EFFECT OF NITROGEN LEVELS AND TIME OF APPLICATIONS ON YIELD AND QUALITY OF SOYBEAN

ZAKIA AKTHER

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

JUNE, 2014

EFFECT OF NITROGEN LEVELS AND TIME OF APPLICATIONS ON YIELD AND QUALITY OF SOYBEAN

BY
ZAKIA AKTHER
Registration No. 07-02485

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree
of

MASTER OF SCIENCE (M.S)
IN
AGRONOMY

SEMESTER: JANUARY - JUNE, 2014

Approved by:

Prof. Dr.Tuhin Suvra Roy	**Prof. Dr.Md.Fazlul Karim**
Supervisor	**Co-Supervisor**

Dr. H. M. M. Tariq Hossain
Chairman
Examination committee

DEPARTMENT OF AGRONOMY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
PABX: 9110351 & 9144270-79

CERTIFICATE

This is to certify that the thesis entitled **" EFFECT OF NITROGEN LEVELS AND TIME OF APPLICATIONS ON YIELD AND QUALITY OF SOYBEAN"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **AGRONOMY**, embodies the results of a piece of *bona fide* research work carried out by, **ZAKIA AKTHER Registration. No. 07-02485,** under my supervision and guidance. No part of this 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:

Dhaka, Bangladesh

Supervisor
Prof. Dr. Tuhin Suvra Roy
Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka-1207

Dedicated

To My

Beloved Parents

ACKNOWLEDGEMENTS

At every moment I would like to express my profound gratefulness to the Almighty Allah, the merciful and the Beneficent to all creations for blessing to present this thesis.

The Author wishes to express her sincere gratitude and indebtedness to her honorable teacher and research Supervisor Professor Dr. Tuhin Suvra Roy Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for her scholastic guidance, outstanding assistance, valuable advice and suggestions for the successful completion of the research work and preparation of this manuscript.

She sincerely expresses her heartfelt gratitude and deepest sense to her Co-Supervisor, Professor Dr. Md. Fazlul Karim , Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for her co-operation and constructive suggestions in all phases of the research.

The Author wishes to pay her gratefulness to other honorable teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for their valuable suggestions during the study period and research work.

She is grateful to her friends for their encouragement and inspiration. The Author is also grateful to her parents and younger brother.

The author also acknowledges the SAURES authority for providing budget to successfully conduct the research.

The Author

Date:

EFFECT OF NITROGEN LEVELS AND TIME OF APPLICATIONS ON YIELD AND QUALITY OF SOYBEAN

By

Zakia Akther

ABSTRACT

A field experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka during January 2013 to March 2013,to find out the effect of 4 nitrogen levels viz., N_1 (10 kg ha^{-1}), N_2 (20 kg ha^{-1}), N_3 (30 kg ha^{-1}), N_4 (40 kg ha^{-1}) and different splitting of nitrogen viz., $S_{1=}$ (split application at basal), $S_{2=}$ (split application at basal and at 10 DAS), $S_{3=}$ (split application at basal, at 10 DAS and at 20 DAS) and $S_{4\ =}$(split application at basal, at 10 DAS, at 20 DAS and at 30 DAS) on the seed yield and quality of soybean. The application of nitrogen levels had significant effect on yield and quality contributing parameters of soybean irrespective of splitting of nitrogen. Application of 40 kg ha^{-1} exhibited the best performance for all growth, yield and seed quality of soybean. From 4 split N application (at basal, at 10 DAS, at 20 DAS and at 30 DAS) showed best results whereas lowest in split application at basal. Out of 16 treatment combinations, 40 kg ha^{-1} with 4 split application at basal, at 10 DAS, at 20 DAS and at 30 DAS of nitrogen performed the best in terms of yield and quality of soybean. The maximum yield (2.29 t ha^{-1}) was obtained by 40 kg N ha^{-1} with 4 split application at basal, at 10 DAS, at 20 DAS and at 30 DAS. The maximum protein percentages (40.79%) was found in N_4S_3 combination whereas the minimum (36.10%) was in N_1S_3. These results indicated that the application of 40 kg N ha^{-1} with 4 split application (at basal, at 10 DAS, at 20 DAS and at 30 DAS) would be best for maximizing the seed yield and quality of soybean.

LIST OF CONTENTS

LIST OF CONTENT (Cont'd)

LIST OF CONTENT (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
Anon.	Anonymous
BBS	Bangladesh Bureau of Statistics
BCSRI	Bangladesh Council of Scientific Research Institute
cm	Centimeter
CV %	Percent Coefficient of Variation
DAT	Days After Transplanting
DMRT	Duncan's Multiple Range Test
et al.	And others
e.g.	exempli gratia (L), for example
etc.	Etcetera
FAO	Food and Agricultural Organization
g	Gram (s)
HCl	Hydrochloric Acid
i.e.	id est (L), that is
Kg	Kilogram (s)
KI	Potassium Iodide
LSD	Least Significant Difference
m2	Meter squares
ml	Mili Litre
M.S.	Master of Science
No.	Number
SAU	Sher-e-Bangla Agricultural University
var.	Variety
^{o}C	Degree Celceous
%	Percentage
NaOH	Sodium hydroxide
$NaAsO_2$	Sodium arsenite
GM	Geometric mean
CEC	Cation-exchange capacity
As	Arsenic
mg	Miligram
Na_2HAsO_4	Sodium arsenate
Si	Silicon
DMA	Dimethylarsenic acid
P	Phosphorus
K	Potassium
Ca	Calcium
MPL	Maximum permissible limit
HG-AAS	Hydride Generation–Atomic Absorption Spectroscopy
L	Litre
ICP-MS	Inductivity coupled plasma mass spectrometry
µg	Microgram
S-XRF	Synchrotron-based X-ray fluorescence
DMAA	dimethylarsenic acid
USA	United States of America
WHO	World Health Organization

CHAPTER I

INTRODUCTION

Soybean (*Glycine max.* L.) is one of the most important crops in the world for human being. It is a species of legume native to East Asia, widely grown for its edible bean which has numerous uses. The plant is classed as an oilseed rather than a pulse. Soybean oil and protein content account for about 60% of dry soybeans by weight (protein at 40% and oil at 20%). The remainder consists of 35% carbohydrate and about 5% ash. Soybean is considered by many agencies to be a source of complete protein (Henkel *et al.*, 2000). Soybean is productive and protective agricultural food products and also contributes to maintenance and restoration of soil fertility by biologically fixing a large proportion of atmospheric nitrogen (N). Soybean nitrogen requirement are met in a complex manner, as this crop is capable of utilizing both soil nitrogen and atmospheric nitrogen (Milic *et al.*, 2002). Like other legumes soybean contain symbiotic bacteria called *Rhizobia* within nodules of their root systems. These bacteria have the special ability of fixing nitrogen from atmospheric, molecular nitrogen (N_2) into ammonia (NH_3) (Deacon *et al.*, 1997). Ammonia is then converted to another form, ammonium (NH_4^+), usable by (some) plants. The relative nitrogen supply from these two sources can change widely depending on soil nitrogen supply and conditions for nodule development (Gan *et al.*, 2003). But the ability of soybeans to fix atmospheric N is not always adequate for maximum yield.

Only 25 to 60% of N in soybean dry matter originates from symbiotic N_2 fixation, the remainder comes from soil-N (Harper, 1974). Varvel and Peterson (1992) found that soybean plants act as a sink for soil-N and effectively use N regardless of source. Therefore, N fertilization could benefit soybean. Nitrogen fertilizer has had positive effects on soybean growth and yield (AI-Ithawi *et al.*, 1980; Brevedan *et al.*, 1978;

Eaglcsham *et al.,* 1983; Touchton and Ricker, 1986). While the need for nitrogen is mainly supplied by activities of symbiotic bacteria in root, N application at planting is vital for initial growth of plants when bacteria are not active sufficiently. On the other hand too much N application, early in the growing season, leads to bacteria inaction. Applying sufficient rate of N in this stage is very important since applying too much N leads to environmental pollution, economical loss and bacteria inaction during growth season. The yield potentiality of soybean is about 2.3 t ha^{-1}. However, in farmer's field its average yield is much lower due to lack of improved agronomic practices of which judicious fertilizer application is an important determinant for better performance of soybean. Nitrogen is one of the key elements of soil fertility and also one of the most important nutrient elements affecting the yield of soybean. However, several studies have shown that the symbiotic N-fixation is not able to meet high N-requirement of this crop particularly under the N-deficient conditions. Positive role of nitrogen in increasing yield, protein content and nutrient uptake of soybean is being reported earlier (Duraisami and Mani, 2001).

For increased soybean yield, it is essential to understand the interactions taking place between inorganic N supply and plant growth throughout the entire period of crop development. Over the years, there has been interest in using nitrogen fertilization as a means to increase soybean yield due to the recognition of the large requirement by soybean for high productivity (Yoshihiko and Takaji, 1999). Therefore, Soybean yield could be increased by adding nitrogen fertilizers in critical growth stages of soybean (Laharia *et al*., 2002). Sij *et al*. (1979) showed that N fertilizer application at planting would increase the initial vegetative growth. Starling *et al*. (2000) showed that N in starter fertilizer, at planting, would improve plant growth and yield. Additionally, as the price of N increases, growers will give greater consideration to N management practices that are more efficient and save money. Split application of nitrogen supplies nitrogen according to the demand of a growing crop and can improve nitrogen use efficiency. Split nitrogen (N) applications to soybean are not a very common practice in Bangladesh. However, splitting N applications may decrease the loss of N applied at planting due to denitrification. Not only can crops more efficiently use N when split applications are made, but also total N applied can be decreased with a split application. Split application reduces the risk of losses as leaching. Split application of nitrogen can increase grain yield and grain protein content.

Objectives of the Research work:

1. To study the effect of nitrogen level and application time on yield of soybean.
2. To estimate of nitrogen level and application time of grain protein content.
3. To find the best combination of nitrogen level and splitting number for soybean cultivation.

CHAPTER II

REVIEW OF LITERATURE

Soybean [*Glycine max* (L.)] is one of the most important and widely used pulse crop worldwide. The production level of soybean is very low compared to the other country which never meets the demand of Bangladesh. The reasons behind such low yield are poor fertilizer management, lack of high yielding varieties, poor crop management, soil type and improved technologies. Many researchers had done the research to find out the effect of nitrogen and timing on different crop but there is very limited research about the effect of levels and splitting of nitrogen on soybean inside the country or the world. However, literature available in this aspect in the country and abroad were reviewed and it will be contributed a positive justification and for further use in future.

2.1 Effect of levels of nitrogen

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 (R_1) and full pod (R_4) combined with rainfed (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 (R_5), 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 rainfed soybean plants.

Wilson *et al.*, (2014) was 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 grain yield and seed quality. Supplemental N totaled 560 kg N ha^{-1} with 40% applied at planting and 60% applied at V5. Grain 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 grain yield and seed oil was not affected. Grain 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 nonlimiting 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 grain yield in modern, MG III cultivars in the tested environments.

Umeh (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) 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 grain yield under condition of our experiment.

Mrkovacki (2008) conducted an experiment to study the effects of different nitrogen rates (0, 30, 60, 90 kg N/ha) on the soybean cultivar Proteinka, inoculated with the NS–Nitragin microbial fertilizer. Trials were set up at Bački Petrovac 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 (2006) was 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 grain 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 grain quality in the unique environments of the northern of Iran.

Taylor (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 ha^{-1}) were studied for 2 yr at three Alabama locations (Fairhope, Shorter, and Crossville). Nitrogen application of 60 to 70 kg ha^{-1} maximized yield and R1 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 (*G. max* (L.) Merr.) cv. PK-416 (V1) and cv. PK-1024 (V2) in relation to sulphur and nitrogen nutrition. Six combinations (T1-T6) 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 T6 (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 *et al.* (2005) was conducted a study to determine the impact of N fertilizer applied to the soil at the beginning pod growth stage on soybean yield and grain 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 grain yield and quality components at individual sites or when combined across individual sites. There were no significant effects on grain yield, with only a 39 kg ha^{-1} increase from applied N. Grain 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, grain N concentration and removal, grain yield, or grain 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 grain quality.

Gutiérrez-Boem *et al.* (2004) was 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 R3 and R5 development stages. Nitrogen fertilization, either at R3 or R5, 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.

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 R5 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 V4 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 $mMNO_3^{\,-}$ 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, branch and node number per plant, shoot/root ratio and leaf area ratio, compared to the N-free treatment. R1 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 beusedto 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 R3-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 R2 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)

Starling (1998) was 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 (Dt_1Dt_1, indeterminate) and Au86-2397D (dt_1dt_1, determinate) and a determinate check cultivar, Cook] were planted in late July in seven Alabama environments during 1995 and 1996. Starter N increased R1 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 R1 developmental stage and 14 cm greater height at R8 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. Grain 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) was 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] thiophosphoric triamide NBPT]) on leaf N concentrations, grain yield, and grain 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 wk 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 grain protein and oil concentrations at some sites, but overall combined analysis indicated nonsignificant 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 grain. 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 R3 growth stage can provide positive economic returns for producers growing irrigated soybean with high yield potential.

Krishna *el 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 P205 ha^{-1}) and high in available K (572 kg K20 ha^{-1}).

Jadhav *el 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" 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 PIOs (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 Katoch *et a1* (1983) conducted a pot culture study on nodulation of soybean in a silty clay loam soil (0.C 2%), and found that nodule number and weight per plant were highest when 30 kg N ha^{-1} was applied. With an increased dose of N to 60 kg N ha^{-1}, the nodule weight and nodule number of the crop were significantly reduced.

