EFFECT OF FERTILIZER ON THE GROWTH AND YIELD OF SOYBEAN (*Glycine max* L.) VARIETIES

BY

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CERTIFICATE

This is to certify that the thesis entitled, "*EFFECT OF FERTILIZER ON THE GROWTH AND YIELD OF SOYBEAN (Glycime max L.) VARIETIES*" submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of *MASTER OF SCIENCE (M.S.)* in *AGRONOMY* embodies the result of a piece of bonafide research work carried out by *MAHFILA ZAFREEN*, Registration No. ***26159/00456*** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 27.6.07

Place: **Dhaka, Bangladesh**

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Prof. Dr. A. K. M. Ruhul Amin


DEDICATED TO
MY
BELOVED NEPHEW

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ABSTRACT

An experiment was conducted at the Agronomy Field of Sher-e-Bangla Agriculture University, Dhaka-1207 during the period from August, 2006 to study the responses of soybean varieties to different doses of fertilizer. The experiment was carried out with three soybean varieties viz. Shohagh, Bangladesh soybean-4 and BARI soybean-5 and four levels of fertilizer viz. no fertilizer, half of the recommended dose, recommended dose and double of the recommended dose. The experiment was laid out in split plot design with three replications.

The results showed that variety and fertilizer dose significantly influenced the growth, development, yield characters and yield of the soybean. Among three varieties, Bangladesh soybean-4 had maximum plant height, dry matter, number of branches plant^{-1}, pod length, number of pod plant^{-1} number of seeds pod^{-1}, seed yield, stover yield, biological yield and harvest index. Fertilizer at recommended dose significantly increased yield with higher values of harvest index as the yield attributes like pods plant^{-1}, seed pod^{-1} and 1000-seed weight were higher.

In most of the cases Bangladesh soybean-4 coupled with fertilizer at recommended dose was found to influence yield but double of the recommended dose was found to be associated with better growth. The highest seed yield (2683.0 kg ha^{-1}) was found with the interaction of Bangladesh soybean-4 with fertilizer at recommended dose. This was achieved due to maximum number of pod plant^{-1} (41.67), number of seed pod^{-1} (2.04) and greater pod length (3.60).

ABBREVIATIONS

FULL NAME	ABBREVIATION
Agro-ecological Zone	AEZ
And others (at elli)	*et al.*
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Coefficient of variation	CV
Cultivar	cv.
Centimeter	cm
Dry matter	DM
Days after sowing	DAS
Degree Celsius	^{0}C
Gram	g
Harvest index	HI
Hectare	ha
Hour	hr
Kilogram	kg
Least significant difference	LSD
Meter	m
Millimeter	mm
Number	no
National Seed Board	NSB
percent	%
Sher-e-Bangla Agricultural University	SAU
Bangladesh Agricultural University	BAU
Square meter	m^2

CONTENTS

CONTENTS (cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter 1

Introduction

INTRODUCTION

The cultivated soybean (*Glycine max* (L) Merrill) belongs to the family Leguminosae, sub-family Papilionaceae. It is one of the leading oilseed crops of the world and contains 20% edible oil. Soybean seeds also contain 43.32% protein, 19.5% fat, 20.9% carbohydrate and a good amount of other nutrients like calcium, phosphorus, iron, vitamins etc. Protein is essential for proper development and maintenance of human body. Generally man gets protein from plant and animal sources. There is an acute shortage of edible oil in Bangladesh. However, the poor people cannot afford high priced animal protein as meat, egg, fish and milk (Wahab *et al.*, 2002).

Soybean was introduced in Bangladesh around 1942; but its cultivation did not expand satisfactorily. In recent years MCC, CDP, BARC, BARI, BAU, BCSIR and other some NGOs (GKF, RDRS etc) are trying to expand its cultivation. Soybean is also used as a pulse crop in Bangladesh. In many Asian countries the seeds are cooked, roasted or fried and eaten. In Bangladesh the use of soybean is gradually increasing. The most common method of eating soybean in the home is soya-dhal, soya chatni, soya khichuri, soya-milk, soya-curd, soya-flour and roasted soybean snacks. Besides, soybean is used for making chanachur, biscuit and baby food. Its milk is comparable to cow's milk (Smith, 1975).

Soybean being a leguminous crop improves the soil by fixing the atmospheric nitrogen through *Rhizobium* bacteria that lives in root nodules. Soybean plants can fix 94 kg/ha nitrogen in the soil (Steward, 1966).

Soybean can be cultivated under a wide range of climatic and soil conditions. Optimum temperature for rapid germination and optimum growth is 30^0C. Soil moisture demand is not high. As such, it can be grown under rained conditions in the Kharif II season as well as in the Rabi season with supplementary irrigation. Soybean is tolerant to a wide range of soil textures varying from loam, clay or sandy loam. For the Rabi season soils with a good moisture holding capacity are important, where irrigation is not available. The acreage under soybean cultivation in Bangladesh has increased since 1983. In 1989-90, soybean was grown in 1551 acres of land and in 1991-92 it covered 1937 acres. The area planted in 1992-93 under the CDP and MCC Programme was estimated to be 1945 acres. This indicates that the total land area under soybean is not stable. It may be attributed mainly to the less availability of quality seed. Therefore, it is very important that high quality seed is produced and properly stored. Sulzberger and Melean (1988) noted that low precipitation, absence of early morning fog or dew, and low humidity before and during the harvest are some of the factors that determine seed quality in soybean. They also observed that high temperature coupled with high rainfall exert severe stress on developing seeds. However, soybeans are usually very sensitive to hot and humid conditions. Most research conducted in MCC and BARI indicates that the varieties like Bragg and Davis have low viability at harvest time. Damage at this stage is called field injury. The variety Pb-1 known as Shohag is the best variety found to be used for the production of high quality seed in Bangladesh. This variety if sown between June 15 to July 15 matures in mid October-November.

Phosphorus plays an important role for the growth, development of a strong root system and seed formation of soybean plant. Lillee and Rahman (1992) reported that most farmers grow soybean without fertilizer or only with urea resulting lower yield (593 kg/ha). Aleman *et al.* (1976) observed that in soybean (cv. Mandarin) seed yields were 0.74 t/ha with 150 kg N + 225 kg P_2O_5/ha, 0.71 t/ha with 200 kg N + 300 kg P_2O_5/ha and 0.70 t/ha with 200 kg N/ha.

Thus a package of production technology needs to be developed to save foreign exchange and to meet the deficient of edible oil in Bangladesh. Therefore, to increase its yield per unit area, it is necessary to use good quality seed, adopt improved cultural practices including maintenance of optimum plant population and use of proper dose of manures and fertilizers specially phosphorus. The objectives of the experiment are:

a) to findout the maximum yield of soybean varieties
b) to determine the appropriate fertilizer doses for achieving higher yield of soybean and
c) to study the interaction of soybean varieties and different doses of fertilizer.

Chapter 2

Review of literature

REVIEW OF LITERATURE

Experimental evidences available from home and abroad reveal that plant and yield contributing characters of soybean are influenced by several factors of which different doses of fertilizer is remarkable one. Some of the pertinent literatures have been reviewed below:

2.1. Effect on growth parameter

Chiezey *et al.* (1992) reported that total dry matter and seed yield of soybean cv. Samsoy were increased with increasing phosphorus from 0 to 60 kg P_2O_5 ha^{-1}.

Surendra *et al.* (1995) reported that soybean cv. PK-262 gave seed yield of 2.46 t ha^{-1} at without phosphorus application but the highest yield was 3.34 t ha^{-1} obtained with 80 kg P_2O_5 ha^{-1}. Plant N uptake, total biomass and soil organic carbon were also highest with 80 kg P_2O_5 ha^{-1}.

Rabbani *et al.* (2004) studied 3 genotypes of soybean under different fertilizer doses during November 2000 to February 2001 at Mymensingh, Bangladesh. The growth and yield parameters were evaluated from 30 to 90 DAS at 15 days intervals. Plant height, leaf area index, crop growth rate, shoot dry weight, number of filled pods $plant^{-1}$, number of seeds $plant^{-1}$, seed yield and harvest index were highest with fertilizer at 20+40+60 DAS. The highest number of branches was obtained with fertilizer at 20+40+60 DAS and 20+40+60+80 DAS. The chlorophyll content increased whereas the number of empty pods decreased with increasing fertilizer frequency. The genotypes significantly varied in terms of growth attributes to various growth stages except shoot dry weight at 90 DAS.

Quah and Jaafar (1994) found that plant height of Soybean significantly increased by nitrogen fertilizer at 50 kg ha^{-1} Suhartatik (1991) reported that NP fertilizers significantly increased the plant height of Soybean.

Sardana and Verma (1987) conducted an experiment in New Delhi, India, in 983-84. They found that application of nitrogen and phosphorous resulted in significant increases in plant height of Soybean.

Bothe *et al.* (2000) studied the effect of phosphorus fertilizer (0, 25, 50 and 75 kg p_2o_5 ha^{-1}) and observed that phosphorus at the rate of 75 kg ha^{-1} gave highest values for plant height (71.20cm) of soybean.

Ramasamy *et al.* (2000) reported that P rate i.e 40, 60 and 80 kg P_2O_5 ha^{-1}, significantly increased the plant height and number of branches $plant^{-1}$. Highest plant height, root length and number of branches $plant^{-1}$ were observed at 80 kg P_2O_5 ha^{-1} in six soybean varieties.

In an experiment Singh *et al.* (2001) in Allahabad, Uttar Pradesh, India during kharif in 1990-91 studied the effect of 0, 30, 60 or 90 kg N ha^{-1} and 0, 30, 60 or 90 kg P_2O_5 ha^{-1}on the growth and development of soybean. They found that the plant height significantly increased with the higher rate of nitrogen and phosphorus of the study.

Prabhakaran and Lourduraj (2003) conducted field experiments during summer (February – May) and southwest monsoon (June – September) seasons of 1996 to 1997 to study the growth and yield responses of soybean. They found that application of nitrogen and phosphorus significantly increased the plant height, leaf area index, dry matter production and grain yield.

Hao *et al.* (2003) conducted experiments to find out effects of soybean cv. Bei during 92-98 and 2000 in Heilongjing, China. They found that the pods per plant, seeds per pod and 1000-seed weight had positive correlations with soybean yield. Leaf area index and dry matter accumulation significantly increased with fertilizer application.

Vieira *et al* (1980) reported the effects of 0, 110, 220 and 330 kg P_2O_5/ha on yield and plant characteristics of soybeans cv. VFV – 2 and Cristalina. Application of P increased the seed yield, plant height and weight, and number and weight of pods and seeds/plant. However, effects were not significant between the different P rates. Cristalina produced lower yields than UFV – 2 but had greater plant height and higher number of pods and seeds/plant.

2.2 Effect of Variety

Gopani and Kabaric (1970) found that seed yield in six soybean varieties were positively correlated with stem thickness, number of branches pod^{-1}, seed pod^{-1}, days to flowering and days to pods formation.

Molhotra (1974) observed that the number of pods $plant^{-1}$ and seed yield had the highest co-efficient of genetic variation and predicted genetic advances as a percentage of the mean in 37 varieties of soybean. The study of the discriminate functions indicated that selection for the traits such number of pods $plant^{-1}$, seeds $plant^{-1}$ and primary branches $plant^{-1}$ would be effective.

Singh *et al.* (1974) observed the variability in days to flowering and maturity, plant height and 1000-seed weight among 15 varieties of soybean. They also observed that Bossier, Devis and Bragg took 53, 44 and 42 days to flowering and 122, 109 and 116 days to maturity.

Lantican (1976) reported that the average number of days to flowering, yield, maturity and plant height of the variety Bragg at Laguna, Philippines were 29 days, 1.08 t ha^{-1}, 93 days and 60.0 cm in Thailand, 17 days, 1.42 t ha^{-1} , 83 days and 19.8 cm in Khmer Repubic and 28 days, 0.56 t ha^{-1} , 79 days and 25.7 cm at Selangon, Malaysia.

