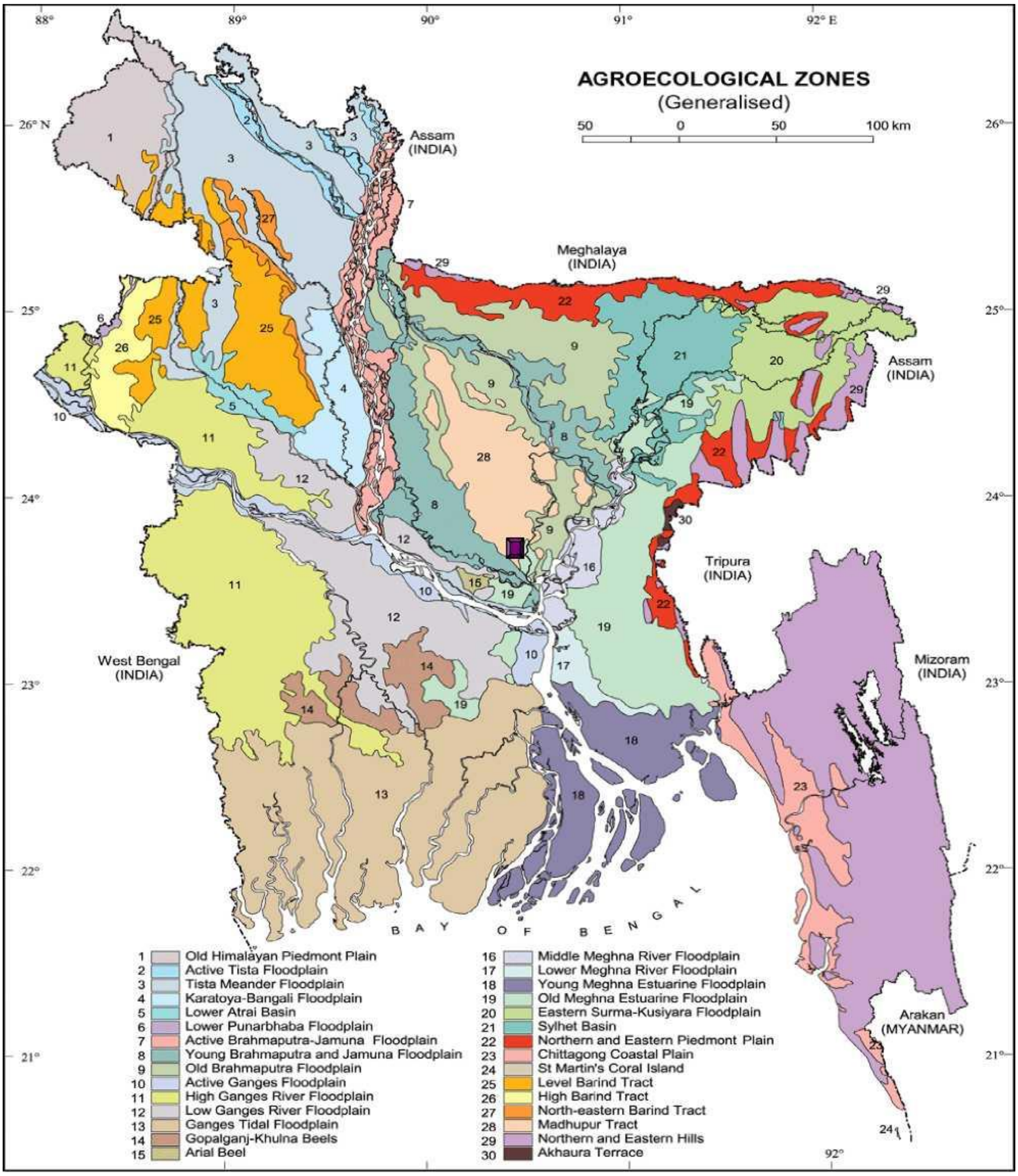

Fig. 10. Map of Bangladesh remarked with study area

Appendix II.Monthly records of Temperature, Rainfall, and Relative humidity of the experiment site during the period from October 2015 to December 2015

Year	Month	Air Temperature (^{0}c)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2015	October	30.5	20.5	25.5	71.0	3.0	218.5
2015	November	29.5	18.6	24.0	69.5	0.0	233.2
2015	December	26.9	16.2	21.5	68.6	0.0	210.5