Kang (1975) stated that in the former bean yields with IARI and CB 1809 inoculants were better than with Nitragin-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.

2.2 Effect of splitting of nitrogen

Maryam (2013) was 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}. This research demonstrates that applying N as starter has the potential to increase soybean yield but this may or may not translate into improved grain quality in the unique environments of the northern of Iran.

Gan *et al.* (2003) said that N_2 fixation alone cannot meet the N requirement for maximizing soybean yield, and that N top-dressing at the flowering stage was more efficient than N top-dressing at the vegetative stages. However, the effect of N fertilizer application at other reproductive stages of soybean is unknown. Thus, a field experiment was conducted to study the effects of N applications at various reproductive stages on growth, N_2 fixation and yield of three soybean genotypes. The results showed that starter N at 25 kg ha^{-1} resulted in minimum yield, total N accumulation and total amount of N_2 fixed in all three genotypes. N top-dressing at 50 kg ha^{-1} at the V_2 or R1 stages, significantly increased N accumulation, yield and total amount of N_2 fixed in all three genotypes. However, N top-dressing at the same rate at either the R3 or R5 stage did not show this positive effect in any of the three genotypes. Thus, the best timing for N top-dressing during reproduction is at the flowering stage, which increased seed yield by 21% for Wuyin 9, 27% for You 91-

19, and 26% for Jufeng, respectively, compared to the treatment without N top-dressing.

Wood (1993) was conducted a field experiments at seven locations from 1990 to 1991 in Alabama to determine soybean response to N fertilization at various growth stages. Treatments included a factorial arrangement of soybean cultivar ('Stonewall' or 'Sharkey') and N rate/timing treatments in a split plot design. Nitrogen rate/timing treatments were: (i) no N, (ii) 30 lb N/acre at planting, (iii) 50 lb N/acre at first bloom (R_l), and (iv) 50 lb N/acre at early pod fill (R5). Plant samples were collected at R_1 and R_5 for dry matter yield and N determination. Grain yields were determined and grain samples were collected at harvest for protein and oil analyses. In general, Stonewall exhibited highest grain yields and seed oil concentrations, while Sharkey had highest protein concentrations. A positive grain yield response to N fertilizer was observed at five of seven locations. Yield responses, however, were inconsistent among those locations with respect to N rate/timing treatments and interaction with soybean cultivar. Grain yield response to N fertilization appeared to be dependent on soil nitrate-N concentration at planting. Nitrogen applied at R5 was the most reliable application time for increasing grain yields, however, yield decreases from N applied at R5 were also observed for both cultivars. Nitrogen fertilization affected seed oil and protein concentrations at only one location. Results of this work suggest that fertilizer-N application to soybean is, at best, a risky proposition.

Afza (1987) were conducted a field experiments to determine the effects of the amount, time and method of fertilizer N application on the efficiency of N uptake, N_2 fixation and yield of soybean. Soil and foliar fertilizer N, applied during the pod-filling stage were absorbed by plants with equal and high efficiency, compared to appreciably lower utilization efficiency for N applied before seedling emergence. These results reveal that the soybean roots were active in N uptake during these late stages of growth. Nitrogen fertilization during pod-filling resulted in significant yield increases over the control treatment which received an early application of 20 Kg N/ha. Seed yield increases were, however, more pronounced than total dry matter yield, and virtually the entire late-applied N was translocated into the pods. Nitrogen fixation in soybean was not influenced by the application of 40 kg N/ha to plants as soil or foliar N during the pod-filling stage. However, 80 kg N/ha supplied during pod-filling as 40 kg soil plus 40 kg foliar N/ha significantly reduced the amount of N_2 fixed. The results obtained in these studies suggest that inadequate N supply during pod-filling limited soybean yields, and that by the judicious application of fertilizer N during the late stages of growth, it was possible to enhance soybean yields without necessarily inhibiting N_2 fixation.

2.3 Interaction effect of levels and splitting of nitrogen

Caliskan (2008) was conducted a study to evaluate the effects of N and Fe fertilization on growth and yield of double cropped soybean (cv. SA 88, MG III) in a Mediterranean-type environment in Turkey during 2003 and 2004. The soil of the experimental plots was a Vertisol with 176 g $CaCO_3$ kg^{-1} and pH 7.7 and 17 g organic matter kg^{-1} soil. Soybean seeds were inoculated prior to planting with commercial peat inoculants. N fertilizer rates were 0, 40, 80, and 120 kg N ha^{-1} of which half was applied before planting and the other half at full blooming stage (R2). Fe fertilizer rates were 0, 200 and 400 g Fe EDTA (5.5% Fe and 2% EDTA) ha^{-1}. It was sprayed as two equal portions at two trifoliate (V2) and at five trifoliate stages (V5). Plants were sampled at flower initiation (R1), at full pod (R4) and at full seed (R6) stages. Application of starter N increased biomass and leaf area index at R1 stage whereas Fe fertilization did not affect early growth parameters. N application continued to have a positive effect on growth parameters at later stages and on seed yield. Fe fertilization increased growth parameters at R4 and R6 stages, and final seed yield in both years. There was a positive interaction between N and Fe at the N rates up to 80 kg N ha^{-1}. However, further increase in N rate produced a negative interaction. Fertilization of soybean with 80 kg N ha^{-1} and 400 g Fe ha^{-1} resulted in the highest seed yield in both years. We concluded that application of starter and top dressed N in combination with two split FeEDTA fertilization can be beneficial to improve early growth and final yield of inoculated soybean in Mediterranean-type soils.

Ahmad *et al.,* 1999, was conducted an experiment to find out the effect of split application of sulphur and nitrogen on growth and yield attributes of *Brassica* genotypes differing in time of flowering. In his experiment 40 kg S ha^{-1} as $CaSO_4$ (gypsum) was applied either in a single basal application (S_1) or in two (S_2) or three (S_3) split applications; and 100 kg N ha^{-1} as urea was applied either in two (N_2) or three (N_3) splits. Split application of S and N (S_2N_2 or S_3N_3) resulted in significant improvement in growth and yield of both the genotypes compared with the application of S in a single basal application and N in two splits (S_1N_2). V_1 responded better when S and N was applied in two split doses (S_2N_2) than when it was applied as S_1N_2 or S_3N_3. Seed yield, biological yield and harvest index were improved by 38.3, 26.3 and 9.5%, respectively, by S_2N_2 over the results obtained with S_1N_2. In the case of V2, three split applications of S and N (S_3N_3) resulted in maximum growth and yield. Seed yield, biological yield and harvest index improved by 41.3, 26.9 and 11.6% respectively, with this treatment.

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 research field, Sher-e-Bangla Agricultural University, Dhaka during the period from January 2013 to April 2013. Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude (Google maps, 2014) at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone “AEZ-28” of Madhupur Tract (BBS, 2011). 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, having p^H 5.8. The physicochemical properties and nutrient status of soil of the experimental plots are given in Appendix IA, IB and IC.

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, 1987). 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 Plant materials and features

Bangladesh Agricultural Research Institute (BARI) was released BARI Soybean 5 in 2010. BARI Soybean 5 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%. The characteristics of the variety used are as follows.

BARI Soybean-5: The variety is high yield potential as released in 2002. The grain yield ranges from 1.6-2.0 t ha^{-1} under optimum management. It requires 90-100 days to mature. The average height of BARI Soybean-5 is 40-60 cm. Each plant contains average 25-35 pods. Pod is medium with 2-3 grains per pod. Grains are creamy in color, bright and slightly smaller than Shaohag (1000-grain weight 9-14 g).

3.5 Treatments

The experiment consisted of two treatment factors as mentioned below:

a) Factor A: Nitrogen level (on main plot)

i) N_1= 10 kg ha^{-1}

ii) N_2= 20 kg ha^{-1}

iii) N_3= 30 kg ha^{-1}

iv) N_4 = 40 kg ha^{-1}

b) Factor B: Splitting of Nitrogen (on sub plot)

i) S_1= 1 split apply at basal

ii) S_2= 2 split application at basal and at 10 DAS)

iii) S_3= 3 split application at basal, at 10 DAS and at 20 DAS)

iv) S_4= 4 split application at basal, at 10 DAS, at 20 DAS and at 30 DAS)

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 3m x 2m and total numbers of plots were 48. There were 16 treatment combinations. Each block was divided into 16 unit plots. Different nitrogen levels were placed along the main plot and splitting of Nitrogen treatments were placed in the sub plot. Field of the experiment was done on January 11, 2013 with interplot spacing of 0.50 m and inter block spacing of 1 m. A layout of the experimental plot is given on Plate 1.

3.7 Land preparation

The land of the experimental field was first opened on January 03, 2013 with a power tiller. Then it was exposed to the sunshine for 7 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. Insecticides 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 were applied according to BARI recommendation. Nitrogen fertilizers were applied as per treatments in each plot. Fertilizers other than nitrogen fertilizer were given during final land preparation. The BARI recommended doses of TSP, MOP, gypsum and boron are given below:

Fertilizers	**Dose (ha^{-1})**	**Quantity $plot^{-1}$**
TSP	175 kg	105 g
MOP	120 kg	72 g
Gypsum	115 kg	69 g
Boron	10 kg	6 g

Source: BARI (2011)

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 January 11, 2013 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. Overcrowded 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 15 days after first thinning according to the treatment.

3.11.2 Weeding

First weeding was done at 20 DAS and second one at 35 DAS along with thinning to keep the plots free from weeds and to keep the soil loose and aeratedwith optimum plant population.

3.11.3 Irrigation

The first irrigation was done at 20 DAS before flowering. Second irrigation was provided at 55 DAS, seed forming stage. 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

Ten plants were collected randomly from each plot. These 10 plants were used for taking yield component data.

3.14 Harvest and post-harvest operations

The crop was harvested on March 2, 2013. At maturity, when all leaves are fallen down. then the plants were harvested. 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, 45, 60, 75 DAS and at harvest.

b. Number of leaves plant^{-1} from 30 DAS to harvest.

c. Number of branches plant^{-1} from 45 DAS to harvest.

d. Total dry matter weight of plant from 30 DAS to harvest.

3.15.2 Yield contributing characters

a. Number of pods plant^{-1}
b. Pod length (cm)
c. Seeds pod^{-1}
d. Weight of 1000 grains (g)

3.15.3 Yield and harvest index

a. Grain yield plot^{-1}
b. Grain yield (t ha^{-1})
c. Straw yield (t ha^{-1})
d. Biological yield (t ha^{-1})
e. Harvest index (%)

3.15.4 Quality characters

a. Moister percentage
b. Protein percentage

3.16 Procedure of sampling for growth study during the crop growth period

Plant height (cm)

The height of the soybean plants was recorded from 30 days after sowing (DAS) at 15 days interval up to harvest. The plant height was counted as beginning from the ground level up to tip of the top leaf. The average height of ten plants randomly selected was considered as the height of the plant for each plot.

Number of leaves plant^{-1}

Total number of leaves plant^{-1} was taken from 30 DAS at 15 days interval up to 75 DAS. The average number of leaves plant^{-1} of ten plants was considered as the number of leaves plant^{-1} for each plot.

Number of branches plant^{-1}

Total number of branches plant^{-1} was taken from 45 DAS at 15 days interval up to 75 DAS. The average number of branches plant^{-1} of ten plants was considered as the number of branches plant^{-1} for each plot.

Total dry matter weight

The total dry matter weight was calculated from the summation of dry matter weight of roots and shoots of 10 plants. Then the mean weight was calculated to have individual plant weight and expressed in gram.

3.17 Procedure of collecting data on yield and yield components

For assessing yield parameters data were collected from 10 randomly selected plants from each of the plots. For measuring grain and straw yield, an area of 1.0 m^2 from center of each plot was harvested.

Number of pods plant^{-1}

The number of pods plant^{-1} was recorded from randomly selected 10 plants of each plot. Data was recorded at harvest time. Mean data was expressed in centimeter (cm).

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 ten randomly selected pods from randomly selected plants of each plot. Data was recorded at harvest time. Mean data was expressed in centimeter (cm).

Number of seeds pod^{-1}

Data on the number of seed pod^{-1} was counted. Ten spike bearing plants were randomly selected and the average data were collected from inner rows of each plot except harvest area during the time of harvesting.

Number of filled grains spike^{-1}

The total number of filled grains from randomly selected 10 spikes were counted of which gave the number of filled grains spike^{-1}. Presence of any food material in the grains was considered as filled grain.

Weight of 1000 grains (g)

One thousand cleaned dried grains were randomly collected from the seed stock of each plot and were sun dried properly at 10% moisture content. These dried seeds were weighted using an electric balance and the weight was expressed in gram.

Grain 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 threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in the sun.

Biological yield

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + Straw yield

Harvest index (%)

Harvest index is the relationship between grain yield and biological yield (Gardner *et al.,* 1985). It was calculated by using the following formula:

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

3.18 Procedure of data collection for quality characters

For assessing quality parameters data were collected from 10 randomly selected plants from each of the plots. After collecting the seed, the seed samples were sun dried and then packed in polythene bag by proper labeling. These labeled packed samples were immediately sent to **Bangladesh Council of Scientific and Industrial Research (BCSIR)**, Dhaka for determination of moisture percentage and crude protein percentage. The methods of analyses has been presented in Appendix ID.

3.19 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 package 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 effect of levels and numbers of splitting of nitrogen on the growth, development, yield and quality of soybean. 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 Plant height

4.1.1 Effect of nitrogen levels

Plant height of soybean varied significantly due to different levels of nitrogen treatments at different days after sowing (Figure 1). At harvesting stage numerically the highest plant height (59.85 cm) was obtained from 40 kg N ha^{-1} (N_4) which is statistically similar (58.08) to 30 kg N ha^{-1} (N_3) whereas the lowest (47.66 cm) was recorded from 10 kg N ha^{-1} (N_1). Umeh (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 periods upto at harvest.