Rahman and Haque (1978) found variation in yield and days to maturity in soybean. In three years, averaged over 33 trials of five varieties (namely Davis, L-74, Bragg, Clark and Williams) gave seed yield ranged 1660-1961 kg ha^{-1}.

Das *et al.* (1982) conducted an experiment with nine soybean cultivars involving six quantitative characters in both the winter and summer seasons. The result indicated that Bragg had higher seed yield, 1000-seed weight and pods $plant^{-1}$ than other varieties.

Khaleker *et al.* (1991) observed in an investigation in India with two soybean varieties MACS 13 and Monetta that both plant height and seed yield were significantly increased with higher plant densities.

Mahajan *et al.* (1993) observed that seed yield was positively correlated with seed yield $plant^{-1}$, branches $plant^{-1}$, days to 50% flowering, days to maturity and plant height in 51 soybean genotypes gown in India during the Kharif season of 1990.

Saka *et al.* (1996) studied with 11 determinate soybean genotypes and a wide range of seed sizes. They reported that the number of seeds $plant^{-1}$ was negatively correlated with seed size and seed size was strongly correlated with width.

Sabbe and Delong (1996) in a field trial with eight soybean cultivars observed that cv. Hutcheson was the highest yielding cultivars.

Sridhara *et al.* (1998) conducted a field trial and found that number of branches plant^{-1} and number of pods plant^{-1} were the significant contributors of seed yield.

Taware *et al.* (1998) evaluated eight promising cultivars of soybean and found that an early maturity (MACS 63) cultivar gave the highest yield (2032 kg ha^{-1}).

Saad (1995) conducted in a field trail in Egypt in 1992-93 with soybean cultivars Evans, William 82, Clark, Crawford and Colombus. He observed that Clark produced the highest number of branches plant^{-1}, Colombus produced the highest number of pods plant^{-1} and plant height while Crawford had the highest number of seeds pod^{-1}, seed weight and seed yield.

2.3. Effect of nitrogen

Tank *et al.* (1992) reported that mungbean fertilized with 20 kg N ha^{-1} could be assigned to produce significantly longer pod over the rest of the higher (40 kg N ha^{-1}) and lower (Unfertilized control) levels of N.

Sarkar and Banik (1991) carried out a field trail and showed that application of 10 kg N ha^{-1} to mungbean resulted in appreciable improvement in pod length over the control.

During field trail, carried out by Sardana and Verma (1987) in Delhi, India , in 1983-84, it was found that application of nitrogen fertilizer resulted in significant increased in pod length of soybean varieties.

Jamro *et al.* (1990) observed that application of N in soybean cv. Bossier increased seeds pod^{-1}.

Karim (1977) reported that there was no significant effect of N on the number of seeds pod^{-1} in soybean.

Quah and Jaafar (1994) reported that 1000-seed weight of soybean cv. Hardu was increased significantly by the application of nitrogen at 50 kg ha^{-1}.

Sarkar and Banik (1991) revealed that application of 10 kg N ha^{-1} to soybean resulted in appreciable improvement in yield attributes like 1000-seed weight over the control (no nitrogen).

Sardana and Verma (1987) carried out an experiment on soybean cv. Bossier. They reported that application of nitrogen resulted in significant increases in 1000-seed weight of soybean. Patel and Parmar (1986) observed that increasing N application to 16 soybean varieties from 0 to 45 kg ha^{-1} increased 1000-seed weight.

Raju and Varma (1984) conducted a field trail during the Kharif season of 1979 and 1980 to study the response of mungbean var. Pusa Baishakhi to varying levels of nitrogen application (15, 30, 45 and 60 kg N ha^{-1}) in the presence and /or absence of *Rhizobium* seed inoculation. Two more treatments viz. control and Rhizobium treatment alone were also included in this study. They observed that 1000-seed weight was the maximum when applied of Rhizobium along with 15 kg N ha^{-1}.

Rani and Kodandaramaiah (1997) stated that seed yield of soybean cv. Hardu was increased by 1.89 t ha^{-1} with application of 90 kg N ha^{-1} compared to 1.50 t ha^{-1} without applied N.

Vara *et al.* (1994) observed from a field experiment on soybean cv. Gujrat soybean that the seed yield of 1156, 1276 and 1304 kg ha^{-1} with 0, 20 and 40 kg ha^{-1} of N, respectively.

Singh *et al.* (1992) observed in a field trial on soybean with 0-50 kg N ha^{-1} that the highest seed yield of 30 kg N ha^{-1}, although there was not significant differences between the treatments.

Jamro *et al.* (1990) observed that application of 0, 30, 60 or 90 Kg N ha^{-1} in soybean cv. Bossier increased seed yield from 6.72 to 12.34 g $plant^{-1}$ with increased rate of N from 0 to 90 kg N ha^{-1}. Joshi *et al.* (1989) observed that increasing N rates from 0-40 kg ha^{-1} increased seed yield of soybean.

Olsen *et al.* (1975) observed that the yield of 'Bragg' soybean was not increased by N fertilizer applied on the soil surface at 112 and 224 kg ha^{-1}.

Sarkar and Banik (1991) conducted a field experiment, results showed that straw yield of mungbean increased significantly up to 10kg N ha^{-1} on an average stover yield increased by 24 percent due to 10 kg N ha^{-1} over no nitrogen.

Leelavathi *et al.* (1991) observed that nitrogen application increased stover yield of mungbean to a certain level with different row spacing.

Mahmoud *et al.* (1988) observed that nitrogen application increased the stover production up to a certain level with different row spacings in mungbean.

2.4 Effect of phosphorus

Bothe *et al.* (2000) studied the effect of phosphorus fertilizer (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) and observed that phosphorus at the rate of 75 kg ha^{-1} gave highest values, for dry matter $plant^{-1}$ (57.46g) for Bragg.

Trabulsi (1985) studied the effects of phosphorus at the rate of 0, 200, 400 and 600 kg p ha^{-1} (applied as super phosphate) on inoculated soybean cultivar Williams and Davis on calcareous soil in Saudi Arabia and found that weight of plant was increased with increasing phosphorus at the rate of up to 400 kg ha^{-1} for Williams and 600 kg ha^{-1} P for Davis.

Vieira *et al.* (1980) reported that application of phosphorus increased plant weight but effect was not significant between the different phosphorus rates for Bossier.

Tomar *et al.* (1991) in a trial with 0, 30, 60 or 90 kg P_2O_5 ha^{-1}on a clay loam soil, the yield of soybean was found to increase only with 30 kg P_2O_5 ha^{-1} but the higher phosphorus did not give further significant increase.

Singh and Bajpai (1990) in a trial of 0-100 kg P_2O_5 ha^{-1} observed that 80 kg $P_2O_5ha^{-1}$ gave highest seed yield of 2.04 t ha^{-1} compared with 1.45 tha^{-1}. They also added that increasing phosphorus rate increase the number of pods $plant^{-1}$ in 37 varieties.

Syafruddin *et al.* (1990) observed that application of phosphorus increased number of pods $plant^{-1}$ and decreased the percentage of empty pods in soybean cv. Orba.

Haque *et al.* (1978) found that increased doses of phosphorus increased the number of pods $plant^{-1}$.

Patel and Patel (1991) conducted a field experiment and the result of the experiment revealed that pod length of mungbean varieties showed superiority at 60g P_2O_5 ha^{-1} followed by 40 kg P_2O_5 ha^{-1} application rate. Thus pod length was found to be increased with the increasing levels phosphorus from 0 to 60 kg ha^{-1}.

Sardana and Verma (1987) observed in a field trial, in Delhi, India, in 1983-84 that application of phosphorus fertilizers resulted in significant increases in pod length of soybean.

Tomar and Singh (2004) conducted an experiment in Madhya Pradesh, India. during kharif season and observed that the number of seeds pod^{-1} increased with the increase of phosphorus application.

Arya and Kalra (1988) observed that application of phosphorus had no effect on the growth of the summer mung (*Vigna radiata)* while number of grains pod^{-1} and number of grains pod^{-1} were found to be incresed with increasing levels of phophorus from 0-50 kg P_2O_5 ha^{-1}.

Karim (1977) found that seed pod^{-1} incresed with increasing amount of phosphorus in Lee soybean.

Islam *et al.* (2004) in an experiment with 60, 72 and 84 kg P_2O_5 ha^{-1} level in soybean (PB-1) observed that 84 kg P_2O_5 gave highest number of seeds pod^{-1}.

Vieira *et al.* (1980) reported that application of phosphorus increased number of seeds $plant^{-1}$ but effect were not significant between different phosphorus levels in soybean (PB-1).

Hanumanthappa *et al.* (1998) carried out an experiment to know the effect of different levels of phosphorus on yield components of soybean varieties. They found that 1000-seed weight varied significantly with phosphorus levels.

Tomar *et al.* (1991) in a trial with 0, 30, 60 or 90 kg P_2O_5 ha^{-1} on a clay loam soil and found that the yield of soybean was found to increase only with 30 kg P_2O_5 ha^{-1} but the higher phosphorus did not give further significant increased in yield. Applied phosphorus from 26 to 51 kg ha^{-1} increased 1000 seed weight.

Kalia *et al.* (1986) showed that 100 kg P_2O_5 ha^{-1} produced the highest seed yield of (2.04 t ha^{-1}) compared to without phosphorus 1.45 t ha^{-1}. They also added that increasing phosphorus rate increased the 1000-seed weight.

Islam *et al.* (2004) in an experiment with 60, 72 and 84 kg P_2O_5 ha^{-1} in soybean cv. PB-1 observed that seed yield increased with the increase of phosphorus application.

Shah *et al.* (2001) in an experiment with 0, 40, 60 and 80 kg P_2O_5 ha^{-1} observed that phosphorus uptake efficiency and yield of soybean was increased with the increases of phosphorus application.

Navale *et al.* (2000) in an experiment in Mahharastra, India, during the kharif season observed that seed yield significantly increased upto 120 kg P_2O_5 ha^{-1}.

Osman *et al.* (2000) found the highest seed yield of soybean with 60 kg P_2O_5 ha^{-1} out of 20, 40 and 60 kg P_2O_5 ha^{-1}.

Raychaudhuri *et al.* (1997) stated that inoculation with Rhizobium and phosphorus (60 kg P_2O_5 ha^{-1}) significantly increased grain yield of soybean.

Uppal *et al.* (1997) reported that highest seed yield was obtained with upto 80 kg P_2O_5 ha^{-1} when applied at 30% available soil moisture depletion (ASMD).

Wu and Wu (1996) observed that soybean with super phosphate alone (without inoculums) increased yield by 5.3% over control. Vara *et al.* (1994) observed increasing yield with increased of phosphorus level in soybean cv. Gujrat soybean^{-1}. They also observed the application of 40, 60 and 80 kg P_2O_5 ha^{-1} produced 1199, 1255 and 1282 kg ha^{-1} seed yield, respectively.

Singh and Bajpai (1990) in a trial of 0-100 kg P_2O_5 ha^{-1} observed that 80 kg P_2O_5 ha^{-1} gave highest seed yield of 2.04 t ha^{-1} compared with 1.45 t ha^{-1} without phosphorus.

Kalia *et al.* (1986) observed that 100 kg P_2O_5 ha^{-1} increased the seed yield significantly compared to other doses through favorable effect of yield attributes.

Krisnamoorthy *et al.* (1981) used 0, 40, 80 and 120 kg P_2O_5 ha^{-1} and obtained highest seed yields 1.77 and 2.02 t ha^{-1} in summer and monsoon season, respectively, by applying 120 kg P_2O_5 ha^{-1}.

Narayana *et al.* (1995) observed that soybean seed yield was increased with the increased rate of phosphorus application from 0 to 50 kg P_2O_5 ha^{-1}.

