INFLUENCE OF IRRIGATION, FERTILIZER DOSE AND PLANT DENSITY ON THE YIELD OF SOYBEAN

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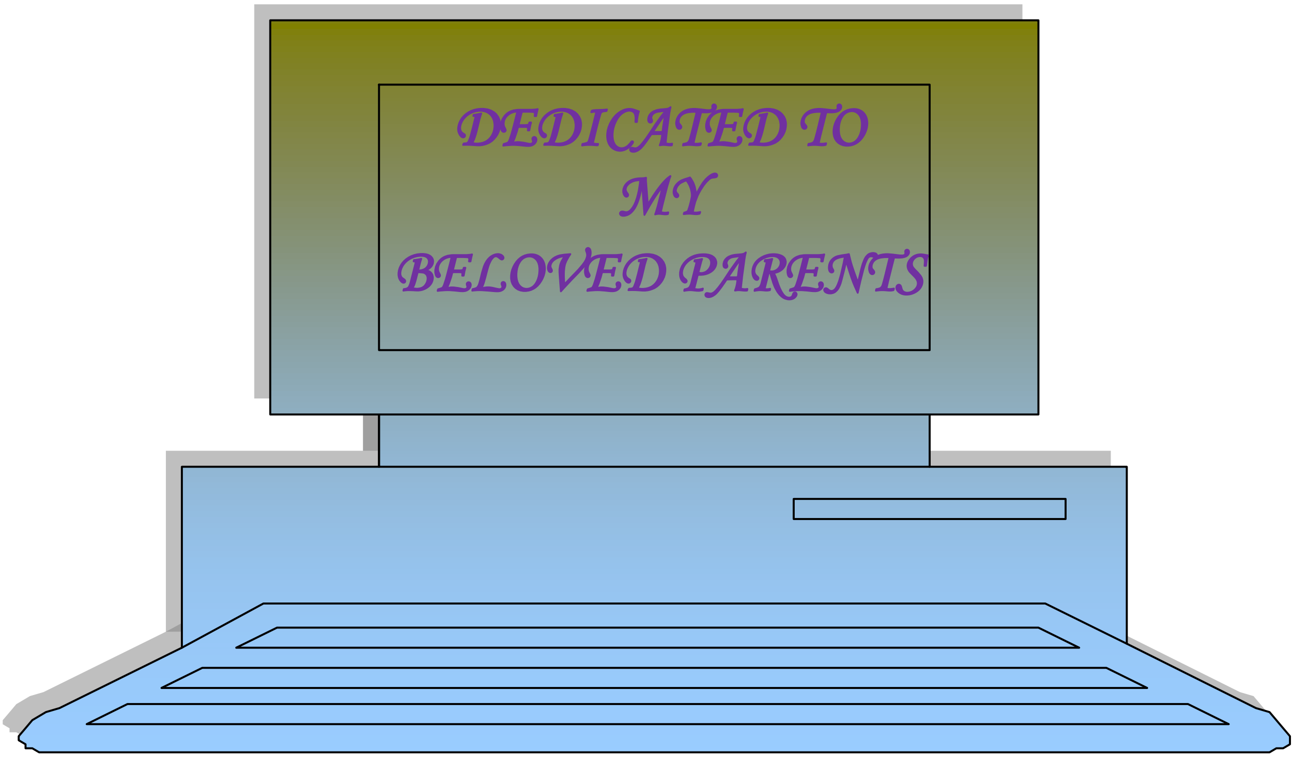
CERTIFICATE

This is to certify that the thesis entitled, "***INFLUENCE OF IRRIGATION, FERTILIZER DOSE AND PLANT DENSITY ON THE YIELD OF SOYBEAN***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of ***MASTER OF SCIENCE (M.S.) IN AGRONOMY,*** embodies the result of a piece of *bona fide* research work carried out by ***FERDAUSI RAHMAN,*** Registration No**.10-04214** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: **(Prof. Dr. Md. Jafar Ullah)**

Place: Dhaka, Bangladesh **Research Supervisor**


DEDICATED TO
MY
BELOVED PARENTS

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INFLUENCE OF IRRIGATION, FERTILIZER DOSE AND PLANT DENSITY ON THE GROWTH AND YIELD OF SOYBEAN