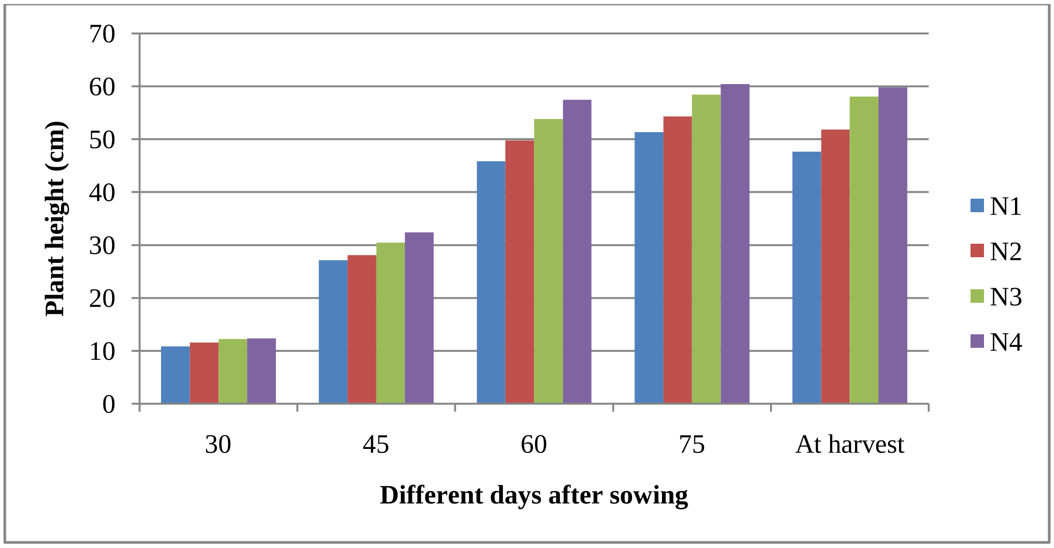

Figure 1. Effect of nitrogen levels on the plant height of soybean at different days after sowing.

[N_1= 10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1}]
(SE= 0.21, 0.61, 1.44, 0.55 and 0.90 for 30, 45, 60, 75 DAS and at harvest, respectively**)**

4.1.2 Effect of splitting of nitrogen

Plant height of soybean varied significantly due to splitting numbers of nitrogen at different days after sowing (Figure 2). At harvesting stage the highest plant height (57.01 cm) was recorded from 4 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) of nitrogen, which is statistically similar (55.81 cm) to 3 split application(1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) (S_3) of nitrogen whereas the lowest plant height (51.84 cm) was recorded from 1 split application at basal (S_1) of nitrogen. Fig 2 showed that plant height increased with increasing the number of split application of nitrogen irrespective of all growth period but not at harvest. Ahmad *et al.* (1999) observed that three split applications of N resulted in maximum growth and yield. In this present experiment 4 split application of nitrogen (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) increased the growth character like plant height.

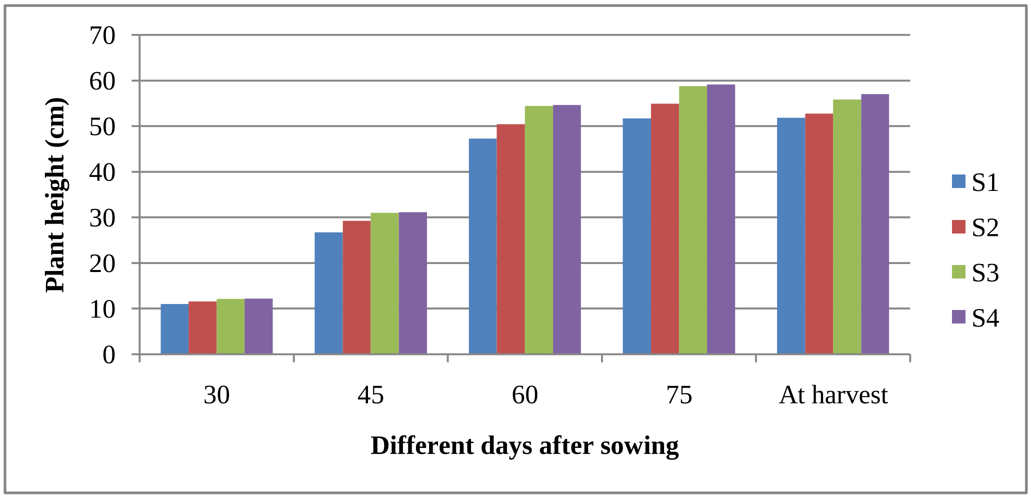

Figure 2. Effect of splitting of nitrogen on the plant height of soybean at different days after sowing.

[S_1= 1 split apply at basal; S_2= 2 split apply (1st at basal and 2nd at 10 DAS); S_3= 3 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

(SE= 0.14, 0.79, 1.18, 0.79 and 1.37 for 30, 45, 60, 75 DAS and at harvest, respectively**)**

4.1.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen in terms of plant height also exposed significant variation at different days after sowing (Table 1). At harvesting stage numerically the highest plant height (63.73 cm) was recorded from N_4S_4 treatment combination which was statistically similar to N_4S_3, N_3S_4, N_3S_3, N_4S_2, N_4S_1, N_3S_1 and N_3S_2 treatment combination whereas the lowest (45.23 cm) was recorded from N_1S_1 treatment combination.

Table 1. Interaction effect of nitrogen level and splitting of nitrogen on the plant height (cm) of soybean at different days after sowing

Treatments	Plant height (cm) at different days after sowing				
	30	**45**	**60**	**75**	**At harvest**
N_1S_1	10.20 f	24.79 d	43.07 e	47.60 h	45.23 e
N_1S_2	10.77 ef	26.86 cd	45.05 de	50.33 gh	46.63 de
N_1S_3	11.19 de	28.37 b~d	47.49 c~e	53.57 fg	49.33 c~e
N_1S_4	11.25 c~e	28.55 b~d	47.64 c~e	53.90 e~g	49.43 c~e
N_2S_1	10.80 ef	25.63 d	45.67 de	50.80 gh	50.40 c~e
N_2S_2	11.47 c~e	28.56 b~d	48.77 c~e	53.31 fg	50.95 c~e
N_2S_3	12.00 a~d	29.07 b~d	52.25 b~d	56.55 d~f	52.27 b~e
N_2S_4	12.06 a~d	29.21 b~d	52.31 b~d	56.63 d~f	53.77 b~e
N_3S_1	11.40 cde	27.37 b~d	48.65 c~e	53.39 fg	55.35 a~d
N_3S_2	12.00 a~d	30.03 a~d	52.47 b~d	57.17 c~f	55.60 a~d
N_3S_3	12.70 ab	32.03 a~c	56.98 ab	61.24 a~d	60.28 ab
N_3S_4	12.79 a	32.30 ab	57.13 ab	61.93 a~c	61.10 ab
N_4S_1	11.78 b~d	28.98 b~d	51.79 b~d	55.05 e~g	56.37 a~c
N_4S_2	12.17 a~c	31.67 a~c	55.38 a~c	58.82 b~e	57.93 a~c
N_4S_3	12.75 a	34.43 a	61.13 a	63.77 ab	61.37 ab
N_4S_4	12.80 a	34.60 a	61.49 a	64.00 a	63.73 a
SE	0.29	1.58	2.36	1.58	2.73
CV (%)	4.24	9.28	7.92	4.88	9.98

[N_1=10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1};
S_1= 1 split apply at basal; S_2= 2 split apply (1st at basal and 2nd at 10 DAS); S_3= 3 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

In a column mean values having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of significance.

4.2 Number of leaves

4.2.1 Effect of nitrogen levels

Number of leaves of soybean varied significantly due to different levels of nitrogen at different days after sowing except 30 DAS, 45 DAS and at harvest (Figure 3). At 75 DAS the maximum number of leaves (16.78) was recorded from 40 kg N ha^{-1} (N_4) whereas the minimum (12.75) was recorded from 10 kg N ha^{-1} (N_1). Finally at harvest the number of leaves did not show significant variation due to different nitrogen levels; the maximum number of leaves (2.22) was recorded from 40 kg N ha^{-1} (N_4) whereas the minimum (2.05) was recorded from 10 kg N ha^{-1} (N_1).

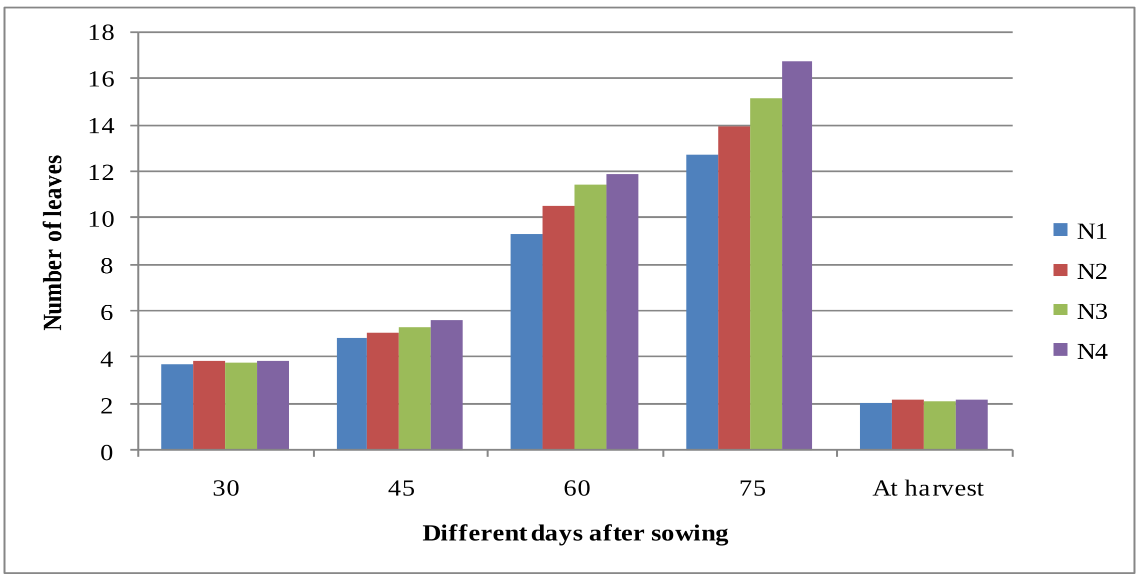

Figure 3. Effect of nitrogen levels on the number of leaves of soybean at different days after sowing.

[N_1= 10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and $N_{4=}$ 40 kg ha^{-1}]

(SE= 0.11, 0.23, 0.09, 0.30 and 0.10 for 30, 45, 60, 75 DAS and at harvest, respectively**)**

4.2.2 Effect of splitting of nitrogen

Number of leaves of soybean varied significantly due to splitting of nitrogen at different days after sowing except 30 DAS, 45 DAS and at harvest (Figure 4). At 75 DAS numerically the maximum number of leaves (15.55) was recorded from 4 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) of nitrogen which is statistically similar (15.47) to 3 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) (S_3) of nitrogen whereas the minimum (13.25) was recorded from 1 split application at basal (S_1) of nitrogen. Finally at harvest the number of leaves did not show significant variation due to different splitting of nitrogen; the maximum number of leaves (2.18) was recorded from 3 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) (S_3) of nitrogen whereas the minimum (2.13) was recorded from 1 split application at basal (S_1) of nitrogen.

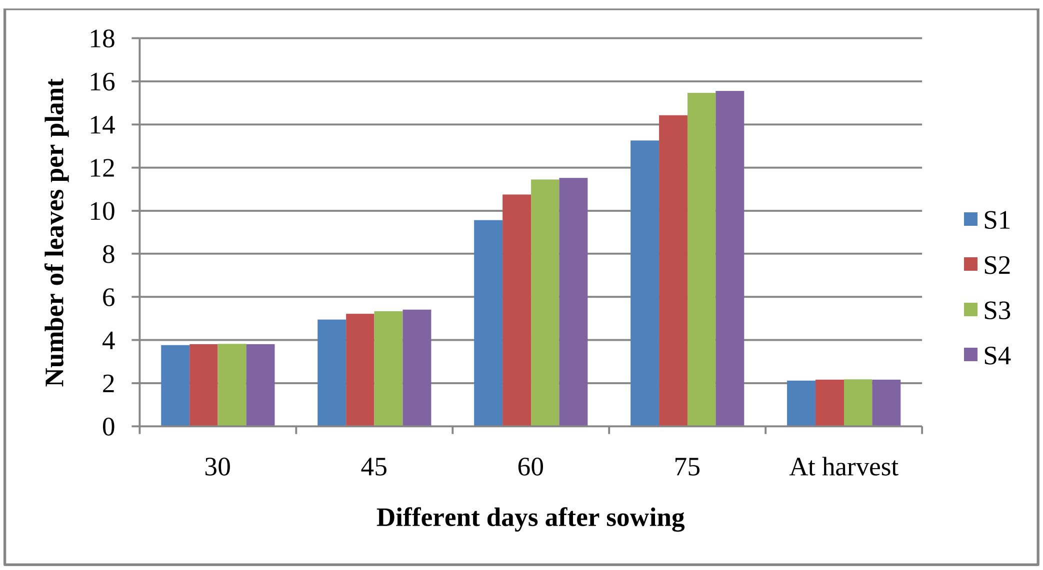

Figure 4. Effect of splitting of nitrogen on the number of leaves of soybean at different days after sowing.