Bhuiyan *et al.* (1995) reported that soybean cv. Shohag (pb-1) produced 63.7% and 69.8% higher seed yield at 50 kg P_2O_5 ha^{-1} than the control in Joydebpur and Jessore, respectively.

Vyas *et al.* (1993) conducted a field experiment during the rainy seasons of 1986-87 with soybeans cv. JS-44 and JS 76-188 were given with 0, 20, 40, 60, 80, 100 or 120 kg P_2O_5 ha^{-1}. They observed that the relationship between applied P and seed yield was quadratic.

Pedro and Solarzano (1990) reported that seed yield of soybean cv. Cristalina increased from 0.09 - 0.12 t ha^{-1} with no applied P to 2.72 - 2.89 t ha^{-1} with 230 kg P_2O_5 ha^{-1}.

Syafruddin *et al.* (1990) observed that application of P increased number of pods $plant^{-1}$, harvest index and seed yield and decreased the percentage of empty pods in soybean cv. Orba. Seed yield was 0.75, 0.81 and 1.19 t ha^{-1} with 0, 45 or 90 kg P_2O_5 ha^{-1}, respectively without added $ZnSO_4$. Zn application further increased yield except when the highest P rate was supplemented with 2% $ZnSO_4$. The highest seed yield (1.7 t ha^{-1}) was given by 90 kg P_2O_5 ha^{-1} plus $ZnSO_4$.

Naidu and Pillai (1989) found that application of an equivalent of 0, 50, 100 or 200 kg N or P_2O_5 ha^{-1} increased seed yield with up to 100 kg N and 100 kg P_2O_5 ha^{-1}.

Goswami *et al.* (1991) reported that soybeans were sown with 20, 40 or 60 kg P_2O_5 ha^{-1} as diammonium phosphate (DAP) or single super phospate (SSP) by various methods; drilling seed DAP spearately; dilling seed + 50% DAP or SSP broadcasting 50% DAP or SSP. They observed that seed yield was increased from 0.67 to 1.03 t ha^{-1} in 1987 and from 1.43 to 12.79 t ha^{-1} in 1988 with 20-60 kg P_2O_5 ha^{-1}.

Kausandiker *et al.* (2003) reported that application of P_2O_5 at 90 kg P_2O_5 ha^{-1} give the highest number of pods $plant^{-1}$, 100-seed weight, crude protein, seed yield and straw yield.

Purushothaman *et al.* (1986) studied the effects of 0, 60 or 80 kg P_2O_5 ha^{-1} as basal or split application on the yield of soybean cv Co 1 during the Kharif (monsoon) and Rabi (winter) seasons. The combined application of 60 kg P_2O_5 as a basal application with 20 kg P_2O_5 in 3 foliar applications at 30, 40 and 50 days after

sowing gave the highest grain yields of 1.74 and 1.13 t/ha in Kharif and Rabi seasons, respectively; 40 kg P_2O_5 as a basal application with 20 kg P_2O_5 in 3 split applications gave the lowest yields of 1.42 and 1.02 t/ha in Kharif and Rabi, respectively, followed by a basal application of 80 kg P_2O_5 (1.42 and 1.02 t/ha, respectively).

Islam *et al.* (2004) in an experiment with 60, 72 and 84 kg P_2O_5 ha^{-1} in soybean (PB-1) observed that stover yield increased with the increase of phosphorus application.

Tomar and Singh (2004) in an experiment in Modhya Pradesh, India, during kharif season observed that stover yield increased with the increase of phosphorus application for 3 genotypes of soybean.

2.5. Interaction effect of nitrogen and phosphorus

Samiullah *et al.* (1987) reported that number of pods $plant^{-1}$ was the highest with 10kg N+75 kg P_2O_5 ha^{-1} in summer mungbean.

Patel *et al.* (1984) studied the effects of 0, 10, 20 and 30 kg N ha^{-1} and 0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1} on the growth and seed yield of mungbean. Result revealed that application of 40 kg P_2O_5 ha^{-1} along with upto 20 kg N ha^{-1} significantly increased the number of pods $plant^{-1}$ of mungbean; further increase in phosphorus rates was not economical.

Yien *et al.* (1981) in an experiment applied nitrogen and phosphorus fertilizers to mungbean and reported that combined application of nitrogen and phosphorus fertilizers increased the number of pods $plant^{-1}$.

Paikera *et al.* (1989) studied the effects of 20 and 40 kg N ha^{-1} and 40, 60 and 80 kg P_2O_5 ha^{-1} on the growth and yield of soybean. Result revealed that application of 40 kg N along with 40 kg P_2O_5 ha^{-1} gave highest number of seeds pod^{-1} and 1000-seed weight.

Agarwal *et al.* (1996) stated that in the wet season soybean cv. PB-1, Bragg and clerk-63 were grown in combination of 0, 40 or 80 kg P_2O_5 ha^{-1}, and 0 and 20 kg N ha^{-1}. Application of 20 kg N + 80 kg P_2O_5 ha^{-1} gave maximum yield of 1.71 t ha^{-1}.

Svoboda (1988) stated that at fertilizer applied before emergence, before flowering and after flowering of with out fertilizer, seed yields were 20.96% higher in 1980 and 9.2% higher in 1981 with fertilizer compared to without fertilizer. He also observed that fertilizer increased seed weight $plant^{-1}$, 1000-seed weight, seed weight pod^{-1}, number of seeds pod^{-1}.

From the above review of literature, it was observed that application of nitrogen and phosphorus played significant role on the growth and yield performance of soybean.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

In this chapter the details of different materials used and methodology followed for this experiment are described.

3.1. Experimental Site

3.1.1. Location

The experiment was conducted in the Sher-e-Bangla Agricultural University farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28. For better understanding about the experimental site are shown in the map of AEZ of Bangladesh in Appendix - I.

3.1.2. Climate

The experimental area under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gushy winds in Kharif season (April – September) and less rainfall associated with moderately low temperature during the rabi season (October – March). The weather data during the study period at the experimental site are shown in Appendix – II.

3.1.3. Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The physical and chemical properties of the soil has been presented in Appendix –III.

3.2. Planting material

Three soybean varieties Shohagh, Bangladesh Soybean-4 and BARI Soybean-5 were used as test crops. Seeds of these varieties were collected from Oil Seed Division, BARI, Joydebpur, Gazipur. Healthy seeds were selected.

3.2.1. Shohag

Shohag was released in 1990 by National Seed Board. Life duration is about 95-100 days. Plant height is 36-42 cm. Flower colour is pinkish. Seed colour is cream and size is medium. The variety is photosensitive. Seed yield is about 1.6 – 1.8 t ha^{-1}.

3.2.2. Bangladesh soybean-4

Bangladesh soybean-4 was released in 1994 by National Seed Board (NSB). At maturity, the plants attain at a height of 36-42 cm and its life duration is about 95-100 days. Its flower is pinkish. The seed is small in size compared to other varieties and its colour is greenish yellow. The yield is about 1.6 – 2.5 t ha^{-1}.

3.2.3. BARI soybean-5

This variety was released in 1990 by National Seed Board (NSB) during 2002. Its fild duration is about 95-115 days. Plant height is 40-60 cm. Flower colour is pinkish. Seed colour is cream. Seed size is medium. Seed yield is about 1.6 – 2.0 t ha^{-1}.

3.3. Experimental details

3.3.1. Treatments

Two sets of treatments included in the experiment were as follows:

A. Fertilizer (Main plot)

(i) F_0 = Control (No fertilizer)

(ii) F_1 = (N+P) Half of the recommended dose

(iii) F_2 = (N+P) Recommended dose

(iv) F_3 = (N+P) Double of the recommended dose

B. Soybean Variety (Sub plot)-3

(i) S_1 = Shohag

(ii) S_2 = Bangladesh Soybean-4

(iii) S_3 = BARI Soybean-5

3.3.2. Design and layout of the experiment

The experiment was laid out in a split - plot design with 3 replications. Each replication was divided into 4 main plots and again each main plot was divided into three sub-plots. The fertilizer dose and variety were assigned in the main and sub-plots, respectively at random. Thus there were altogether 36 unit plots. The size of the unit plot was $10m^2$ (4.0m × 2.5m). The plot to plot and replication to replication distances were maintained 0.75 and 1.0m, respectively.

3.4. Experimental Procedure

3.4.1. Land preparation

The experimental field was first opened on 10 August, 2006 with the help of a power tiller. After that the land was finally prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a good conditioned field. All kinds of weeds and residues of previous crop were removed from the field. The field layout was made on 16 August, 2006 according to the design immediately after final land preparation. Individual plots were cleaned and finally leveled with the help of wooden plank.

3.4.2. Application of fertilizer

The plots were fertilized with urea, TSP, muriate of potash and gypsum at the rate of 60, 175, 120 and 115 kg ha^{-1}, respectively (BARI, 1995). All the fertilizers were applied at the time of final land preparation as per treatment mentioned in chapter 3.3.1.

3.5. Sowing of seeds

Sowing was done on 17 August, 2006. Seeds were sown in 30 cm apart rows and seed to seed distance was maintained as 6 cm. Furrows were made by hand rake and seeds were placed in the furrows by hand and then covered properly with the soil.

3.6. Intercultural operations

The following intercultural operations were done to ensuring the normal growth of the plant.

3.6.1. Thinning

Two seeds were sown in each place. One seedling was allowed to grow in each place and excess seedling was thinedout within 15-21 DAS.

3.6.2. Weeding

The crop was weeded twice. First weeding was done at 30 days after sowing (DAS) and second one at 45 DAS. Demarcation boundaries and drainage channels were also kept weed free.

3.6.3. Plant protection

The soybean plants were infested by hairy caterpillars (*Diacrisia obliqua*) 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 .

3.7. General observation

The field was frequently observed to notice any change in plant characters. The crop had been promising since the initial stage and it maintained a satisfactory condition till harvest.

3.8. Harvesting and post harvest operation

Maturity of crop was determined when 90% of the pods became brown in color. Ten pre-selected plants were harvested in each plot from which yield contributing characters data were collected and plants of 6 mid lines were harvested for collecting yield data. The harvested plants were bundled, properly tagged and then brought to the threshing floor.

3.9. Threshing

The crop bundles were sun dried for four days by spreading them on the threshing floor. Seeds were separated from the stover by bitting the plants with the help of stick.

3.10. Drying

Seeds were cleaned and dried in the sun for three to four consecutive days. After proper drying of seeds to a moisture content of 12-14%, were kept in polythene bags. Stovers were also dried in the sun properly.

3.11. Cleaning and weighing

Dried seeds and stover were cleaned and weighted plot wise. After that the weights were converted into kg ha^{-1} .

3.12. Collection of data

A. Crop growth characters

Ten plants in each plot were selected and tagged. All the growth data (expect dry weight) were recorded from these 10 selected plants.

(i) Plant height (cm) at 15 days interval starting from 30 DAS.

(ii) Number of leaf $plant^{-1}$ at 15 days interval starting from 30 DAS.

(iii) Dry matter weight $plant^{-1}$ (g) at 15 days interval starting from 30 DAS

B. Crop characters

(i) Number of branches $plant^{-1}$

(ii) Number of pods $plant^{-1}$

(iii) Pod length (cm^{-1})

(iv) Weight of 1000-seeds (g)

C. Yield and Harvest Index

(i) Grain yield (kg ha^{-1})

(ii) Stover yield (kg ha^{-1})

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

(iv) Harvest Index (%).

3.13. Methods of recording data

3.13.1. Plant height(cm)

The height of sample plants (10) were measured from the ground level to the tip of the main shoot. It was done 4 times on 30, 45, 60 and 75 DAS and at harvest. In each time data were averaged and expressed in cm.

3.13.2. Number of leaves $plant^{-1}$

Total number of leaves for ten sample plants of each plot was counted in 5 times on 30, 45, 60 and 75 DAS. For each count mean value was determined and expressed in number of leaves $plant^{-1}$.