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

Appendix III. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

Constituents	:	0-15 cm depth
P^H	:	5.45-5.61
Total N (%)	:	0.07
Available P (µ g/g)	:	18.49
Exchangeable K (µ g/g)	:	0.07
Available S (µ g/g)	:	20.82
Available Fe (µ g/g)	:	229
Available Zn (µ g/g)	:	4.48
Available Mg (µ g/g)	:	0.825
Available Na (µ g/g)	:	0.32
Available B (µ g/g)	:	0.94
Organic matter (%)	:	0.83

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

Appendix IV: Soybean yield response to nitrogen and boron application on plant Height

Source of variation	Degrees of freedom	Mean square of plant height			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	0.531	3.688	3.396	5.538
Factor A	3	7.103*	41.201*	37.958*	30.162*
Error	6	0.120	45.118	28.167	17.750
Factor B	3	1.443**	13.868*	13.917*	8.942*
AB	9	0.085**	3.382**	7.162*	7.548*
Error	24	0.289	3.545	4.085	3.351

Appendix V: Soybean yield response to nitrogen and boron application on number of leaves/plant

Source of variation	Degrees of freedom	Number of leaves/plant			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	1.112	2.311	1.412	3.111
Factor A	3	11.112*	14.322*	17.412*	14.141*
Error	6	1.114	5.136	8.140	7.115
Factor B	3	2.226*	8.551**	10.326*	9.414**
AB	9	0.115*	2.226*	5.114**	6.752*
Error	24	0.139	2.663	3.551	3.743

Appendix VI: Soybean yield response to nitrogen and boron application on number of branches/plant

Source of variation	Degrees of freedom	Mean square of number of branches/plant			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	0.154	0.015*	0.944	0.627
Factor A	3	7.588*	4.058*	8.618*	5.500*
Error	6	1.142	7.552	8.319	7.113
Factor B	3	13.54*	9.797*	10.89**	8.675*
AB	9	8.473**	2.340*	9.439*	12.96*
Error	24	0.111	1.170	1.167	2.039

Appendix VII: Soybean yield response to nitrogen and boron application on number of pods/plant

Source of variation	Degrees of freedom	Mean square of number of pods/plant				
		30 DAS	35 DAS	40 DAS	45 DAS	50 DAS
Replication	2	1.009	2.099	20.203	1.087	2.040
Factor A	3	11.090*	11.514*	12.887*	13.794 *	11.404*
Error	6	1.436	3.119	6.624	4.577	5.214
Factor B	3	12.706**	8.103*	10.71*	14.245*	15.610*
AB	9	6.213*	10.184**	7.694*	9.405*	12.644**
Error	24	2.003	2.013	3.394	2.039	3.016

Appendix VIII: Soybean yield response to nitrogen and boron application on yield contributing parameters

Source of variation	Degrees of freedom	Mean square of yield contributing parameters		
		Pod length	Number of seeds/pod	1000 seed weight
Replication	2	1.291	1.027	3.040
Factor A	3	1.144*	1.085*	6.404*
Error	6	0.436	1.119	2.624
Factor B	3	1.048*	1.623*	10.610*
AB	9	0.685**	0.525**	9.644**
Error	24	0.247	0.265	3.016

Appendix IX: Soybean yield response to nitrogen and boron application on yield and harvest index

Source of variation	Degrees of freedom	Mean square of yield and harvest index		
		Seed Yield	Stover yield	Harvest index
Replication	2	4.003	5.023	1.294
Factor A	3	114.345*	118.220*	2.642*
Error	6	11.436	13.119	6.624
Factor B	3	213.83*	237.77*	9.900*
AB	9	318.742*	232.208**	7.742*
Error	24	12.061	14.022	1.823

LIST OF PLATES

Plate 1: Signboard of experiment field

Plate 2: Field view of the experiment field

Plate 3: Best treatment of the experiment field (N_2B_2)

Plate 4: Control treatment of the experiment field (N_0B_0)

Plate 5: Best treatment of the experiment field showing pods/plant (N_2B_2)

Plate 6: Control treatment of the experiment field showing pods/plant (N_0B_0)