[S_1= 1 split apply at basal; S_2= 2 split apply (1st at basal and 2nd at 10 DAS); S_3= 3 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

(SE= 0.10, 0.17, 0.09, 0.43 and 0.13 for 30, 45, 60, 75 DAS and at harvest, respectively**)**

4.2.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on number of leaves also showed significant variation at different days after sowing except 30 DAS, 45 DAS and at harvest (Table 2). At 75 DAS numerically the maximum number of leaves (18.45) was recorded from N_4S_4 treatment combination which was statistically similar to N_4S_3, N_4S_2, N_3S, and N_3S_3 treatment combination whereas the minimum (11.93) was recorded from N_1S_1 treatment combination. Finally at harvest the maximum number of leaves (2.28) was recorded from N_4S_3 treatment combination whereas the minimum (1.88) was recorded from N_1S_1 treatment combination.

Table 2. Interaction effect of nitrogen level and splitting of nitrogen on the number of leaves of soybean at different days after sowing

Treatments	Number of leaves at different days after sowing				
	30	45	60	75	At harvest
N_1S_1	3.53	4.60	8.683 i	11.93 d	1.88
N_1S_2	3.73	4.80	9.417 h	12.87 d	2.08
N_1S_3	3.80	4.93	9.583 gh	13.07 d	2.15
N_1S_4	3.73	5.00	9.667 gh	13.12 d	2.08
N_2S_1	3.93	5.00	9.250 h	13.25 cd	2.28
N_2S_2	3.84	5.07	10.67 de	13.73 b~d	2.19
N_2S_3	3.87	5.13	11.17 d	14.45 b~d	2.22
N_2S_4	3.80	5.13	11.20 d	14.47 b~d	2.15
N_3S_1	3.87	5.00	10.05 fg	13.78 b~d	2.22
N_3S_2	3.80	5.40	11.18 d	14.68 b~d	2.15
N_3S_3	3.70	5.57	12.25 bc	16.13 a~c	2.05
N_3S_4	3.80	5.57	12.33 ab	16.18 ab	2.15
N_4S_1	3.77	5.20	10.28 ef	14.02 b~d	2.12
N_4S_2	3.87	5.63	11.75 c	16.42 ab	2.22
N_4S_3	3.93 a	5.73	12.80 ab	18.23 a	2.28
N_4S_4	3.90 a	5.93	12.88 a	18.45 a	2.25
SE	ns	ns	0.18	0.87	ns
CV (%)	9.35	11.06	2.93	10.22	12.18

[N_1= 10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1};
S_1= 1 split apply at basal; S_2=2 split apply (1st at basal and 2nd at 10 DAS); S_3=3 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

4.3 Number of branches

4.3.1 Effect of nitrogen levels

Number of branches of soybean varied significantly with different levels of nitrogen at different days after sowing except 45 DAS (Figure 5). At harvest the maximum number of branches (3.53) was recorded from 40 kg N ha^{-1} (N_4) which is statistically similar (3.39) to 30 kg N ha^{-1} (N_3) whereas the minimum (3.21) was recorded from 10 kg N ha^{-1} (N_1).

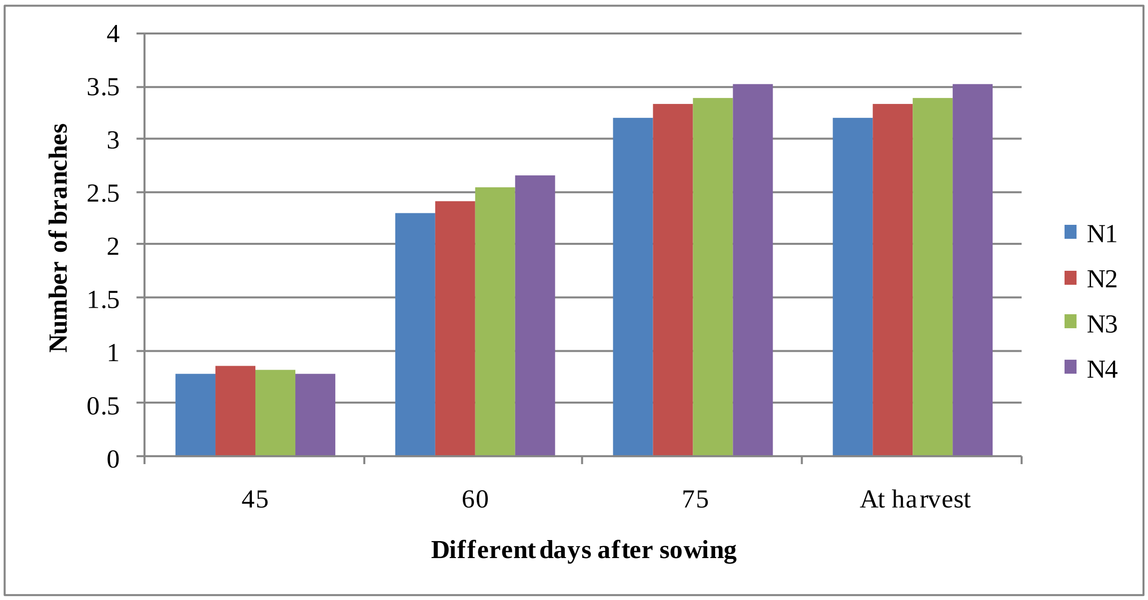

Figure 5. Effect of nitrogen levels on the number of branches of soybean at different days after sowing.

[N_1= 10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1}]

(SE= 0.03, 0.04, 0.04 and 0.04 for 45, 60, 75 DAS and at harvest, respectively)

4.3.2 Effect of splitting of nitrogen

Number of branches of soybean varied significantly due to splitting of nitrogen at different days after sowing (Figure 6). At harvest the maximum number of branches (3.51) was recorded from 4 split application (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS) (S_4) of nitrogen which is statistically similar (3.48) to 3 split application (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS) (S_3) of nitrogen whereas the minimum (3.15) was recorded from 1 split application at basal (S_1) of nitrogen.

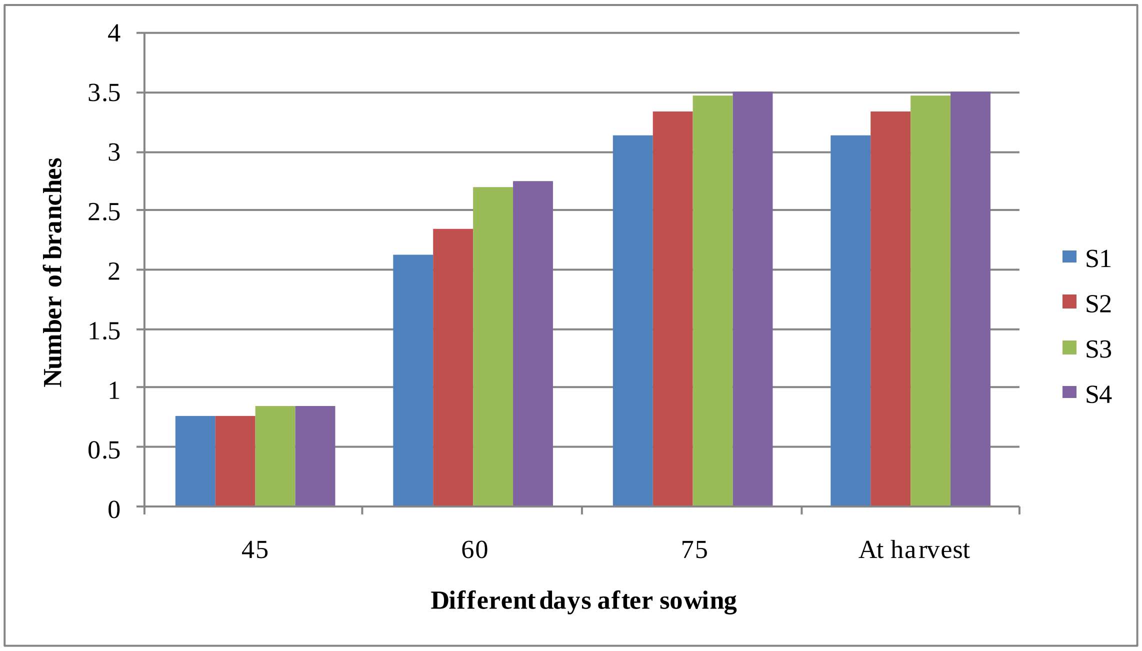

Figure 6. Effect of splitting of nitrogen on the number of branches of soybean at different days after sowing.

[S_1= 1 split apply at basal; S_2= 2 split apply (1^{st} at basal and 2^{nd} at 10 DAS); S_3= 3 split apply (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS) and S_4= 4 split apply (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS)]
(SE= 0.02, 0.07, 0.03 and 0.03 for 45, 60, 75 DAS and at harvest, respectively**)**

4.3.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on number of branches was also significant at different days after sowing except 45 DAS (Table 3). At 75 DAS the maximum number of branches (3.7) was recorded from N_4S_4 treatment combination which was statistically similar to N_4S_3 whereas the minimum (3.08) was recorded from N_1S_1 treatment combination.

Table 3. Interaction effect of nitrogen level and splitting of nitrogen on the number of branches of soybean plant at different days after sowing

Treatments	Number of leaves at different days after sowing			
	45	**60**	**75**	**At harvest**
N_1S_1	0.71	2.06 e	3.08 i	3.08 i
N_1S_2	0.74	2.10 e	3.21 g~i	3.21 g~i
N_1S_3	0.87	2.52 a~e	3.27 gh	3.27 gh
N_1S_4	0.84	2.57 a~d	3.31 e~g	3.31 e~g
N_2S_1	0.82	2.10 e	3.11 hi	3.11 hi
N_2S_2	0.82	2.30 c~e	3.30 f~h	3.30 f~h
N_2S_3	0.89	2.63 a~c	3.47 c~f	3.47 c~f
N_2S_4	0.88	2.68 a~c	3.49 b~e	3.49 b~e
N_3S_1	0.83	2.15 de	3.16 g~i	3.16 g~i
N_3S_2	0.77	2.45 b~e	3.34 d~g	3.34 d~g
N_3S_3	0.82	2.80 ab	3.50 b~d	3.50 b~d
N_3S_4	0.86	2.83 ab	3.56 a~c	3.56 a~c
N_4S_1	0.73	2.24 c~e	3.26 g~i	3.26 g~i
N_4S_2	0.77	2.60 a~d	3.51 b~d	3.51 b~d
N_4S_3	0.83	2.88 ab	3.66 ab	3.66 ab
N_4S_4	0.85	2.91 a	3.70 a	3.70 a
SE	ns	0.14	0.06	0.06
CV (%)	9.63	9.47	2.94	2.94

[N_1= 10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1};
S_1= 1 split apply at basal; S_2= 2 split apply (1st at basal and 2nd at 10 DAS); S_3= 3 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

4.4 Dry weight

4.4.1 Effect of nitrogen levels

This research work exhibited distinct variations in dry matter weight of soybean at different days after sowing (Figure 7). At harvest the maximum dry weight (13.11 g) was recorded from 40 kg N ha^{-1} (N_4), which was statistically similar to (12.1 g) 30 kg N ha^{-1} (N_3), whereas the minimum (8.58 g) recorded from 10 kg N ha^{-1} (N_1).

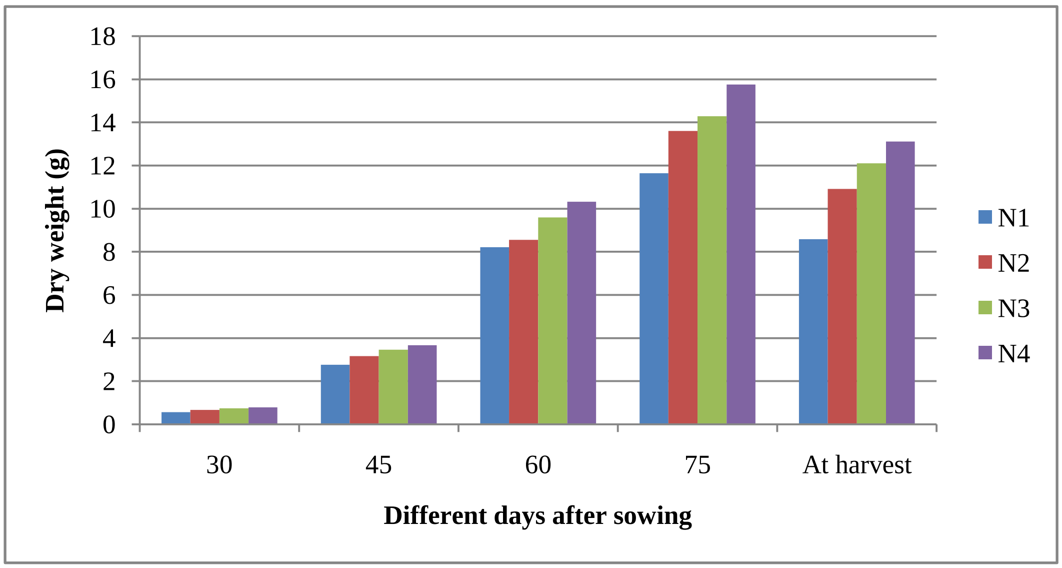

Figure 7. Effect of nitrogen levels on the dry weight of soybean plant at different days after sowing.