3.13.3. Dry weight of plant (g)

Shoot and root of 10 seedling were collected and dried separately for 48 hours in an electric oven set at 65^0C. The dry weight of the samples was taken using a sensitive digital electric balance. The mean weight was calculated to have individual plant weight and expressed in gram.

3.13.4. Number of branches $plant^{-1}$

All the branches present on ten sample plants were counted and averaged to have number of branches $plant^{-1}$.

3.13.5. Pod length (cm)

The length of pod of 10 sample pods were measured and mean length was expressed in cm.

3.13.6. Number of pods plant^{-1}

All the pods of sample plants of each plot were counted out to determine the average number of pods plant^{-1}.

3.13.7. Number of seeds pod^{-1}

Number of total seeds of ten sample pods from each plot was noted and the mean number was expressed per pod basis.

3.13.8. 1000- seed weight (g)

One thousand sun dried seeds were counted at random from the seed stock of sample plants. Weights of 1000 seeds were then recorded by means of a digital electrical balance.

3.13.9. Seed yield (kg ha^{-1})

Seeds obtained from each unit plot were dried in sun and weighted out. The seed weight was expressed as kg ha^{-1} on 12-14% moisture basis. Grain moisture content was measured by using a digital moisture meter.

3.13.10. Stover yield (kg ha^{-1})

The stover plot^{-1} was dried separately and weights were recorded. These weights were converted to kg ha^{-1}.

3.13.11. Biological yield (kg ha^{-1})

Seed yield and stover yield were altogether regarded as biological yield.

Biological yield (t ha^{-1}) = Seed yield (kg ha^{-1}) + Stover yield (kg ha^{-1})

3.13.12. Harvest index (%)

Harvest index was calculated on the ratio of grain to biological yield and expressed as percentage. It was calculated by using the following formula (Gardner *et al.*, 1985).

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

Where, Biological yield= Seed yield + Stover yield.

3.14. Statistical analysis of data

Data were analyzed using the analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) with the help of computer based statistical package programme, MSTAT. The mean differences among the treatments were compared by least significant difference (LSD) test at 5% level of significance.

Chapter 4

Results and Discussion

RESULTS AND DISCUSSION

The results of the present study have been discussed in this chapter. Experimental results pertaining to the effect of fertilizer on the growth and yield of soybean varieties. The parameters considered were plant height (cm) number of leaf plant^{-1}, dry matter plant^{-1} (g), plant height at harvest (cm), number of branches plant^{-1}, pod length (cm), number of pods plant^{-1}, number of seeds pod^{-1}, 1000 seed weight (g), seed yield (kgha^{-1}), stover yield (kg ha^{-1}) and harvest index (%). Results of the experiment have been presented in Tables 1 to 6 and Fig 1 to 6. The mean square values of the said parameters together with the sources of variation and their corresponding degrees of freedom have been shown in Appendices IV to VI.

4.1. Plant height

4.1.1. Effect of fertilizer

The effect of fertilizer on plant height of soybean is presented in (Fig.1) Maximum plant height was observed in applied fertilizer at double of the recommended dose treatments in all the stages of life cycle. The lowest plant height was found with half of the recommended doses. The plant response in terms of height was found higher in the middle stage of growth (from 45 DAS to 60 DAS) because of better growth of this period. The results corroborates with the findings of Kazi *et al.* (2002).

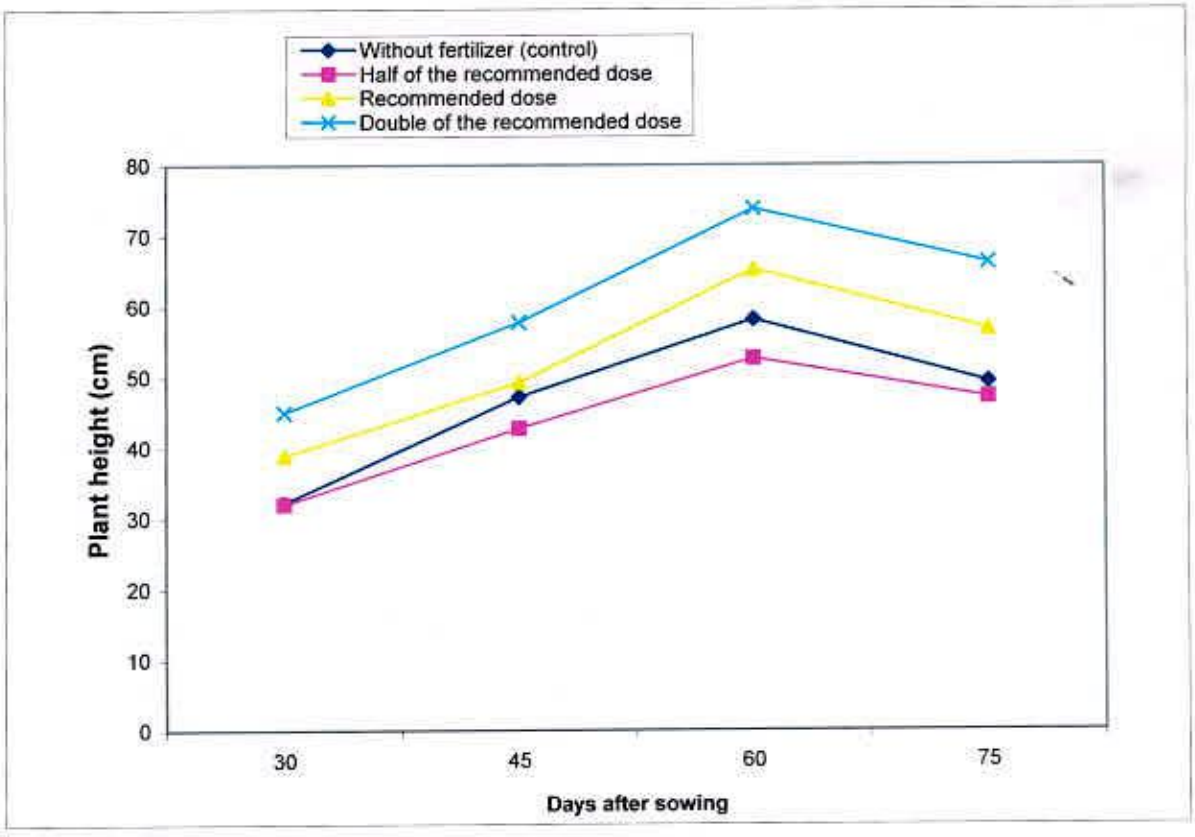

Fig. 1. Effect of fertilizer on plant height of Soybean

4.1.2. Effect of variety

At the early stage of growth up to 30 DAS, the growth of plants of the tested three varieties was slow. At this stage, among the three varieties BARI soybean-5 showed significantly highest plant height (39.11cm) and Bangladesh soybean-4 showed the lowest height (35.26 cm). After 60 days, the plant height reduced slightly for all varieties. The reduction in plant height at later stage may be attributed to dry up and defoliation of dried leaves of the plant. Among the three varieties Bangladesh soybean-4 gave significantly highest plant height.

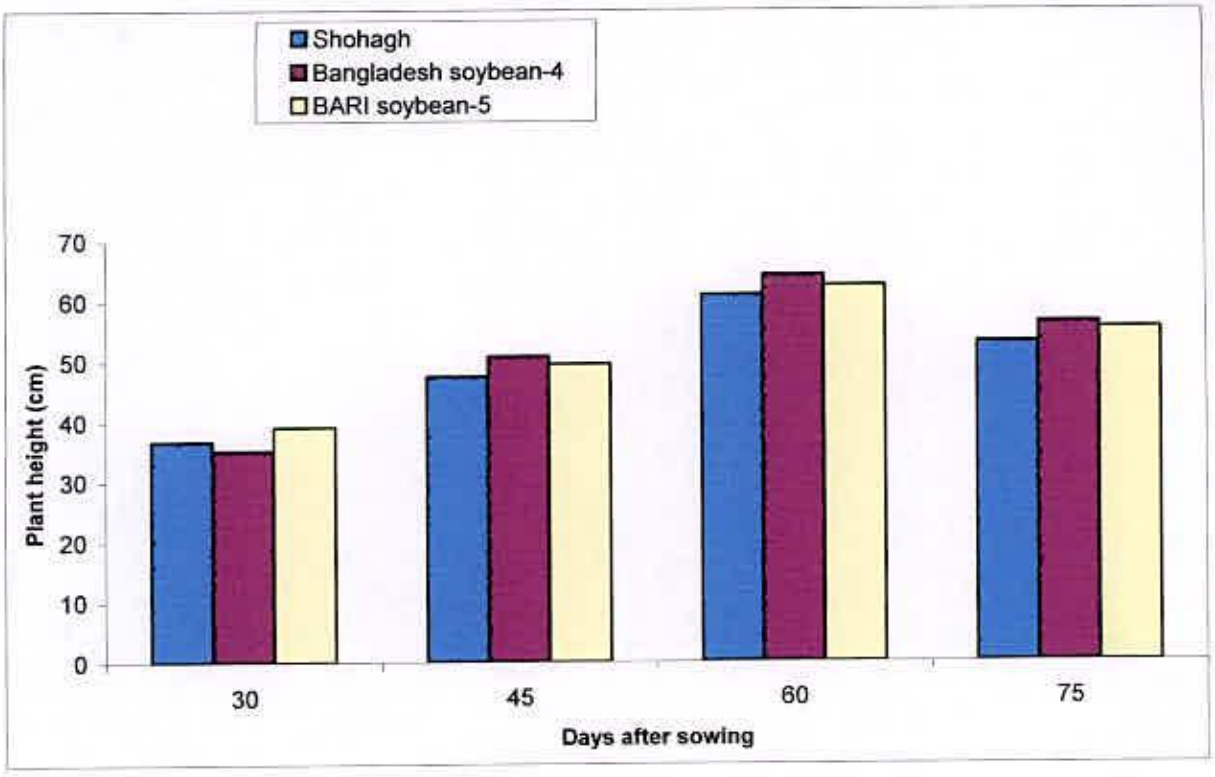

Fig. 2. Effect of variety on plant height of Soybean

4.1.3. Interaction effect of fertilizer and variety

The interaction effect of fertilizer and variety had a great effect on plant height of soybean (Table 1). In this study, the figure showed that at 30 DAS the tallest plant was found from the interaction between fertilizer at double of the recommended dose and BARI soybean-5. At 45, 60 and 75 DAS growth stages the tallest plant were found in the interaction treatment of fertilizer at double of the recommended dose x Bangladesh soybean-4.

Table 1. Interaction effect of fertilizer and variety on plant height of soybean

Fertilizer x variety	Days after sowing			
	30	45	60	75
Without fertilizer (control) x Shohagh	32.61	45.82	55.86	47.22
Without fertilizer (control) x Bangladesh soybean-4	31.61	48.27	59.58	50.40
Without fertilizer (control) x BARI soybean-5	32.54	47.52	58.92	50.27
Recommended dose x Shohagh	30.63	41.84	51.86	46.54
Recommended dose x Bangladesh soybean-4	30.28	43.99	53.59	47.70
Recommended dose x BARI soybean-5	35.22	42.44	52.44	46.94
Half dose of recommended dose x Shohagh	37.65	46.83	64.00	56.12
Half of the recommended dose x Bangladesh soybean-4	37.66	51.22	67.45	57.84
Half of the recommended dose x BARI soybean-5	41.36	49.74	64.27	56.33
Double of the recommended dose x Shohagh	46.25	55.43	71.68	62.06
Double of the recommended dose x Bangladesh soybean-4	41.49	59.71	76.01	69.01
Double of the recommended dose x BARI soybean-5	47.32	58.23	73.71	67.49
LSD (0.05)	2.531	2.041	1.554	2.533
CV(%)	13.95	8.39	11.44	12.67

4.2. Number of leaves plant^{-1}

4.2.1. Effect of fertilizer

The effect of fertilizer on number of leaves plant^{-1} is presented in (Fig. 3). The figure indicated that number of leaves plant^{-1} increased sharply with the increases of fertilizer dose upto 60 DAS. After that it reduced rapidly upto 75 DAS. The fertilizer treatment of half of the recommended dose produced the highest number of leaf plant^{-1} at 45 DAS. At 60 and 75 DAS the highest number of leaves plant^{-1} was found to produce from the fertilizer applied at double of the recommended dose.