[N_1=10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1}]

(SE= 0.02, 0.16, 0.53, 0.81 and 0.68 for 30, 45, 60, 75 DAS and at harvest, respectively**)**

4.4.2 Effect of splitting of nitrogen

Dry weight content of soybean plant varied significantly due to splitting of nitrogen at different days after sowing except 45 DAS (Figure 8). At harvest the maximum dry weight (12.25 g) was recorded from 4 split application(1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS) (S_4) of nitrogen which was statistically similar (12.17 g) to 3 split application (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS) (S_3) of nitrogen whereas the minimum (9.68 g) was recorded from 1 split application at basal (S_1) of nitrogen.

The ability of the plant to produce dry matter depends on the size, efficiency and duration of the photosynthetic organs. Split application of S and N improved all of this character (Ahmad *et al.*, 1999**).**

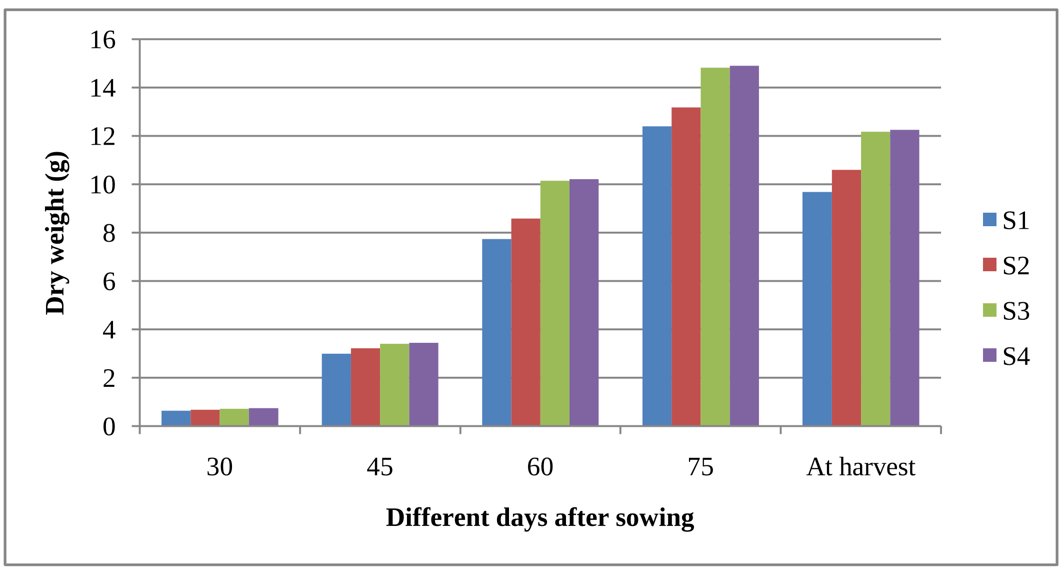

Figure 8. Effect of splitting of nitrogen on the dry weight of soybean plant at different days after sowing.

[S_1= 1 split apply at basal; S_2= 2 split apply (1^{st} at basal and 2^{nd} at 10 DAS); S_3= 3 split apply (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS) and S_4= 4 split apply (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS)]

(SE= 0.02, 0.20, 0.37, 0.63 and 0.62 for 30, 45, 60, 75 DAS and at harvest, respectively**)**

4.4.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on dry weight of soybean plant showed significant variation at different days after sowing except 45 DAS and 75 DAS (Table 4). At harvest numerically the maximum dry weight of soybean plant (14.93 g) was recorded from N_4S_4 treatment combination which was statistically similar to N_4S_3, N_4S_3, N_3S_2, N_3S_3, N_3S_4, N_4S_1, N_4S_2 N_2S_3 and N_2S_4 whereas the minimum (8.17 g) was recorded from N_1S_1 treatment combination.

Table 4. Interaction effect of nitrogen level and splitting of nitrogen on the dry weight of soybean plant at different days after sowing

Treatments	Dry weight of plant at different days after sowing				
	30	45	60	75	At harvest
N_1S_1	0.48 e	2.57	7.20 c	11.23	8.17 d
N_1S_2	0.53 de	2.81	7.95 c	11.39	8.33 d
N_1S_3	0.63 cd	2.83	8.83 bc	11.95	8.88 cd
N_1S_4	0.65 b~d	2.85	8.88 bc	12.04	8.97 b~d
N_2S_1	0.66 bc	2.96	7.63 c	12.02	9.22 b~d
N_2S_2	0.67 bc	3.09	8.37 bc	13.03	10.54 b~d
N_2S_3	0.67 bc	3.29	9.07 bc	14.65	11.90 a~d
N_2S_4	0.67 bc	3.34	9.11 bc	14.71	11.96 a~d
N_3S_1	0.70 bc	3.19	7.92 c	12.89	10.56 b~d
N_3S_2	0.74 a~c	3.42	8.80 bc	13.83	11.69 a~d
N_3S_3	0.75 a~c	3.62	10.80 ab	15.13	13.00 a~c
N_3S_4	0.79 ab	3.63	10.84 ab	15.27	13.14 ab
N_4S_1	0.72 a~c	3.29	8.17 c	13.45	10.80 a~d
N_4S_2	0.75 a~c	3.57	9.23 bc	14.46	11.81 a~d
N_4S_3	0.83 a	3.89	11.91 a	17.55	14.90 a
N_4S_4	0.85 a	3.93	11.99 a	17.58	14.93 a
SE	0.04	ns	0.75	ns	1.245
CV (%)	10.18	21.52	14.10	15.73	13.29

[N_1= 10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1};

S_1= 1 split apply at basal; S_2= 2 split apply (1st at basal and 2nd at 10 DAS); S_3= 3 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

4.5 Number of pods plant^{-1}

4.5.1 Effect of nitrogen levels

Number of pods plant^{-1} was varied significantly with different nitrogen levels (Table 5). The maximum number of pods plant^{-1} (31.87) was recorded from 40 kg N ha^{-1} (N_4) application which was statistically similar (31.17) to the 30 kg N ha^{-1} (N_3) application whereas the minimum (23.11) was recorded from 10 kg N ha^{-1} (N_1) treatment. Results demonstrated that pods number gradually increased with increasing N levels,but N_3 and N_4 showed similar values.

4.5.2 Effect of splitting of nitrogen

Different splitting of nitrogen significantly influenced the number of pod plant^{-1} (Table 6). 4 split applications (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) of nitrogen produced the maximum number of pod plant^{-1} (31.46) which was statistically similar (30.67) to 3 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) (S_3) of nitrogen while the minimum (23.99) was obtained from the 1 split application at basal (S_1) of nitrogen. Results demonstrated that pods number gradually increased with increasing split number of N levels, but S_3 and S_4 showed similar values.

4.5.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on number of pod plant^{-1} of soybean showed significant variation (Table 7). The maximum number of pod plant^{-1} of soybean (35.47) was recorded from N_4S_4 treatment combination which was statistically similar to N_4S_3, N_4S_2, N_3S_4, N_3S_3, N_2S_4 and N_2S_3 whereas the minimum (19.87) was recorded from N_1S_1 treatment combination.

4.6 Length of pod

4.6.1 Effect of nitrogen levels

Length of pod did not exposed significantly with different nitrogen levels (Table 5). However, numerically the highest length of pod (3.29 cm) was recorded from 40 kg N ha^{-1} (N_4) while the lowest (3.07 cm) was recorded from 10 kg N ha^{-1} (N_1) treatment.

4.6.2 Effect of splitting of nitrogen

Different splitting of nitrogen did not influenced significantly the length of pod (Table 6). However, numerically 4 split application (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS) (S_4) of nitrogen produced the maximum length of pod (3.30 cm) while the minimum (3.07 cm) was recorded from the 1 split application at basal (S_1) of nitrogen.

4.6.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on the length of pod of soybean did not expose significantly also (Table 7). Numerically the maximum length of pod of soybean (3.40 cm) was recorded from N_4S_4 treatment combination whereas the minimum (2.90 cm) was recorded from N_1S_1 treatment combination.

4.7 Number of seeds pod^{-1}

4.7.1 Effect of nitrogen levels

Number of seeds pod^{-1} was exposed significantly with different nitrogen levels (Table 5). The maximum number of seeds pod^{-1} (2.52) was recorded from 40 kg N ha^{-1} (N_4), which was statistically similar (2.40) to 30 kg N ha^{-1} (N_3) whereas the minimum (1.69) was recorded from 10 kg N ha^{-1} (N_1) treatment.

4.7.2 Effect of splitting of nitrogen

Different splitting of nitrogen significantly influenced the number of seed pod^{-1} (Table 6). 4 split applications (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) produced the maximum number of seed pod^{-1} (2.38) which was statistically similar (2.35) to 3 split appliation (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) (S_3) of nitrogen while the minimum (1.87) was obtained from the 1 split application at basal (S_1) of nitrogen.

4.7.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction of nitrogen level and splitting of nitrogen on number of seed pod^{-1} of soybean showed significant variation (Table 7). The maximum number of seed pod^{-1} of soybean (2.8) was recorded from N_4S_4 treatment combination, which was statistically similar to N_4S_3, N_4S_2, N_3S_4, N_3S_3, N_2S_4 and N_2S_3 whereas the minimum (1.5) was recorded from N_1S_1 treatment combination.

4.8 1000 grains weight

4.8.1 Effect of nitrogen levels

1000 grains weight of soybean did not varied significantly with different nitrogen levels (Table 5). The maximum 1000 grains weight of soybean (12.57 g) was recorded from 30 kg N ha^{-1} (N_3) treatment whereas the minimum (11.14 g) was from 10 kg N ha^{-1} (N_1) treatment.

4.8.2 Effect of splitting of nitrogen

Different splitting of nitrogen also did not influenced significantly the 1000 grains weight of soybean (Table 6). 4 split applications (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS) (S_4) produced the maximum 1000 grains weight of soybean (12.28) while the minimum (11.59 g) was recorded from the 1 split application at basal (S_1) of nitrogen.

4.8.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on 1000 grains weight of soybean did not influenced significantly also (Table 7). However, numerically the maximum 1000 grains weight of soybean (13.78 g) was recorded from N_3S_4 treatment combination whereas the minimum (10.89 g) was recorded from N_1S_1 treatment combination.

Table 5. Effect of nitrogen levels on yield related parameter of soybean

Treatments	Number of pods plant^{-1}	Length of pod (cm)	Number of seeds pod^{-1}	1000 grain weight (g)
N_1	23.11 c	3.07	1.69 c	11.14
N_2	26.94 b	3.16	2.08 b	11.64
N_3	31.17 a	3.25	2.40 a	12.57
N_4	31.87 a	3.29	2.52 a	12.07
SE	0.96	ns	0.06	ns

[N_1= 10 kg ha^{-1}; N_2=20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1}]

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

Table 6. Effect of splitting of nitrogen on yield related parameter of soybean

Treatments	Number of pods plant^{-1}	Length of pod (cm)	Number of seeds pod^{-1}	1000 grain weight (g)
S_1	23.99 c	3.07	1.87 c	11.59
S_2	26.97 b	3.16	2.08 bc	11.68
S_3	30.67 a	3.25	2.35 ab	11.88
S_4	31.46 a	3.30	2.38 a	12.28
SE	0.94	ns	0.09	ns

[S_1= 1 split apply at basal; S_2= 2 split apply (1st at basal and 2nd at 10 DAS); S_3= 3 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4 4 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

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

Table 7. Interaction effect of nitrogen levels and splitting of nitrogen on yield related parameter of soybean

Treatments	Number of pods plant^{-1}	Length of pod (cm)	Number of seeds pod^{-1}	1000 grain weight (g)
N_1S_1	19.87 f	2.90	1.53 f	10.89
N_1S_2	22.40 ef	3.04	1.66 ef	10.98
N_1S_3	25.00 d~f	3.16	1.77 d~f	11.25
N_1S_4	25.17 d~f	3.19	1.80 d~f	11.45
N_2S_1	22.10 ef	3.07	1.83 def	11.53
N_2S_2	25.77 d~f	3.15	2.04 c~f	11.64
N_2S_3	29.87 a~d	3.20	2.22 a~e	11.65
N_2S_4	30.03 a~d	3.24	2.23 a~e	11.76
N_3S_1	26.33 de	3.14	1.97 def	11.94
N_3S_2	28.87 b~d	3.20	2.27 a~e	12.11
N_3S_3	34.33 ab	3.30	2.67 a~c	12.46
N_3S_4	35.17 a	3.38	2.70 ab	13.78
N_4S_1	27.67 c~e	3.16	2.15 b~f	12.00
N_4S_2	30.83 a~d	3.26	2.35 a~d	12.00
N_4S_3	33.50 a~c	3.35	2.77 ab	12.14
N_4S_4	35.47 a	3.40	2.80 a	12.12
SE	1.887	ns	0.191	ns
CV (%)	11.56	5.73	15.23	10.80

[N_1= 10 kg ha^{-1}; N_2=20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1};

[S_1= 1 split apply at basal; S_2= 2 split apply (1st at basal and 2nd at 10 DAS); S_3= 3 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

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

4.9 Yield (t ha^{-1})

4.9.1 Effect of nitrogen levels

Yield of soybean varied significantly with different nitrogen levels (Table 8). The maximum yield of soybean (1.85 t ha^{-1}) was recorded from 40 kg N ha^{-1} (N_4), which was statistically similar (1.77 t ha^{-1}) to 30 kg N ha^{-1} (N_3) whereas the lowest (1.09 t ha^{-1}) was recorded from 10 kg N ha^{-1} (N_1).

4.9.2 Effect of splitting of nitrogen

Different splitting of nitrogen also influenced significantly the yield of soybean (Table 9). The 4 split applications (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS) (S_4) of nitrogen produced the maximum yield of soybean (1.85 t ha^{-1}), which was statistically similar (1.83 t ha^{-1}) to 3 split application (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS) (S_3) of nitrogen while the minimum (1.05 t ha^{-1}) was obtained from the 1 split application at basal (S_1) of nitrogen.

Application of nitrogen at later growth stages either at pre-flowering or at pod filling resulted in higher grain yield as compared to application of nitrogen at sowing alone. This might be because of the beneficial effect of applying nitrogen to soybean in later stages which helped in regaining photosynthetic efficiency of crop and thereby increasing the crop yield. Thus it helped the crop to tide over nitrogen stress incurred during nodule degeneration (Sinha, 1997; Sekhon *et al.*, 1990). Prahraj (1994) observed significantly higher grain yield when additional nitrogen was applied at pod formation stage. Caliskan (2008) concluded that application of starter and top dressed N in combination with two split fertilization can be beneficial to improve early growth and final yield of soybean.

4.9.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on yield of soybean varied significantly (Table 10). The maximum yield of soybean (2.29 t ha^{-1}) was recorded from N_4S_4 treatment combination, which was statistically similar to N_4S_3, N_3S_4 and N_3S_3 whereas the minimum (0.85 t ha^{-1}) recorded from N_1S_1 treatment combination. Caliskan (2008) reported that 40 kg N ha^{-1} application of starter and top dressed N in combination with two split fertilization can be beneficial to improve early growth and final yield of soybean.

4.10 Straw yield (kg ha^{-1})

4.10.1 Effect of nitrogen levels

This research work exhibited distinct variations in straw yield of soybean with different nitrogen levels (Table 8). The maximum straw yield of soybean (2440.58 kg ha^{-1}) was recorded from 40 kg N ha^{-1} (N_4), which was statistically similar (2281.83 kg ha^{-1}) to 30 kg N ha^{-1} (N_3) whereas the minimum (1753.92 kg ha^{-1}) was recorded from 10 kg N ha^{-1} (N_1).

4.10.2 Effect of splitting of nitrogen

Straw yield of soybean plant varied significantly due to splitting of nitrogen (Table 9). The 4 split applications (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS) (S_4) of nitrogen produced the maximum straw yield of soybean (2346.25 kg ha^{-1}), which was statistically similar (2282.08 kg ha^{-1}) to 3 split applications (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS) (S_3) of nitrogen while the minimum (1815.0 kg ha^{-1}) was obtained from the 1 split application at basal (S_1) of nitrogen.

4.10.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on straw yield of soybean expose significantly (Table 10). The maximum straw yield of soybean (2785.0 kg ha^{-1}) was recorded from N_4S_4 treatment combination, which was statistically similar to

N_4S_3, N_3S_4 and N_3S_3 whereas the minimum (1650 kg ha^{-1}) was recorded from N_1S_1 treatment combination.

4.11 Biological yield (kg ha^{-1})

4.11.1 Effect of nitrogen levels

This research work exhibited distinct variations in biological yield of soybean due to different nitrogen levels (Table 8). The maximum biological yield of soybean (4287.08 kg ha^{-1}) was recorded from 40 kg N ha^{-1} (N_4), which was statistically similar (4050.0 kg ha^{-1}) to 30 kg N ha^{-1} (N_3) whereas the minimum (2840.0 kg ha^{-1}) was recorded from 10 kg N ha^{-1} (N_1).

4.11.2 Effect of splitting of nitrogen

Biological yield of soybean plant varied significantly due to splitting of nitrogen (Table 9). The 4 split applications (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) of nitrogen produced the maximum biological yield of soybean (4195.42 kg ha^{-1}),which was statistically similar (4108.92 kg ha^{-1}) to 3 split applications (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) (S_3) of nitrogen while the minimum (2869.75 kg ha^{-1}) was obtained from the 1 split application at basal (S_1) of nitrogen.

4.11.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on biological yield of soybean showed significant variation (Table 10). The maximum biological yield of soybean (5082.67 kg ha^{-1}) was recorded from N_4S_4 treatment combination, which was statistically similar to N_4S_3, N_3S_4 and N_3S_3 whereas the minimum (2495 kg ha^{-1}) was recorded from N_1S_1 treatment combination.

4.12 Harvest index

4.12.1 Effect of nitrogen levels

Harvest index of soybean did not varied significantly due to various treatments of nitrogen levels (Table 8). However, numerically the highest (42.33%) harvest index was obtained from 40 kg N ha^{-1} (N_4) and the lowest (37.75%) harvest index of soybean was recorded from 10 kg N ha^{-1} (N_1) .

4.12.2 Effect of splitting of nitrogen

Harvest index of soybean did not varied significantly due to various treatments of splitting of nitrogen (Table 9). However, numerically the highest (43.59%) harvest index was obtained from 4 split applications (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS) (S_4) and the lowest (36.37%) harvest index of soybean was recorded from the 1 split application at basal (S_1) of nitrogen.

4.12.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on harvest index of soybean showed significant variation (Table 10). The maximum harvest index of soybean (45.86%) was recorded from N_3S_3 treatment combination which was statistically similar to N_4S_3, N_4S_4, N_4S_2, N_3S_4, N_3S_4, $N_3S_{2,}$ N_2S_2, N_2S_3 and N_2S_4 whereas the minimum (33.77%) was recorded from N_1S_1 treatment combination.

Table 8. Effect of nitrogen levels on yield related parameter of soybean

Treatments	Yield (t ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index
N_1	1.09 c	1753.92 c	2840.00 c	37.75
N_2	1.48 b	1979.17 b	3456.83 b	42.22
N_3	1.77 ab	2281.83 a	4050.00 a	43.14
N_4	1.85 a	2440.58 a	4287.08 a	42.33
SE	0.088	75.53	161.7	ns

[N_1=10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1}]

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

Table 9. Effect of splitting of nitrogen on yield related parameter of soybean

Treatments	Yield (t ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index
S_1	1.05 c	1815.00 c	2869.75 c	36.37
S_2	1.45 b	2009.17 b	3461.83 b	41.63
S_3	1.83 a	2282.08 a	4108.92 a	43.83
S_4	1.85 a	2346.25 a	4195.42 a	43.59
SE	0.073	63.32	128.2	0.909

[S_1= 1 split apply at basal; S_2= 2 split apply (1st at basal and 2nd at 10 DAS); S_3= 3 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

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

Table 10. Interaction effect of nitrogen levels and splitting of nitrogen on yield related parameter of soybean

Treaments	Yield (t ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index
N_1S_1	0.85 g	1650.00 f	2495.00 e	33.77 f
N_1S_2	1.11 fg	1700.00 f	2813.33 e	38.96 c~f
N_1S_3	1.19 e~g	1818.33 ef	3012.67 e	38.94 c~f
N_1S_4	1.19 e~g	1843.33 ef	3040.00 e	39.31 b~f
N_2S_1	1.00 fg	1700.00 f	2703.33 e	37.13 ef
N_2S_2	1.36 d~f	1840.00 ef	3200.00 c~e	42.43 a~e
N_2S_3	1.76 cd	2150.00 c~e	3913.33 bc	45.04 ab
N_2S_4	1.78 b~d	2227.67 c~e	4007.67 bc	44.26 a~c
N_3S_1	1.17 fg	1910.00 d~f	3077.67 de	37.67 d~f
N_3S_2	1.68 cd	2193.33 c~e	3873.33 b~d	43.40 a~d
N_3S_3	2.11 a~c	2490.00 a~c	4597.67 ab	45.86 a
N_3S_4	2.12 a~c	2530.00 a~c	4653.033 ab	45.61 a
N_4S_1	1.20 fg	2000.00 d~f	3200.00 c~e	36.89 ef
N_4S_2	1.65 c~e	2303.33 b~d	3957.67 bc	41.74 a~e
N_4S_3	2.24 ab	2670.00 ab	4910.00 a	45.49 a
N_4S_4	2.29 a	2785.00 a	5082.67 a	45.18 ab
SE	0.1461	126.6	256.4	1.819
CV (%)	16.36	10.38	12.14	7.62

[N_1= 10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1};

[S_1= 1 split apply at basal; S_2= 2 split apply (1st at basal and 2nd at 10 DAS); S_3= 3 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split apply (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

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

4.13 Moisture percentage

4.13.1 Effect of nitrogen levels

Moisture percentage of soybean varied significantly due to various treatments of nitrogen levels (Table 11). The maximum moisture percentage (13.81%) was obtained from 40 kg N ha^{-1} (N_4) and the minimum (12.38%) moisture percentage of soybean was recorded from 30 kg N ha^{-1} (N_3) .

4.13.2 Effect of splitting of nitrogen

Moisture percentage of soybean varied significantly due to various treatments of splitting of nitrogen (Table 12). The highest (13.73%) moisture percentage was obtained from 4 split applications (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS) (S_4) and the lowest (12.43%) moisture percentage of soybean was recorded from the 1 split application at basal (S_1) of nitrogen.

4.13.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on moisture percentage of soybean showed significant variation (Table 13). The maximum moisture percentage of soybean (14.85%) was recorded from N_4S_3 treatment combination which was statistically similar (14.80%) to N_4S_4 treatment combination whereas the minimum (11.82%) was recorded from N_3S_3 treatment combination.

4.14 Protein percentage

4.14.1 Effect of nitrogen levels

Protein percentage of soybean varied significantly due to various treatments of nitrogen levels (Table 11). The maximum protein percentage (39.29%) was obtained from 30 kg N ha^{-1} (N_3) and the minimum (38.14%) protein percentage of soybean was recorded from 40 kg N ha^{-1} (N_4) .

4.14.2 Effect of splitting of nitrogen

Protein percentage of soybean varied significantly due to various treatments of splitting of nitrogen (Table 12). The highest (39.24%) protein percentage was obtained from 4 split applications (1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS, 4^{th} at 30 DAS) (S_4) and the lowest (38.0%) protein percentage of soybean was recorded from the 3 split applications(1^{st} at basal, 2^{nd} at 10 DAS, 3^{rd} at 20 DAS) (S_3) of nitrogen .

4.14.3 Interaction effect of nitrogen level and splitting of nitrogen

Interaction effect of nitrogen level and splitting of nitrogen on protein percentage of soybean showed significant variation (Table 13). The maximum protein percentage of soybean (40.79%) was recorded from N_4S_3 treatment combination whereas the minimum (36.10%) was recorded from N_1S_3 treatment combination.

Table 11. Effect of nitrogen levels on protein content of soybean

Treatmets	Moisture %	Protein %
N_1	13.30 b	38.49 c
N_2	12.64 c	39.24 b
N_3	12.38 d	39.29 a
N_4	13.81 a	38.14 d
SE	0.046	0.0009

[N_1= 10 kg ha^{-1}; N_2= 20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1}]

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

Table 12. Effect of splitting of nitrogen on protein content of soybean

Treatments	Moisture %	Protein %
S_1	12.43 c	38.94 c
S_2	12.72 c	38.99 b
S_3	13.25 b	38.00 d
S_4	13.73 a	39.24 a
SE	0.108	0.0009

[S_1= 1 split apply at basal; S_2= 2 split (apply 1st at basal and 2nd at 10 DAS); S_3= 3 split (apply 1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split (apply 1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

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

Table13. Interaction effect of nitrogen levels and splitting of nitrogen on protein content of soybean

Treatments	Moisture %	Protein %
N_1S_1	13.00 b~e	37.79 m
N_1S_2	13.00 b~e	39.27 f
N_1S_3	13.53 bc	36.10 p
N_1S_4	13.68 b	39.03 h
N_2S_1	12.14 gh	38.44 j
N_2S_2	12.74 d~g	40.35 b
N_2S_3	12.80 d~g	37.90 l
N_2S_4	12.89 c~f	40.29 d
N_3S_1	12.20 f~h	40.31 c
N_3S_2	11.93 h	40.20 e
N_3S_3	11.82 h	38.96 i
N_3S_4	13.56 bc	37.68 n
N_4S_1	12.39 e~h	39.22 g
N_4S_2	13.19 b~d	36.14 o
N_4S_3	14.85 a	40.79 a
N_4S_4	14.80 a	38.18 k
SE	0.217	0.002
CV (%)	2.88	4.55

[N_1= 10 kg ha^{-1}; N_2=20 kg ha^{-1}; N_3= 30 kg ha^{-1} and N_4= 40 kg ha^{-1};

[S_1= 1 split apply at basal; S_2= 2 split (apply 1st at basal and 2nd at 10 DAS); S_3= 3 split (apply 1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) and S_4= 4 split (apply 1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS)]

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

CHAPTER V

SUMMARY AND CONCLUSION

The present piece of work was done at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka during the period from January 2013 to April 2013 to find out the effect of levels and no of splitting of nitrogen on the seed yield and quality of soybean.

The experiment was laid out in a split plot design with three replications. The size of the individual plot was 3 m x 2 m and total numbers of plots were 48. There were 16 treatment combinations. Nitrogen levels treatments were placed at the main plot and splitting of nitrogen treatments were placed in the sub plots.

The experiment was carried out with four different levels of nitrogen treatments *i.e.* N_1= 10 kg ha^{-1} nitrogen, N_2= 20 kg ha^{-1} nitrogen, N_3= 30 kg ha^{-1} nitrogen and N_4= 40 kg ha^{-1} nitrogen in the main plot and four splitting of nitrogen treatments viz. S_1= 1 split application of nitrogen at basal, S_2= 2 split application (at basal and at 10 DAS) of nitrogen, S_3= 3 split application (at basal, at 10 DAS and at 20 DAS) of nitrogen and S_4= 4 split application (at basal, at 10 DAS, at 20 DAS and at 30 DAS) of nitrogen in the sub plot in split plot design.