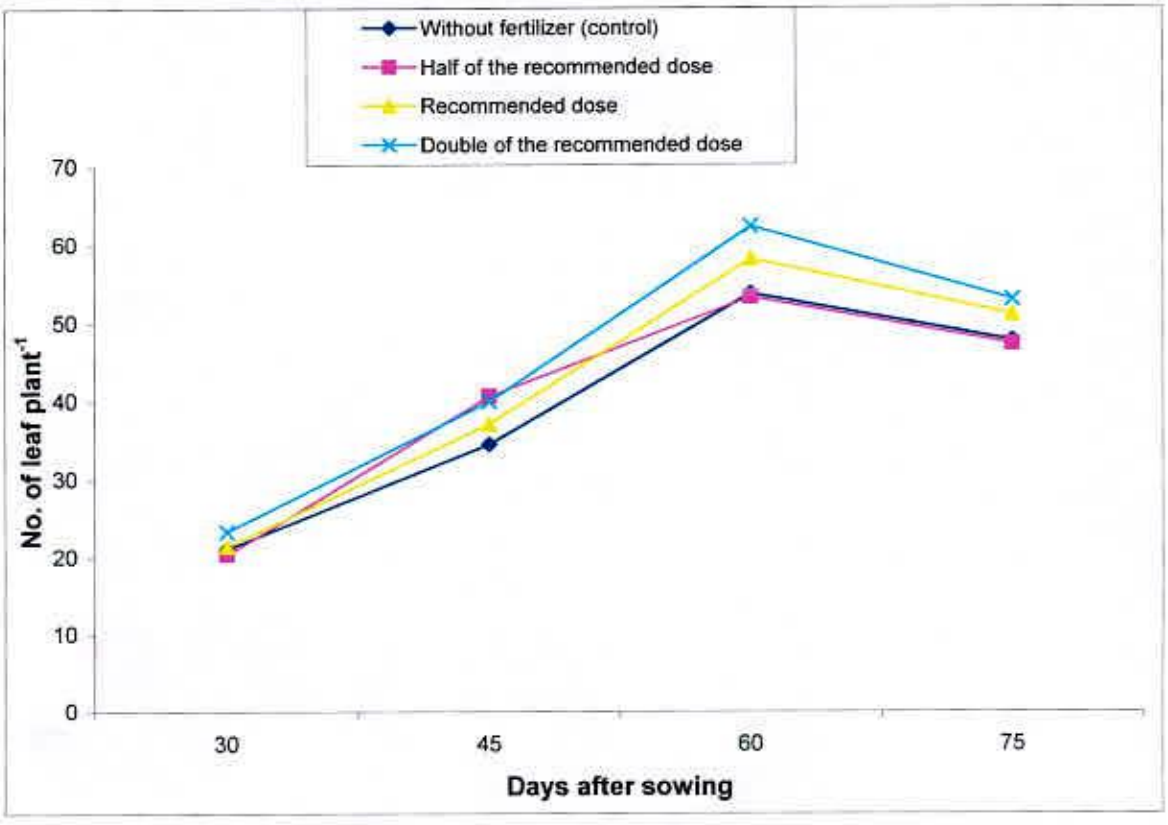

Fig. 3. Effect of fertilizer on number of leaf plant^{-1}

4.2.2. Effect of variety

Significant variation was found among the varieties for number of leaves plant^{-1} at 45, 60 and 75 DAS (Fig. 4). Shohagh produced significantly the highest number of leaves plant^{-1} at 45 DAS than other varieties. At 60 and 75 DAS showed the reverse result of leaf plant^{-1} than 45 DAS. In this two dates (60 and 75 DAS) Bangladesh Soybean-4 and BARI soybean-5 showed the higher leaves plant^{-1} than Shohagh. Saad (1995) observed similar result who reported variety Clark produced the highest number of branched plant^{-1} compared to variety Evens, William-82, Crawford and Calombus.

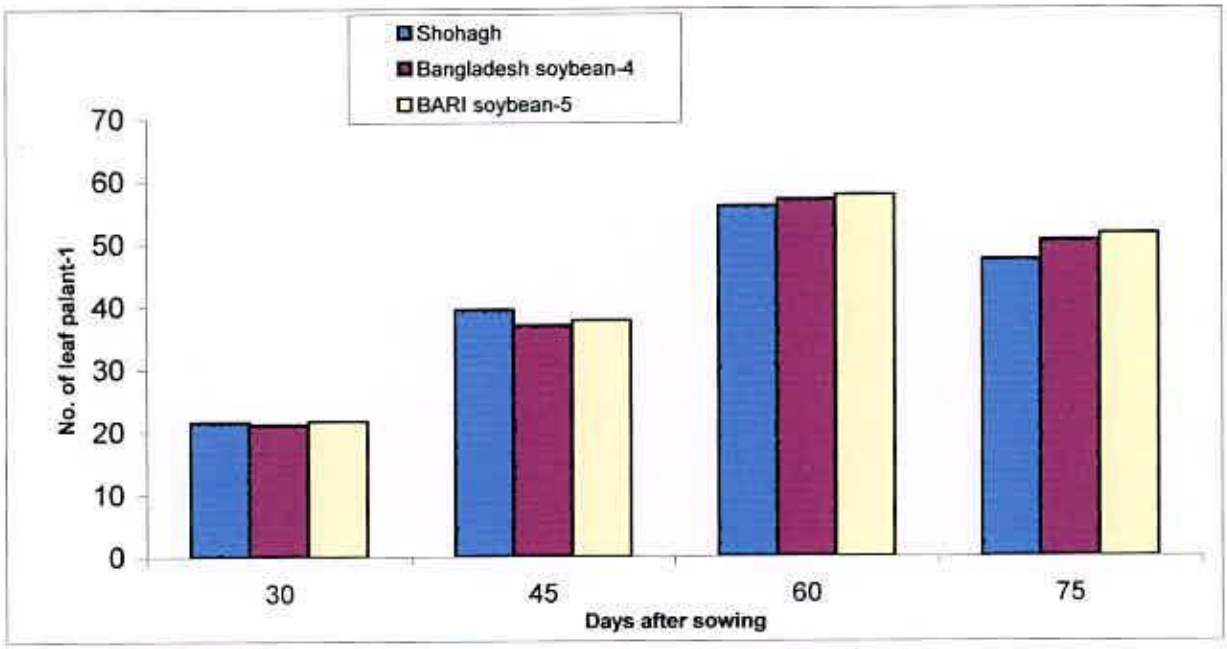

Fig. 4. Effect of variety on number of leaf plant^{-1} of Soybean

4.2.3. Interaction effect of fertilizer and variety

The effect of interaction between fertilizer and variety on number of leaves plant^{-1} of soybean was significant (Table 2). The figure showed that the number of leaves plant^{-1} increased gradually with the advancement of growth stages and the highest number was observed at 60 DAS for all the interactions. After 60 DAS the number of leaves plant^{-1} reduced slightly which may perhaps the defoliation of older leaves with the advancement of ages of plants.

Table 2. Interaction effect of fertilizer dose and variety on number of leaf plant^{-1}

Fertilizer x variety	Days after sowing			
	30	45	60	75
Without fertilizer (control) x Shohagh	21.33	35.66	54.33	48.33
Without fertilizer (control) x Bangladesh soybean-4	22.00	34.00	55.00	49.00
Without fertilizer (control) x BARI soybean-5	20.00	34.00	52.00	46.00
Recommended dose x Shohagh	20.00	41.00	53.00	47.00
Recommended dose x Bangladesh soybean-4	19.00	39.00	53.00	47.00
Recommended dose x BARI soybean-5	22.00	42.00	54.00	48.00
Half of the recommended dose x Shohagh	21.33	38.33	54.66	48.33
Half of the recommended dose x Bangladesh soybean-4	21.00	35.00	60.00	52.00
Half of the recommended dose x BARI soybean-5	22.00	38.00	60.00	53.00
Double of the recommended dose x Shohagh	24.00	43.00	62.00	46.00
Double of the recommended dose x Bangladesh soybean-4	23.00	40.00	60.00	54.00
Double of the recommended dose x BARI soybean-5	23.00	37.00	65.00	59.00
LSD (0.05)	1.554	1.554	1.632	2.531
CV(%)	10.16	7.36	11.66	7.94

4.3. Dry matter plant^{-1}

4.3.1. Effect of fertilizer

Clear variations were found in dry matter plant^{-1} with different fertilizer doses among three varieties (Fig. 5). At the advances of growth dry matter production showed an increasing trend with the increases of fertilizer dose. At 75 DAS double of the recommended dose produced the highest dry matter plant^{-1} (12.53g) and the lowest dry matter plant^{-1} (9.42g) was found to produce in without fertilizer (control) treatment. The treatment double of the recommended dose produced the highest dry matter at 30, 45, 60 and 75 DAS and next highest by the treatment recommended dose of the fertilizer. The lowest dry matter was found to produced from the treatment without fertilizer at 30, 45, 60 and 75 DAS.

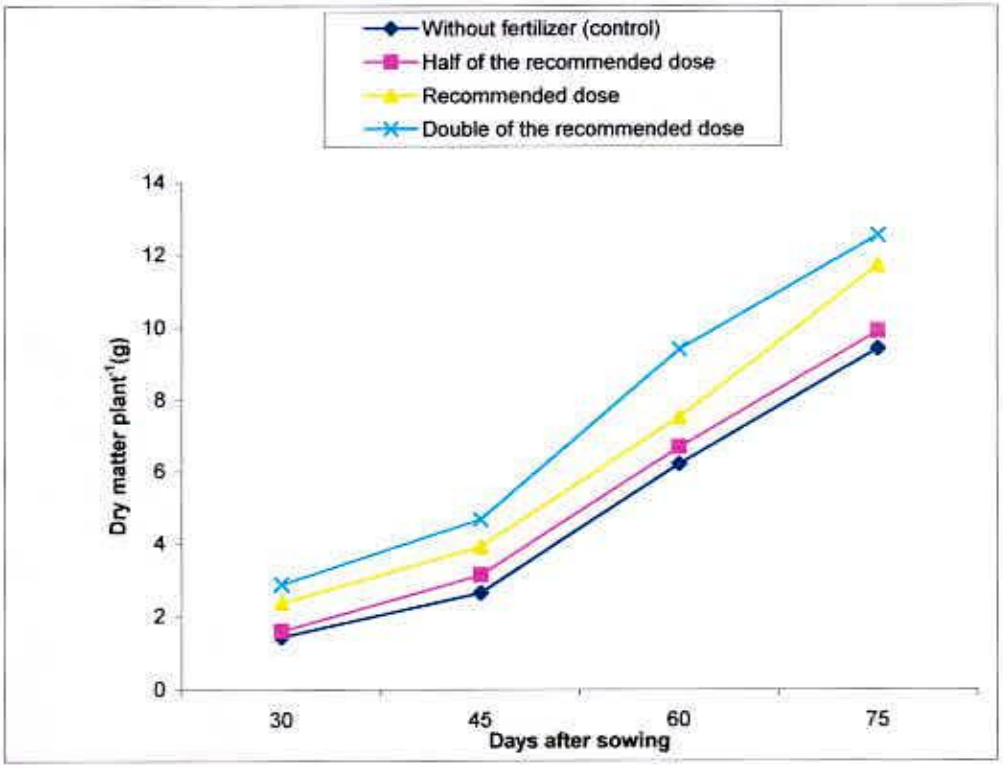

Fig. 5: Effect of fertilizer on dry matter plant^{-1}

4.3.2. Effect of variety

Dry matter production was significantly influenced at 5% level of probability by the varieties at 30, 45, 60 and 75 DAS (Fig. 6). Shohagh showed the lowest dry matter at 30, 45, 60 and 75 DAS. Bangladesh soybean-4 showed higher amount of dry matter than other two varieties for all the growth period (upto 75DAS).