The data on growth parameters viz. plant height (cm), number of leaves plant^{-1}, numbers of branches plant^{-1} and total dry matter weight (g) were recorded during the period from 30 to 75 DAS. At harvest, characters like plant height (cm), number of pod plant^{-1}, pod length (cm), number of seed pod^{-1}, weight of 1000 grains (g), grain yield plot^{-1}, grain yield, straw yield, biological yield and harvest index and the quality matter viz. moisture percentage and protein percentage were recorded. Collected data were statistically analyzed for the evaluation of treatments for the identification of the best variety of potato, the save As concentration and the best combination. Summary of the results and conclusion have been described in this chapter.

Results showed that different levels of nitrogen had significant effect on growth parameters. The rapid increase of plant height was observed from 30 days to 75 days of growth stages which was the highest in 40 kg N ha^{-1} (N_4) and the lowest in 10 kg N ha^{-1} (N_1) at harvesting stage. Conversely, 4 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) of nitrogen produced the tallest and 1 split application at basal (S_1) of nitrogen produced the shortest plant respectively at harvesting stage. In interaction effect of nitrogen level and splitting of nitrogen, N_4S_4 generated tallest plant whereas N_1S_1 produced shortest at harvesting stage.

Considering the different levels of nitrogen, 40 kg N ha^{-1} (N_4) generated the maximum number of leaves, number of branches and dry weight at 75 DAS whereas the minimum recorded from 10 kg N ha^{-1} (N_1). Regarding different splitting of nitrogen, 4 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) of nitrogen produced the maximum number of leaves, number of branches and dry weight at 75 DAS whereas the minimum recorded from 1 split application at basal (S_1) of nitrogen. In combination N_4S_4 generated the maximum number of leaves, number of branches and dry weight at 75 DAS whereas the minimum produced from N_1S_1.

Among the different levels of nitrogen, 40 kg N ha^{-1} (N_4) generated the maximum number of pods $plant^{-1}$, number of seeds pod^{-1}, length of pod and 1000 grain weight whereas the minimum produced from 10 kg N ha^{-1} (N_1). Regarding on different splitting of nitrogen, 4 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) of nitrogen produced the maximum number of pods $plant^{-1}$, number of seeds pod^{-1}, length of pod and 1000 grain weight whereas 1 split application at basal (S_1) of nitrogen produced the minimum numbers. In combination N_4S_4 generated the maximum number of pods $plant^{-1}$, number of seeds pod^{-1}, length of pod and 1000 grain weight whereas N_1S_1 produced the minimum number.

Considering the different levels of nitrogen, 40 kg N ha^{-1} (N_4) generate the maximum yield, straw yield, biological yield and harvest index at harvest stage whereas the minimum generated from 10 kg N ha^{-1} (N_1). Regarding on different splitting of nitrogen, 4 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) of nitrogen produced the maximum yield, straw yield, biological yield and harvest index at harvesting stage whereas the minimum recorded from 1 split application at basal (S_1) of nitrogen. In combination N_4S_4 generated the maximum yield, straw yield, biological yield and harvest index at harvesting stage whereas N_1S_1 produced the minimum one.

Among the different levels of nitrogen, 40 kg N ha^{-1} (N_4) generate the maximum moisture percentage and 30 kg N ha^{-1} (N_3) generate the maximum protein percentage of soybean grain whereas the minimum recorded from N_3 (30 kg N ha^{-1}) and N_4 (40 kg N ha^{-1}) respectively. Regarding on different splitting of nitrogen, 4 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) (S_4) of nitrogen produced the maximum moisture percentage and protein percentage of soybean grain whereas the minimum recorded from 1 split apply at basal (S_1) and 3 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS) (S_3) of nitrogen respectively. In interaction N_4S_3 generated the maximum moisture percentage and N_1S_4 generated the maximum protein percentage whereas the minimum recorded from N_3S_2 and N_1S_4 treatment combination respectively.

Based on the results of the present experiment, the following conclusion can be drawn:

1. Among the levels of nitrogen treatments 40 kg N ha^{-1} produced highest grain yield.
2. Among the splitting of nitrogen, 4 split application (1st at basal, 2nd at 10 DAS, 3rd at 20 DAS, 4th at 30 DAS) of nitrogen produced highest grain yield.
3. Combination of 40 kg N ha^{-1} and 4 split application (at basal, at 10 DAS at 20 DAS, and at 30 DAS) of nitrogen would be promising practice for the optimum soybean grain yield.

REFERENCES

Afza, R., Hardarson, G., Zapata, F. and Danso, S. K. A. (1987). Effects of delayed soil and foliar N fertilization on yield and N_2 fixation of soybean. *Plant Soil*. 97(3): 361-368.

Ahmad, A., Abrol, Y. P. and Abdin, M. Z. (1999). Effect of split application of sulphur and nitrogen on growth and yield attributes of Brassica genotypes differing in time of flowering. Can. J. Plant Sci. 79: 175-180.

AI-Ilhawi, B., Deibert, E. J. and Olson, R. A. (1980). Applied N and moisture level effects on yield, depth of root activity, and nutrient uptake by soybean. *Agron. J.* 72:827-832.

BARI (Bangladesh Agricultural Research Institute). (2011). Krishi Projokti Hatboi (In Bangla). Gazipur, Bangladesh. pp. 270.

Barker, D. W., and Sawyer, J. E. (2005). Nitrogen application to soybean at early reproductive development. *Agron. J. 97*(2): 615-619.

BBS (Bangladesh Bureau of Statistics). (2011). Statistical Year Book of Bangladesh. Bangladesh Bur. Stat. Div. Min. Plan., Govt. Peoples Repub. Bangladesh. pp. 1-330.

Biswas, P. K. (1987). A study on the relative merits of mixed cropping under two levels of irrigations. MS Thesis, Dept. Agron. Sher-e-Bangla Agric. Univ. Dhaka. pp. 38-40.

Bly, A., Woodard, H. J. and Winther, D. (1998) Nitrogen application timing and rate effects on soybean grain parameters at Aurora SD (Soil/Water Research Progress Report, SOIL PR 97-35. Plant Sci. Dep. Agric. Exp. Stn., South Dakota State Univ., Brookings.

Boroomandan, P., Khoramivafa, M., Haghi, Y., and Ebrahimi, A. (2009). The effects of nitrogen starter fertilizer and plant density on yield, yield components and oil and protein content of soybean (*Glycine max* L. Merr). *Pak. J. Biol Sci.* 12(4): 378-382.

Brevedan, R. E., Egli, D. B. and Leggett, J. E. (1987). Influence of N nutrition on flower and pod abortion and yield of soybeans. *Agron. J.* 70:81–84.

Brevedan, R. E., Egli, D. and Leggell, J. E. (1977). Influence of N nutrition on total N, nitrate, and carbohydrate levels in soybean. *Agron. J.* 69: 965-969.

Caliskan, S., Ozkaya, I., Caliskan, M. E., and Arslan, M. (2008). The effects of nitrogen and iron fertilization on growth, yield and fertilizer use efficiency of soybean in a Mediterranean-type soil. *Field Crop Res*. *108*(2): 126-132.

Carpaneto, B., Lorenzo, M., and Abbate, P. E. (2014). Effect of nitrogen fertilization on soyabeans interplanted with wheat in Balcarce. *Rev. Invest. Agro. 40*(1): 54-59.

Deacon, J. (1997). The microbial world: The nitrogen cycle and nitrogen fixation. *Institute of Cell and Molecular Biology University of Edinburgh*.

Dev, S. P., and Tiirk, K. V. B. R. (1976). Effect of organic manure on the nodulation and nitrogen fixation by soybean ***(****Glymne max.(L.)) Indian J. Agric.* Sn. 4 6(6):252-256.

Eaglesham, A, R, J., Hassouna, S. and Seegers, R. (1983). Fcrtilizer-N effects on N_2 fixation by cowpea and soybean. *Agron. J.* 75:61-66.

Flannery, R. L. (1986). Plant food uptake in a maximum yield soybean study. *Better Crop.* 70:6–7.

Freeborn, J. R., Holshouser, D. L., Alley, M. M., Powell, N. L., and Orcutt, D. M. (2001). Soybean yield response to reproductive stage soil-applied nitrogen and foliar-applied boron. *Agron. J., 93*(6): 1200-1209.

Gan, Y., Stulen, I., Posthumus, F., van Keulen, H., and Kuiper, P. (2002). Effects of N management on growth, N_2 fixation and yield of soybean. *Nutr. Cycl. Agroecosys. 62*(2): 163-174.

Gan, Y., Stulen, I., van Keulen, H., and Kuiper, P. J. (2003). Effect of N fertilizer top-dressing at various reproductive stages on growth, N_2 fixation and yield of three soybean (*Glycine max* (L.) Merr.) genotypes. *Field Crop Res*, *80*(2): 147-155.

Gardner, F. P., Pearce, R. B. and Mistechell, R. L. (1985). Physiology of crop plants. Iowa State Univ. Press. Iowa, 500010. p. 66.

Google Maps. (2014). Google maps by Google Inc. [https://maps.google.com]

Gutiérrez-Boem, F. H., Scheiner, J. D., Rimski-Korsakov, H., and Lavado, R. S. (2004). Late season nitrogen fertilization of soybeans: effects on leaf senescence, yield and environment. *Nutr. Cycl. Agroecosys*. *68*(2): 109-115.

Ham, G. E., Liener, I. E., Evans, S. D., Frazier, R. D., and Nelson, W. W. (1975). Yield and composition of soybean seed as affected by N and S fertilization. *Agron. J. 67*(3): 293-297.

Harrcr, J. E. (1974). Soil and symbiotic nitrogen requirements for optimum soybean production, *Crop Sci*. 14: 255-260.

Henkel, J. (2000). Soy. Health claims for soy protein, questions about other components. *FDA cons*. 34(3): 13.

Jadhav, P. J., Jadhav, A. S., and Bachchhav, S.M. (1994). Effects of N, row spacing and plant densities on the yield and quality of soybean (*Glycine mar* (L.) Merr). *J. Maharashtra Agnc. Unrv*. 19(1):75-77.

Jamal, A., Fazli, I. S., Ahmad, S., Abdin, M. Z., and Yun, S. J. (2005). Effect of sulphur and nitrogen application on growth characteristics, seed and oil yields of soybean cultivars. *Korean J. Crop Sci.* 50(5): 340.

Kang, B. T. (1975). Effects of inoculation and nitrogen fertilizer on soybean in Western Nigeria. *Exp. Agr.* 11(01): 23-31.

Katoch, K. K., Aggarwal, G. C., and Garg, F. C. **(**1983). Effect of nitrogen**,** soil campaction and moisture stress on nodulation and yield of soybean *(Glycine max (*L.)M err*). J. Indian* Soc. *So11& I.*3(1): 215-219.

Krishna, K. G., Rao, K. L., Kumar, A. R, and Sreelatha, D. (1995). Response of soybean *(Glycine max (*L.) Merr*)*to mtrogm, phosphorus and Rhizobium. J. Maharashha Agnc Unrv. 20(2): 236-238.

Maryam, V., Sekineh, V., and Mehran, A. (2013). Starter nitrogen fertilizer impact on Soybean yield and quality. *Int. J. Eng. Adv. Technol*. 3(1): 2249-2258.

Mrkovacki, N., Marinkovi, J., and Acimovic, R. (2008). Effect of N fertilizer application on growth and yield of inoculated soybean. *Not. Bot. Horti Agrobot. Cluj-Napoca.* 36(1): 48-51.

Nimje, P. M., and Jagdish Seth, (1988). Effect of phosphorus and farmyard manure on nutrient uptake by soybean (*Glycine mar* (L.) Merr). *Indian J. Agron.* 33(2): 135-142.

Osborne, S. L., and Riedell, W. E. (2006). Starter nitrogen fertilizer impact on soybean yield and quality in the northern Great Plains. *Agron. J. 98*(6): 1569-1574.

Prahraj, C. S. (1994) Growth and productivity of soybean (*Glycine max* L. Merrill) as affected by interacting influence of *Rhizobium*, nitrogen and potassium and herbicide use; and their residual effect on wheat. Ph.D. Dissertation, PAU, Ludhiana.

Rahman, A., Das, M. L. and Khan, H. R. (1982)**.** Effect of inoculation and nitrogen fertilizer on soybean. *Bangladesh J. Bot.* 11(1): 33-36.

Ramamurthy, V. and Shivashankar, K. (1996). Effect of organic matter and phosphorus on growth and yield of soybean (*Glycine max*). *Indian J. Agron. 41*(1): 65-68.

Ray, J. D., Heatherly, L. G., and Fritschi, F. B. (2006). Influence of large amounts of nitrogen on nonirrigated and irrigated soybean. *Crop sci*. *46*(1): 52-60.

Riedell, W. E., Schumacher, T. E. and Pikul, J. L. (1997). Soybean row spacing and nitrogen fertilizer effects on yield and potential nitrate leaching (Soil/Water Research, 1997 Progress Report SOIL PR 97-38. *Plant Sci. Dep. Agric. Exp. Stn*., South Dakota State Univ., Brookings).

Schmitt, M. A., Lamb, J. A., Randall, G. W., Orf, J. H., and Rehm. G. W. (2001). In-season fertilizer nitrogen applications for soybean in Minnestoa. *Agron. J.* 93: 983-988.

Sekhon, H. S., Kaul, J. N. and Dhingra, K. K. (1990) Effect of some agronomic practices on the biological nitrogen fixation in pulses. In : [Somani L L, Bhandari S C, Vyas K K and Saxena S N (Eds)] Biofertilizers, Scientific Pub. Jodhpur, Pp. 85-154.