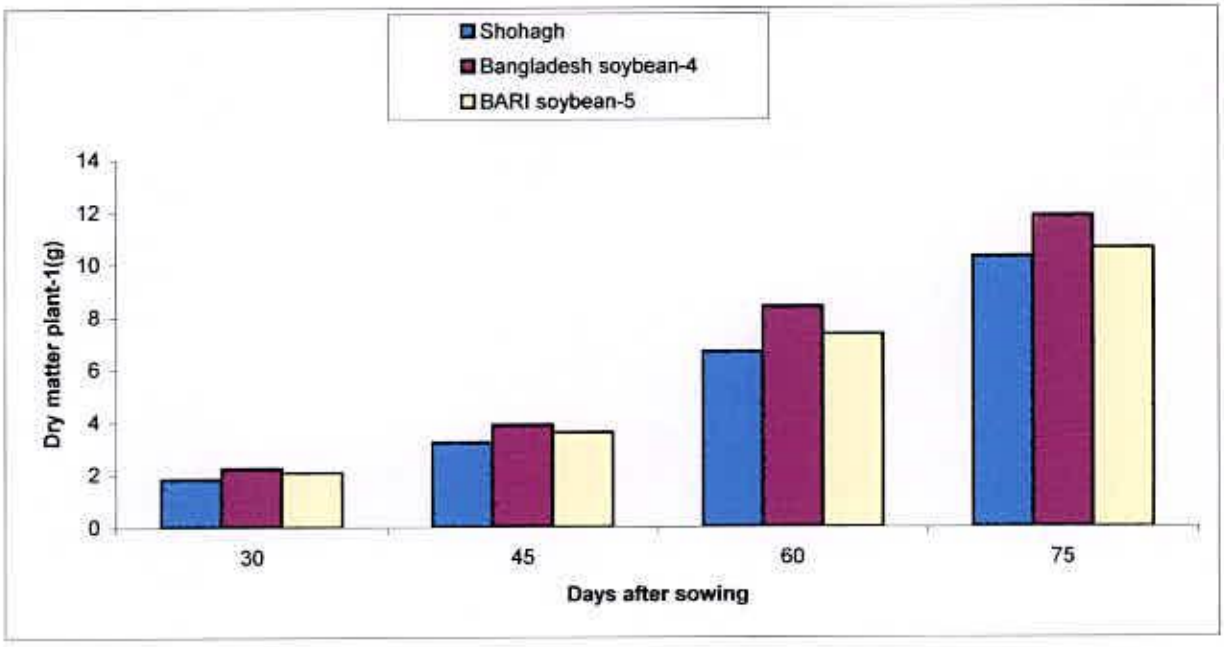

Fig. 6. Effect of variety on dry matter plant^{-1} of Soybean

4.3.3. Interaction effect of fertilizer and variety

The interaction effect between fertilizer dose and variety on dry matter production plant^{-1} has been presented in Table 3. In general, irrespectives of varieties dry matter plant^{-1} increased with higher doses of fertilizer application for all the growth stages. Fertilization with double of the recommended dose x Bangladesh soybean-4 produced the highest dry matter at 45, 60 and 75 DAS. The lower levels of dry matter were found from the interaction treatment without fertilization (control) x shohagh at 45, 60 and 75 DAS.

Table 3 : Interaction effect of fertilizer and variety on dry matter plant^{-1}

Fertilizer x variety	Days after sowing			
	30	45	60	75
Without fertilizer (control) x Shohagh	1.48	2.62	5.78	8.57
Without fertilizer (control) x Bangladesh soybean-4	1.51	2.67	6.69	10.82
Without fertilizer (control) x BARI soybean-5	1.33	2.65	6.15	8.89
Recommended dose x Shohagh	1.38	2.70	5.90	9.00
Recommended dose x Bangladesh soybean-4	1.80	3.39	7.38	11.30
Recommended dose x BARI soybean-5	1.61	3.27	6.74	9.40
Half of the recommended dose x Shohagh	1.73	3.50	6.52	11.45
Half of the recommended dose x Bangladesh soybean-4	2.84	4.56	8.56	12.00
Half of the recommended dose x BARI soybean-5	2.55	3.68	7.63	11.70
Double of the recommended dose x Shohagh	2.83	4.16	8.51	12.10
Double of the recommended dose x Bangladesh soybean-4	2.91	5.00	10.92	13.16
Double of the recommended dose x BARI soybean-5	2.87	4.83	8.82	12.34
LSD (0.05)	0.1341	0.2681	0.2625	0.2681
CV(%)	13.70	4.30	12.04	9.33

4.4. Effect of fertilizer

4.4.1. Plant height (at harvest)

Plant height was significantly influenced by fertilizer dose at 5% level of significance (Table 4.1). In general, application of fertilizer significantly enhanced plant height than control (without fertilizer). However, the tallest plant (58.96 cm) was observed with fertilization at double of the recommended dose. The shortest plant (41.45 cm) was obtained with fertilization at half of the recommended dose which was at par with no fertilization. The second tallest (49.12 cm) plant was found to produce at recommended dose.

4.4.2. Number of branches plant^{-1}

Number of branches plant^{-1} was significant due to different doses of fertilizer application. The highest branches plant^{-1} (4.44) was found with fertilization at double of the recommended dose and the lowest number of branches plant^{-1} (2.61) was obtained in control treatment (without fertilizer). The second highest branches plant^{-1} (3.33) was obtained with fertilization at recommended dose (Table 4.1).

4.4.3. Pod length

There observed a significant difference on pod length due to different doses of fertilization (Table 4.1). The longest pod (3.48 cm) was observed with fertilization at double of the recommended dose plot. The shortest pod (3.34 cm) was obtained with control treatment (no fertilizer).

4.4.4. Number of pods plant^{-1}

Number of pods plant^{-1} was significantly influenced by different doses of fertilizer at 5% level of significance (Table 4.1). Application of fertilizer at different dose produced higher number of pod plant^{-1} (ranged 21.78-27.11) than control (without fertilization). However, fertilization at recommended dose produced highest number of pods plant^{-1} (27.11) that was 30.39% higher

than control (no fertilization). Double of the recommended dose of fertilization produced second highest (25.64) pods plant^{-1} and the third highest was obtained in the half dose treatment. This result agreed of Karte *et al.* (1983).

4.4.5. Number of seeds pod^{-1}

Number of seeds pod^{-1} differed significantly due to different doses of fertilization (Table 4.1). Application of fertilizer at recommended dose showed the highest number (2.05) of seeds pod^{-1}. The second highest number of seeds pod^{-1} (1.86) was recorded with half of the recommended dose fertilizer treated plots. However, control (without fertilizer) plot showed the lowest (1.71) number of seeds pod^{-1}. Variable effects of seeds pod^{-1} was also supported by Svoboda (1988).

4.4.6. 1000 seed weight

The effect of fertilizer dose was significant in respect of 1000 seed weight (Table 4.1). The 1000 seed weight recorded from fertilizer applied plots ranged from 75.90 to 86.00 g. Maximum 1000 seed weight 86.00 g was recorded with recommended dose treatment and the lowest (60.06 g) with no fertilizer treatment. Double of the recommended dose of fertilization showed the second highest (85.20 g) 1000-seed weight. This result agreed with the findings of Svoboda (1988).

Table 4.1 Effect of fertilizer on plant and yield contributing parameters of Soybean

Fertilizer	Plant height (cm)	Branches plant^{-1} (no.)	Pods length (cm)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000 seed weight (g)
Without fertilizer (control)	41.97	2.61	3.34	19.59	1.71	60.06
Half of the recommended dose	41.45	3.22	3.39	21.78	1.86	75.90
Recommended dose	49.12	3.33	3.43	27.11	2.05	86.00
Double of the recommended dose	58.96	4.44	3.48	25.64	1.85	85.20
LSD (0.05)	1.023	0.1964	0.1824	0.7240	0.1930	0.7231
CV(%)	10.87	4.91	4.41	12.64	8.47	9.81

4.4.7. Seed yield

Different doses of fertilizer treatment had significant influence on seed yield of soybean (Table 4.2). Application of fertilizer at different doses significantly increased seed yield than the control (without fertilizer). The highest yield (2243 kg ha^{-1}) was recorded with fertilization at recommended dose and the lowest yield (1083 kg ha^{-1}) was found in without fertilization. However, double of the recommended dose showed the second highest seed yield (2056 kg ha^{-1}). Seed yield increased probably due to positive effect of fertilization for increasing number of pods plant^{-1}, number of seeds pod^{-1} and 1000-seed weight as observed in the present study.

4.4.8. Stover yield

Stover yield was significantly influenced due to fertilizer doses at 5% level of probably (Table 4.2). The table showed that the highest stover yield (2517 kg ha^{-1}) was obtained by fertilizer applied at recommended dose . The lowest stover yield (1401 kg ha^{-1}) was obtained in no fertilizer treatment. In general, application of fertilizer significantly enhanced stover yield than control (without fertilizer).

4.4.9. Biological yield

Different doses of fertilizer exerted significant influence on biological yield (Table 4.2). The highest biological yield (4760 kg ha^{-1}) was produced by fertilizer applied at recommended dose. The lowest (2486 kg ha^{-1}) biological yield was observed in no fertilizer treatment. In general, application of fertilizer significantly enhanced biological yield compared with no fertilizer applied treatment. Fertilizer application increased plant height and number of branches $plant^{-1}$ which in turn probably contributed for higher biological yield for these treatments.

4.4.10. Harvest index

Harvest index varied significantly due to different doses of fertilizer treatments. The highest harvest index (47.00%) was observed by fertilizer applied at recommended dose which was statistically similar with fertilizer applied at half of the recommended dose (46.79%) and double of the recommended dose (46.72%). The lowest harvest index (44.68%) was observed with no fertilization treatment.

Table 4.2 Effect of fertilizer on plant and yield contributing parameter of soybean

Fertilizer	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Without fertilizer (control)	1083	1401	2486	44.68
Half of the recommended dose	1653	1874	3527	46.79
Recommended dose	2243	2517	4760	47.00
Double of the recommended dose	2056	2342	4398	46.72
LSD (0.05)	5.106	4.998	10.09	1.998
CV(%)	7.25	10.12	17.37	12.16

4.5. Effect of variety on plant and yield contributing parameters

4.5.1. Plant height (at harvest)

Plant height varied significantly due to variety (Table 5.1). The tallest plant (56.23 cm) was found in Bangladesh soybean-4 while the shortest plant (52.98) was found in Shohagh.

4.5.2. Number of branches plant^{-1}

The number of branches plant^{-1} was significantly effected by the varieties (Table 5.1). The highest number of branches plant^{-1} (3.58) was found in the variety Bangladesh soybean-4 and the lowest number (3.20) was recoded with the variety BARI soybean-5.

4.5.3. Pod length

Pod length was not significantly influenced due to varieties (Table 5.1). Numerically, maximum pod length (3.50 cm) was found in Bangladesh soybean-4 than BARI soybean-5 (3.38 cm) and Shohagh (3.36 cm).

4.5.4. Number of pods plant^{-1}

Number of pods plant^{-1} was significantly influenced by the varieties (Table 5.1). The highest number of pods plant^{-1} (35.23) was found in Bangladesh soybean-4 which was 118.14 and 83.49% higher than Shohagh and BARI soybean-5, respectively.

4.5.5. Number of seeds pod^{-1}

Number of seeds pod^{-1} exerted nonsignificant effect due to varieties (Table 5.1). From the table it was evident that the maximum number of seeds pod^{-1} (1.91) was found with the variety Bangladesh soybean-4. The minimum number of seeds pod^{-1} (1.78) was observed in the variety Shohagh. This result was suppoted by Molhotra (1974).

4.5.6. 1000 seed weight

Variety exerted significant variation on 1000 seed weight (Table 5.1). The highest 1000 seed weight (96.92 g) was obtained in Shohagh. The lowest 1000 seed weight (53.36 g) was obtained in the variety Bangladesh soybean-4. The variety Shohagh produced 81.63 and 21.01% higher 1000-seed weight than Bangladesh soybean-4 and BARI soybean-5, respectively. The differences in 1000-seed weight among the varieties might perhaps the difference in their genetic make up. The result corroborates with the findings of Das *et al.* (1982).

Table 5.1. Effect of variety on plant and yield contributing parameter of Soybean

Variety	Plant height (cm)	Branchs plant^{-1} (no.)	Pod length (cm)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000 seed weight (g)
Shohagh	52.98	3.41	3.36	16.15	1.78	96.92
Bangladesh soybean-4	56.23	3.58	3.50	35.23	1.91	53.36
BARI soybean-5	55.25	3.20	3.38	19.20	1.90	80.09
LSD (0.05)	0.773	0.144	NS	0.537	NS	0.537
CV(%)	10.87	4.91	4.41	12.64	8.47	9.81

NS= Not Significant

4.5.7. Seed yield

The effect of variety on seed yield was significant (Table 5.2). Bangladesh soybean-4 out yielded by 485 and 332 kg ha^{-1} over Shohagh and BARI soybean-5, respectively. However, the highest seed yield (2031 kg ha^{-1}) was recorded from variety Bangladesh soybean-4. The lowest seed yield (1546 kg ha^{-1}) was obtained from variety Shohagh.

4.5.8. Stover yield

The effect of variety was found to be significant in respect of stover yield (Table 5.2). The stover yield ranged from 1854-2277 kg ha^{-1} among the varieties. Maximum stover weight (2277 kg ha^{-1}) was recorded in Bangladesh soybean-4 and the lowest (1854 kg ha^{-1}) was recorded in Shohagh.

4.5.9. Biological yield

Biological yield differed significantly due to varieties (Table 5.2). From the table, it was evident that the highest biological yield (4308 kg ha^{-1}) was obtained in Bangladesh soybean-4 and that of lowest (3400 kg ha^{-1}) was observed by the Shohagh variety.

4.5.10 Harvest index

Harvest index was significantly influenced by the varieties at 5% level of significance (Table 5.2). The highest harvest index (47.57%) was observed in Bangladesh soybean-4. The second highest (46.14%) harvest index was found in BARI soybean-5 and the lowest (45.17%) was obtained in Shohagh.

Table 5.2 Effect of variety on yield of soybean

Variety	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index(%)
Shohagh	1546	1854	3400	45.17
Bangladesh soybean-4	2031	2277	4308	47.57
BARI soybean-5	1699	1977	3676	46.14
LSD (0.05)	3.822	2.296	6.11	0.9989
CV(%)	7.25	10.11	17.36	12.16

4.6. Interaction effect of fertilizer doses and variety

4.6.1. Plant height (at harvest)

Table 6.1 exerted significant variation on plant height due to interaction between fertilizer dose and variety. The result showed that the tallest plant (62.22 cm) was found in double of the recommended dose × Bangladesh soybean-4 treatment. The shortest plant was recorded with the treatment of half of the recommended dose × Shohagh.

4.6.2. Number of branches plant^{-1}

Significant variation was observed on number of branches plant^{-1} due to interaction effect of fertilizer dose and variety (Table 6.1). The highest number of branches plant^{-1} (4.66) was found in fertilizer applied at double of the recommended dose with Bangladesh soybean-4. The lowest number of branches plant^{-1} (2.35) was found in no fertilizer with Shohagh variety. However, irrespective of varieties fertilizer application increased the number of branches plant^{-1} than the control (without fertilizer).

4.6.3. Pod length

There was a significant variation in pod length due to interaction effect of variety and fertilizer dose. The largest pod (3.60 cm) was found in the interaction of fertilizer at double of the recommended dose × Bangladesh soybean-4 which was similar with the interaction treatments of fertilizer at recommended dose × Bangladesh soybean-4.

4.6.4. Number of pods plant^{-1}

Interaction effect of fertilizer and variety exerted significant influence on the number of pods plant^{-1} (Table 6.1). In general, fertilizer application increased the number of pods plant^{-1} over control (without fertilizer) irrespective of varieties. Irrespective of fertilizer application, Bangladesh soybean-4 showed higher number of pods plant^{-1} than Shohagh and BARI soybean-5. Bangladesh soybean-4 produced the highest number of pods plant^{-1} (40.02) with fertilizer at double of the recommended dose and the lowest number (14.76) was recorded in Shohagh with control fertilizer treatment.

4.6.5. Number of seeds pod^{-1}

Number of seeds pod^{-1} was not significantly due to interaction of fertilizer dose and variety (Table 6.1). Numerically all the fertilizer doses increased the production of number of seed pod^{-1} than control (no fertilizer). The maximum number of seeds pod^{-1} (2.06) was found in Shohagh with recommended dose. The lowest number of seeds pod^{-1} (1.58) was counted in Shohagh with without fertilization treatment.

4.6.6. 1000-seed weight

The interaction effect of fertilizer dose and variety on 1000-seed weight was found significant (Table 6.1). Irrespective of varieties fertilizer doses increased seed weight than without fertilizer treatment. However, the variety Shohagh gave the highest 1000-seed weight (111.64 g) with fertilizer applied at recommended dose. The lowest 1000-seed weight (45.89 g) was found to produce in Bangladesh soybean-4 with without fertilizer (control) applied treatment.

Table 6.1. Interaction effect of fertilizer dose and variety on plant and yield contributing parameters of Soybean

Fertilizer x variety	Plant height (cm)	Branchs plant^{-1} (no.)	Pod length (cm)	Pods plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000 seed weight (g)
Without fertilizer (control) × Shohagh	39.36	2.35	3.23	14.76	1.58	69.26
Without fertilizer (control) × Bangladesh soybean-4	43.59	3.00	3.30	27.22	1.82	45.89
Without fertilizer (control) × BARI soybean-5	42.98	2.50	3.50	16.80	1.75	65.04
Half of the recommended dose × Shohagh	39.03	3.33	3.42	15.66	1.65	96.29
Half of the recommended dose × Bangladesh soybean-4	43.69	3.33	3.50	32.01	2.01	51.99
Half of the recommended dose × BARI soybean-5	41.63	3.00	3.26	17.68	1.92	79.44
Recommended dose × Shohagh	48.60	3.33	3.44	18.16	2.06	111.64
Recommended dose × Bangladesh soybean-4	50.03	3.33	3.60	41.67	2.04	58.01
Recommended dose × BARI soybean-5	48.73	3.33	3.26	21.50	2.05	88.37
Double of the recommended dose × Shohagh	54.86	4.66	3.36	16.05	1.85	110.52
Double of the recommended dose ×Bangladesh soybean-4	62.22	4.66	3.60	40.02	1.80	57.56
Double of the recommended dose × BARI soybean-5	59.80	4.00	3.50	20.85	1.90	87.53
LSD (0.05)	1.547	0.289	0.262	1.074	NS	1.075
CV (%)	10.87	4.91	4.41	12.64	8.47	9.81

NS= Not Significant

4.6.7. Seed yield

The interaction effect of fertilizer and variety on seed yield was significant (Table 6.2). The highest seed yield (2683 kg ha^{-1}) was obtained from variety Bangladesh soybean-4 with fertilization at recommended dose interaction treatment. The lowest seed yield (901.1 kg ha^{-1}) was obtained from variety Shohagh with without fertilizer applied treatment. The result indicated that the response of three varieties was different to different doses of fertilizer in the same location.

4.6.8. Stover yield

Significant influence was found on stover yield due to interaction of fertilizer dose and variety (Table 6.2). Interaction of fertilizer at recommended dose with all the varieties increased the production of stover yield than control (no fertilizer). The lowest stover yield (1209.0 kg ha^{-1}) was found in Shohagh with no fertilizer treatment. The highest stover yield (2869.0 kg ha^{-1}) was found to produce in the interaction of fertilization at recommended dose × Bangladesh soybean-4.

4.6.9. Biological yield

The interaction effect of variety and fertilizer dose on biological yield was significant (Table 6.2). The variety Bangladesh soybean-4 produced the highest biological yield (5552.0 kg ha^{-1}) with fertilizer applied at recommended dose and the lowest biological yield 2114.1 kg ha^{-1} was found in Shohagh with control (no fertilizer). The interaction of fertilization at double of the recommended dose x Bangladesh soybean-4 showed the second highest biological yield (4854.0 kg ha^{-1}).

4.6.10. Harvest index

A significant variation of harvest index observed due to interaction effect of different doses of fertilizer and variety (Table 6.2). The highest harvest index (48.33%) was founded in Bangladesh soybean-4 with fertilization at recommended dose. The lowest harvest index (42.81%) was found in Shohagh variety with control (without fertilization).

Table 6.2. Interaction effect of fertilizer dose and variety on yield of Soybean

Interaction (Fertilizer dose × variety)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Without fertilizer (control) × Shohagh	901.1	1209.0	2114.1	42.81
Without fertilizer (control) × Bangladesh soybean-4	1217.0	1587.0	2804.0	46.74
Without fertilizer (control) × BARI soybean-5	1127.0	1407.0	2534.0	44.49
Half of the recommended dose × Shohagh	1472.0	1736.0	3208.0	45.89
Half of the recommended dose × Bangladesh soybean-4	1920.0	2101.0	4021.0	47.75
Half of the recommended dose × BARI soybean-5	1566.0	1786.0	3352.0	46.72
Recommended dose × Shohagh	1959.0	2305.0	4264.0	45.92
Recommended dose × Bangladesh soybean-4	2683.0	2869.0	5552.0	48.33
Recommended dose × BARI soybean-5	2087.0	2378.0	4465.0	46.74
Double of the recommended dose × Shohagh	1847.0	2167.0	4041.0	46.07
Double of the recommended dose × Bangladesh soybean-4	2304.0	2550.0	4854.0	47.46
Double of the recommended dose × BARI soybean-5	2016.0	2308.0	4324.0	46.62
LSD (0.05)	7.643	4.591	10.090	1.998
CV(%)	7.25	10.11	17.37	12.16

Chapter 5

Summary and Conclusion

SUMMARY AND CONCLUSION

The study was carried out to find out the suitable variety and fertilizer dose for optimum growth and yield of the soybean. The results are summarized below.

The rapid increased in plant height was observed from 30 DAS to 60 DAS. The variety BARI Soybean-5 produced the tallest plant in 30 DAS and Bangladesh soubean-4 produced the tallest plant in 45, 60 and 75 DAS. Significant variation was found in plant height for different fertilizer doses. The maximum plant height was found from applied fertilizer at double of the recommended dose treatment. Likewise, the plant height was found to be significant due to the interaction effect of variety and fertilizer. Maximum plant height was found from the treatment combination of Bangladesh soybean-4 with applied fertilizer at double of the recommended dose in 45, 60, and 75 DAS of the life cycle.

Total dry matter varied in all growth stages with the different varieties. Bangladesh soybean-4 produced the highest dry matter in all growth stages. Significant variation was found in total dry matter plant^{-1} among the different doses of fertilizer. Applied fertilizer at double of the recommended dose gave the best result in respect of dry matter.

In case of interaction effect, the treatment combination of Bangladesh soybean-4 × double of the recommended dose produced the highest dry matter which seemed to be most effective treatment.