Sij, J. W., Turner, F. T. and Craigmiles, J. P. (1979). "Starter nitrogen" fertilization in soybean culture. *Commun. Soil Sci. Plant Anal*.10: 1451–1457.

Sinha, S. K. (1977) Food Legumes, Distribution, Adaptability and Biology of yield. FAO Plant Production and Protection paper 3, AGPC Misc 36: 89-90.

Sorensen, R. C., and Penas, E. J. (1978). Nitrogen fertilization of soybeans. *Agron. J.*, *70*(2): 213-216.

SRDI (Soil Resource Development Institute). (1991). Land and Soil Resource Utilization Guide: Mymensingh Sadar Thana, Mymensingh. (In Bangali). SRDI, Ministry of Agricultural, Dhaka, Bangladesh. p. 3.

Starling, M. E., Wood, C. and Weaver, D. B. (2000). Late-planted soybeans respond to nitrogen starter. *Fluid J.* 28:26–30.

Starling, M. E., Wood, C., and Weaver, D. B. (1998). Starter nitrogen and growth habit effects on late-planted soybean. *Agron. J. 90*(5): 658-662.

Taylor, R. S., Weaver, D. B., Wood, C., and van Santen, E. (2005). Nitrogen application increases yield and early dry matter accumulation in late-planted soybean. *Crop sci. 45*(3): 854-858.

Touchton, J. T., and D. H. Rickerl. (1986). Soybean growth and yield response to Starter fertilizers. *Soil Sci. Soc. Am. J.* 50: 234-237.

Umeh, M. O., Edeoga, H. O., and Omosun, G. (2011). Nitrogen fertilizer type and rate effects on growth and yield response of soybean varieties. *Cont. J. Agron*. 5(2):19-23.

Varvel, G. E. and Peterson. T. A. (1992). Nitrogen fertilizer recovery by soybean in monoculture and rotation systems. *Agron. J.* 84: 215-218.

Welch, L. F., Boone, L. V., Chambliss, C. G., Christiansen, A. T., Mulvaney, D. L., Oldham, M. G., & Pendleton, J. W. (1973). Soybean yields with direct and residual nitrogen fertilization. *Agron. J. 65*(4): 547-550.

Wesley, T. L., Lamond, R. E., Martin, V. L., and Duncan, S. R. (1998). Effects of late-season nitrogen fertilizer on irrigated soybean yield and composition. *J. Prod. Agric.* 11(3): 331-336.

Wesley, T. L., Lamond, R. E., Martin, V. L. and Duncan, S. R. (1999). Applied N at R3 stage bumps soybean yields. *Fluid J.* 25:16–19.

Wilson, E. W., Rowntree, S. C., Suhre, J. J., Weidenbenner, N. H., Conley, S. P., Davis, V. M., ... and Casteel, S. N. (2014). Genetic gain× management interactions in soybean: II. Nitrogen utilization. *Crop Sci. 54*(1): 340-348.

Wingeyer, A. B., Echeverría, H., and Rozas, H. S. (2014). Growth and yield of irrigated and rainfed soybean with late nitrogen fertilization. *Agron. J. 106*(2): 567-576.

Wood, C. W., Torbert, H. A., and Weaver, D. B. (1993). Nitrogen fertilizer effects on soybean growth, yield, and seed composition. *J. Prod. Agric. 6*(3): 354-360.

Woodard, H. J., Bly, A., and Winther, D. (2012). The effect of N applications on agronomic parameters and soybean nodulation (Soil/Water Res. Progress Report, 1998)M Ozaki, Y. Adachi, Y. Iwahori, and N. Ishii, Application of fuzzy theory to writer recognition of Chinese characters, *IOSR J. Eng.* 2(2): 112-116.

APPENDICES

Appendix I. The morphological, physical and chemical properties of the experimental land

A. Morphological properties of the soil

Constituents	Characteristics
Location	Field, Department of Agronomy, SAU, Dhaka
Soil Tract	Madhupur
Land type	high land, fertile, well drained
General soil type	Slightly acidic in reaction with low organic matter content
Agro-ecological one	“AEZ-28” of Madhupur Tract
Topography	Fairly level
Soil colour	Dark grey
Drainage	Well drained

B. Physical properties of the soil

Constituents	Results
Particle size analysis	
Sand (%) (0.0-0.02 mm)	21.75
Silt (1%) (0.02-0.002 mm)	66.60
Clay (%) (<0.002 mm)	11.65
Soil textural class	Silty loam
Colour	Dark grey
Consistency	Grounder

Result obtained from the mechanical analysis of the initial soil sample done in the Soil Resources Development Institute (SRDI), Dhaka.

C. Chemical composition of the initial soil (0-15 cm depth)

Constituents	Results
Soil pH	5.8
Organic matter (%)	1.30
Total nitrogen (%)	0.101
Available phosphorus (ppm)	27
Exchangeable potassium (me/100 g soil)	0.12

Methods of analysis

Texture	Hydrometer methods
pH	Ptentiometric method
Organic carbon	Walkely-Black method
Total N	Modified kjeldhal method
Soluble P	Olsen method ($NAHCO^3$)
Exchangeable K	Flame photometer method (Ammonium)

Result obtained from the mechanical analysis of the initial soil sample done in the Soil Resources Development Institute (SRDI), Dhaka.

Appendix II. Monthly air temperature, rainfall, relative humidity and sunshine hours during the growing season (January 2012 to May 2012)

Month	Year	*Air temperature (^{O}C)			**Rainfall (mm)	*Relative humidity (%)	** Sunshine (hrs)
		Maximum	Minimum	Average			
January	2012	24.92	13.46	19.19	Trace	86.16	160.40
February	2012	28.77	15.33	22.05	Trace	73.57	223.40
March	2012	30.93	18.95	24.94	18.1	75.16	202.10
April	2012	28.53	16.85	22.69	19.58	79.58	119.65
May	2012	27.15	15.99	21.57	23.21	81.62	101.41

* Monthly average and ** Monthly total

Appendix III. Means square values for plant height of soybean at different days after sowing

Sources of variation	DF	Means square values at different days after sowing				
		30	45	60	75	At harvest
Replication	2	0.546	56.120	60.124	16.177	81.623
Nitrogen levels (N)	3	5.784**	67.505*	303.791	199.077	380.930
Error (a)	6	0.546	4.600	24.910	3.582	9.722
Splitting of Nitrogen (S)	3	3.655**	51.487*	149.436	147.912	71.961
NxS	9	0.025	0.957	3.658	1.643	2.817
Error (b)	24	0.248	7.504	16.771	7.517	22.348

*Significant at 5% level

ns- Non significant

Appendix IV. Means square values for number of leaves of soybean at different days after sowing

Sources of variation	DF	Means square values at different days after sowing				
		30	45	60	75	At harvest
Replication	2	0.493	0.578	0.194	1.433	0.253
Nitrogen levels (N)	3	0.072	1.434	15.569	35.642	0.032
Error (a)	6	0.133	0.619	0.104	1.095	0.110
Splitting of Nitrogen (S)	3	0.005	0.491	9.853	14.045	0.003
NxS	9	0.025	0.039	0.372	1.567	0.017
Error (b)	24	0.127	0.335	0.100	2.248	0.121

*Significant at 5% level

ns- Non significant

Appendix V. Means square values for number of branches of soybean at different days after sowing

Sources of variation	DF	Means square values at different days after sowing			
		45	60	75	At harvest
Replication	2	0.078	0.224	0.033	0.033
Nitrogen (N)	3	0.010	0.271	0.204	0.204
Error (a)	6	0.008	0.024	0.031	0.031
Splitting (S)	3	0.025	1.028	0.322	0.322
NxS	9	0.003	0.011	0.006	0.006
Error (b)	24	0.006	0.056	0.010	0.010

*Significant at 5% level

ns- Non significant

Appendix VI. Means square values for dry weight of soybean at different days after sowing

Sources of variation	DF	Means square values at different days after sowing				
		30 DAS	45 DAS	60 DAS	75 DAS	At harvest
Replication	2	0.071	0.720	0.464	5.659	0.643
Nitrogen (N)	3	0.107	1.849	11.204	34.893	13.113
Error (a)	6	0.004	0.290	3.382	7.941	3.587
Splitting (S)	3	0.025	0.485	17.779	18.399	19.56 9
NxW	9	0.004	0.020	1.044	1.541	1.157
Error (b)	24	0.005	0.495	1.672	4.730	1.876

*Significant at 5% level

ns- Non significant

Appendix VII. Means square values for yield contributing characters of Soybean

Sources of variation	DF	Means square values			
		Number of pod $plant^{-1}$	Length of pod	Number of seed pod^{-1}	1000 grain weight
Replication	2	2.040	0.046	0.215	4.095
Nitrogen (N)	3	199.129	0.115	1.647	4.442
Error (a)	6	10.992	0.021	0.045	1.640
Splitting (S)	3	143.809	0.126	0.708	1.118
NxS	9	2.322	0.002	0.037	0.405
Error (b)	24	10.681	0.034	0.109	1.640

*Significant at 5% level

ns- Non significant

Appendix VIII. Means square values for yield contributing characters of Soybean

Sources of variation	DF	Means square values			
		Yield (t ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index
Replication	2	0.047	34973.438	160102.083	5.207
Source of nitrogen (N)	3	1.424	1129584.028	5037619.965	71.513
Error (a)	6	0.094	68461.632	313629.861	9.530
Weed control (W)	3	1.686	730320.139	4612126.910	144.460
NxW	9	0.077	39492.824	224422.280	2.108
Error (b)	24	0.064	48106.944	197177.083	9.924

*Significant at 5% level

ns- Non significant

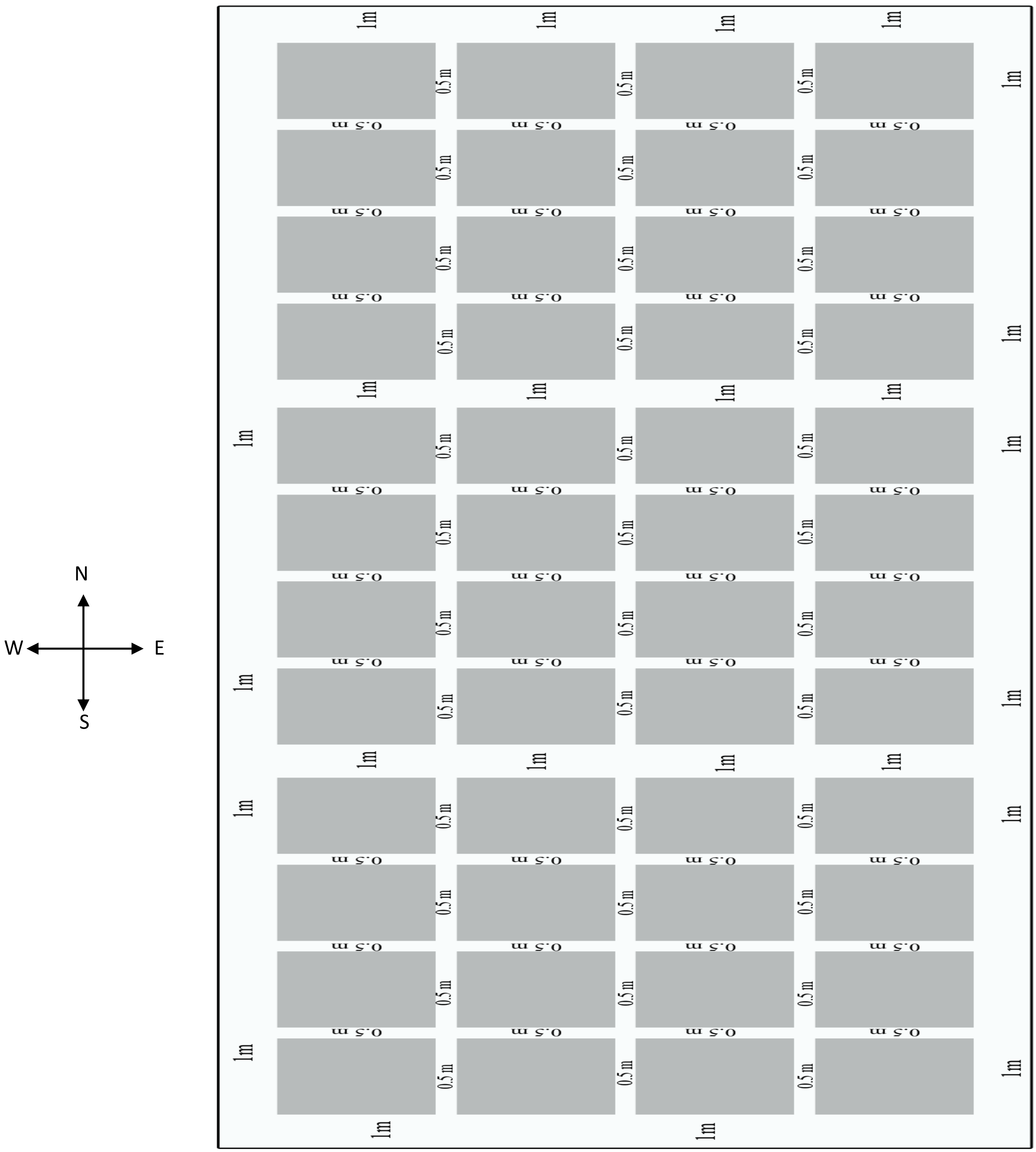

Plate 1. Layout of the experimental field