The highest number of leaves plant^{-1} (57.00) was found with the variety Bangladesh soybean-4 at 60 DAS and the lowest (21.25) from the variety Bangladesh soybean-4 at 30 DAS. Maximum number of leaf was found from a plant when fertilizer was applied at double of the recommended dose in 30, 60 and 75 DAS. The lowest number of leaves plant^{-1} were found from control plots (no fertilization). On the other hand, the interaction of BARI soybean-5 and double of the recommended dose treatment produced the maximum number of leaves plant^{-1} (65.00) at 60 DAS.

Number of branches plant^{-1} was also significantly affected by variety. Bangladesh soybean-4 produced the highest number of branches plant^{-1} whereas BARI soybean-5 produced the lowest. The applied fertilizer at double of the recommended dose treatment supplied necessary nutrient which subsequently increased the number of branches plant^{-1}. Treatment combination of Shohagh × fertilizer at double of the recommended dose and Bangladesh soybean-4 × fertilizer at double of the recommended dose found to be superior for producing more branches plant^{-1} .

The highest pod length (3.50 cm) was found from the Bangladesh soybean-4 and the lowest (3.36 cm) from the Shohagh. Maximum pod length was found when applied fertilizer at double of the recommended dose treatment and that of lowest found from control plots (no fertilization). On the other hand, the interaction of Bangladesh soybean-4 × fertilizer at recommended dose and Bangladesh soybean-4 × fertilizer at double of the recommended dose produced the maximum pod length (3.60 cm).

Bangladesh soybean-4 produced more number of seeds pod^{-1} than Bangladesh soybean-4 and Sohagh. Among the fertilizer treatments, fertilizer applied at recommended dose produced the highest number of seed pod^{-1} which was statistically higher from other fertilizer doses. The interaction treatment of Shohagh × fertilizer at recommended dose produced the highest number of seeds pod^{-1} (2.06).

The maximum seed yield was found in the variety Bangladesh soybean-4 which was 31.41% and 20.13% higher than Shohagh and BARI soybean-5, respectively. Maximum seed yield was found from applied fertilizer at recommended dose, which was 107.11% higher than the yield obtained from the control (without fertilizer). In case of interaction effect, Bangladesh soybean-4 × recommended dose treatment produced the highest seed yield (2683 kg ha^{-1}) compared to other interaction combinations.

Among the three verities Bangladesh soybean-4 produced the highest stover yield. Applied fertilizer at recommended dose treatment produced the highest stover yield. The interaction treatment of Bangladesh soybean-4 × fertilizer at recommended dose produced the highest stover yield than other combinations.

The highest biological yield was obtained from the variety BARI soybean-5 and Shohagh produced the lowest biological yield. Among fertilizer doses, applied fertilizer at recommended dose produced the highest biological yield. The interaction effect showed Bangladesh soybean-4 x recommended dose produced the highest biological yield, whereas, Shohagh x control treatment produced the lowest biological yield.

The variety Bangladesh soybean-4 had the highest harvest index. Fertilizer at recommended dose treatment produced the highest harvest index and the combination of Bangladesh soybean-4 × recommended dose treatment was found to be best in respect of harvest index in this study.

From the present study it may be concluded that fertilizer dose and variety influenced the growth, yield and yield components of soybean. Among the fertilizer doses, applied fertilizer at recommended dose gave the best result. Out of three tested varieties Bangladesh soybean-4 was superior in all respect. The interaction effect of Bangladesh soybean-4 with applied fertilizer at recommended was found most effective.

Chapter 6

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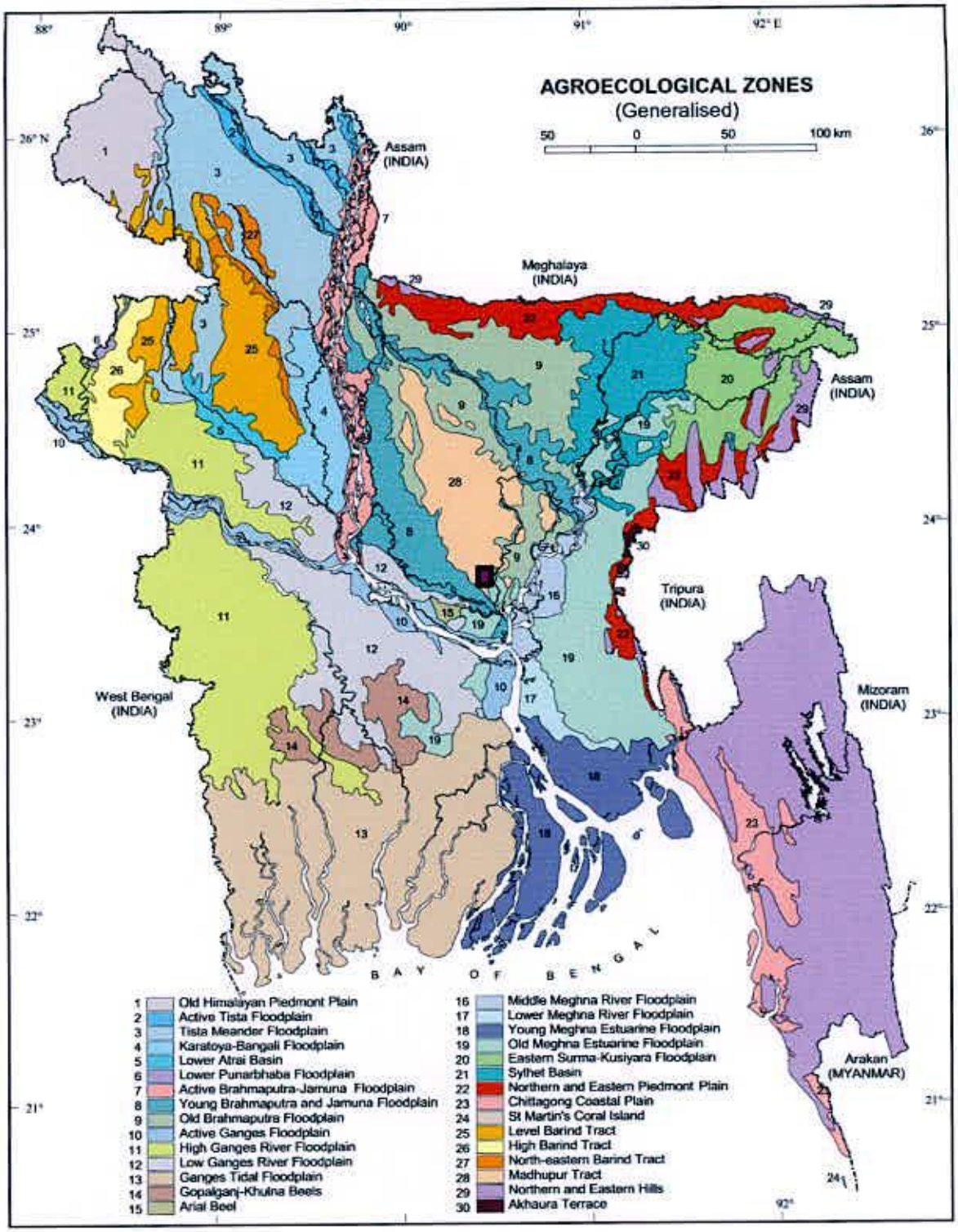
Chapter 7

Appendices



The experimental sites under study

Appendix II: Monthly average of temperature relative humidity and total rainfall of the experiment site during the period from August 2006 to November 2006

Year	Month	Air temperature (^{0}C)			Relative humidity(%)	Rainfall (mm)
		Maximum	Minimum	Mean		
2006	August	32.66	26.80	29.73	84.16	223.50
2006	September	32.08	26.09	29.08	86.97	371.00
2006	October	31.61	24.34	27.97	86.16	205.90
2006	November	29.49	19.55	24.52	84.27	10.70

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

Appendix III: Physical and chemical characteristics of initial soil (0-15 cm depth)

A. Physical composition of the soil.

Soil separates	(%)	Methods employed
Sand	36.90	Hydrometer methods (Day, 1995)
Silt	26.40	- do-
Clay	36.66	- do -
Texture class	Clay loam	-do -

B. Chemical composition of the soil

Soil characteristics	Analytical data	Methods employed
Organic carbon(%)	0.82	Walkley and Black, 1947
Total N (kg ha-1)	1790.00	Bremmer & Mulvaney, 1965
Total S (ppm)	225.00	Bardsley & Lanester, 1965
Total P (ppm)	840.00	Olsen and Sommers, 1982
Available N (kg ha^{-1})	54.00	Bremmer, 1965
Availabe P (kg ha^{-1})	69.00	Olsen and Dean, 1965
Exchangeable K(kg ha^{-1})	89.50	Pratt, 1965
Available S (ppm)	16.00	Hunter, 1984
pH (1:2.5 soil of water)	5.50	Jackson, 1958
CEC	11.23	Chapmen, 1965

Source: Soil Research Development Institute (SRDI)

Appendix IV: Summary of analysis of variance (mean square value) on plant height, number of leaves^{-1} and dry matter

Source of variation	Degrees of freedom	Plant height (cm)				No. of leaves plant^{-1}				Dry matter (g)			
		30	45	60	75	30	45	60	75	30	45	60	75
Replication	2	2.138 NS	1.356 NS	0.800 NS	2.116 NS	0.778 NS	1.333 NS	1.083 NS	2.11 NS	0.006 NS	0.038 NS	0.008 NS	0.029 NS
Fertilizer dose	3	344.857 ***	357.809 ***	755.401 ***	670.981 ***	14.593	71.213 ***	161.213 ***	66.398 **	4.049 ***	7.102 ***	18.063 ***	19.512 ***
Error (a)	6	2.139	1.401	0.808	2.149	0.815	0.630	0.824	2.148	0.006	0.019	0.028	0.018
Variety	2	45.066 ***	33.488 ***	32.901 ***	33.384 **	0.861	19.750 ***	9.250 ***	54.361 ***	0.503 ***	1.311 ***	8.931 ***	7.977 ***
Fertilizer dose x variety	6	7.081 **	1.353 NS	2.114 **	6.676 **	3.676	9.046 ***	15.546 ***	33.731 ***	0.218 ***	0.218 **	0.547 ***	0.714 ***
Error (b)	16	2.139	1.390	0.806	2.141	0.806	0.806	0.889	2.139	0.006	0.024	0.023	0.021

NS= Not Significant
** = Significance at 5% level of probability
*** = Significance at 1% level of probability

Appendix V: Summary of analysis of variance (mean square value) of crop characters

Source of variation	Degrees of freedom	Plant height (cm)	Branches plant^{-1} (no.)	Pod length (cm)	Pods Plant^{-1} (no.)	Seeds pod^{-1} (no.)	1000 seed weight (g)
Replication	2	0.836 NS	0.026 NS	0.016 NS	0.356 NS	0.015 NS	0.366 NS
Fertilizer dose	3	601.452 ***	5.192 ***	0.033 NS	107.427 ***	0.169 **	1308.872 ***
Error (a)	6	0.786	0.029	0.025	0.394 ***	0.028	0.393
Variety	2	60.130 ***	0.419 **	0.067 NS	1259.800 ***	0.062	5791.503 ***
Fertilizer dose x variety	6	5.343 ***	0.157 **	0.055 NS	26.891 ***	0.033	153.003 ***
Error (b)	16	0.799	0.028	0.023	0.385	0.025	0.386

NS= Not Significant
** = Significance at 5% level of probability
*** = Significance at 1% level of probability

Appendix VI: Summary of analysis of variance (mean square value) of yield and harvest index

Source of variation	Degrees of freedom	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Replication	2	19.208 NS	18.778 NS	37.986 NS	3.000 NS
Fertilizer dose	3	2371323.555 ***	2263908.012	2597631.56 ***	10.550
Error (a)	6	19.594	18.778	38.372	3.000
Variety	2	738021.642 ***	571991.160	310012.802	17.452
Fertilizer x variety	6	38219.231 ***	15756.051	53975.282	0.930 ***
Error (b)	16	19.498	5.281	24.779	1.000

NS= Not Significant
** = Significance at 5% level of probability
*** = Significance at 1% level of probability