ABSTRACT

An experiment was conducted at the Agronomy field Laboratory of Sher- e–Bangla Agricultural University, Dhaka-1207 during the period from December, 2011 to April 2012 to study the influence of different levels of irrigation, fertilizer dose and plant density on the growth and yield of soybean. The experiment comprised two doses of fertilizer viz. twenty percent lower of the recommended dose, and the recommended dose (Urea, TSP and MP @ 60, 175 and 120 kg ha^{-1}, respectively) and two levels of irrigation viz. irrigated and no irrigated and three types of plant density viz recommended (44 plants/m^2), twenty percent lower and plus twenty percent greater of the recommended density. The experiment was laid out in split plot design with three replications. The results showed that there was significantly higher soil moisture in the irrigated-fertilized (47.53%), irrigated with recommended density plots (49.96%) and irrigated-fertilized plots having higher density plots (52.8%) in comparison to the that in the non irrigated plots (33.85%). Significantly the highest exudation rate was obtained in the irrigated-fertilized with the highest populated plots (0.077 g/hr) in comparison to the lowest of non irrigated-fertilized recommended density plots (0.02 g/hr). Irrigated-fertilized plots having lower to recommended density showed highest plant height (37 cm), leaf area (147 cm^2/plant), dry weight (6-8 g/plant) and no. of pods/plant (8-10). Significantly the highest seed yield of 1.00-1.04 t/ha were obtained in irrigated-fertilized plots having recommended or higher density.

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LIST OF ACRONYMS

AEZ	Agro- Ecological Zone
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
cm	Centi-meter
cv.	Cultivar
DAT	Days after transplanting
^{0} C	Degree celcius
DF	Degree of freedom
EC	Emulsifiable Concentrate
et al.	and others
etc.	Etcetera
FAO	Food and Agricultural Organization
g	Gram
HI	Harvest Index
HYV	High yielding variety
hr	hour
IRRI	International Rice Research Institute
kg	kilogram
LV	Local variety
LYV	Low yielding varieties
LSD	Least significant difference
m	Meter
m^2	meter squares
MPCU	Mussorie phos-coated urea
MV	Modern variety

mm	Millimeter
viz.	namely
N	Nitrogen
ns	Non significant
%	Percent
CV %	Percentage of Coefficient of Variance
P	Phosphorus
K	Potassium
ppm	Parts per million
PU	Prilled urea
SAU	Sher-e- Bangla Agricultural University
S	Sulphur
SCU	Sulphur coated urea
t ha^{-1}	Tons per hectare
UNDP	United Nations Development Program
USG	Urea supergranules
Zn	Zinc

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Soybean (*Glycine max* (L .) Merrill) belongs to the family Fabaceae sub family Fabaceae. It is one of the major oil seed crops of the world. Among the legume crops soybean contains the highest amount of protein and oil, and a good amount of other nutrients like calcium, phosphorus, iron, and vitamins with about 40% proteins. The oil content of soybean is about 20 % while all other pulse contains about 1-2% oil (Rahman,1992). It is such an excellent crop , if consummed extensively may reduce the fat and protein deficiency in the country . Protein is essential for proper development and maintenance of the human body. Generally human consumes protein from plant and animal sources. The common people of Bangladesh cannot afford for animal protein like egg , milk , meat and fish in their daily diet because of their high cost (Wahab *et al* ., 2002) . Therefore, soybean can play a vital role to supplement proteinous food to the common people of Bangladesh.

Soybean can also play important role in solving the malnutrition problem of Bangladesh. It is not yet a popular crop but its oil is very popular as cooking oil.

Soybean can be used in various ways. It can be used as a pulse crop , can also be used for making nutritious food items like soya dal , soya khechuri , soya pollao, soya bori, soya biscuits , soya bread etc. (Khaleque , 1985 ; Mondal and Wahhab, 2001).

Soybean can be cultivated under a wide range of climatic and soil condition. Soil moisture demand of the crop is not high. As such, it can be grown under rainfed condition in the kharif-2 season as well as in the Rabi season with supplementary irrigation . The average seed yield of soybean at research level in Bangladesh is about 2.25 t ha^{-1} which is comparable to the world average yield (FAO, 2003).

Irrigation and fertilizer can play important role in yield of soybean. Like Irrigation and fertilizer population can also play important role in the in yield of soybean.It may be observed that irrigation had significant effect showing the highest yield of soybean. But different doses of fertilizer and population density did not have significant effect on seed yield. The seed yield also did not vary due the interaction of irrigation and fertilizer; fertilizer and population density. But interaction effect of irrigation at all levels of population density showed significantly higher values in most of the parameters at around the recommended density level

Soybean also can fix a considerable amount of nitrogen to the soil and can be a good crop in the rotation to enrich soil fertility.

The high profitability of soybean attracts a growing number of growers and so today it is one of the most important crop plant trading in the world and its growing area is increasing annually. A package of production technology need to develop to save foreign exchange and to meet the deficiency of edible oil in Bangladesh . Therefore, to increase yield of soybean, it is necessary to adopt improved cultural practices including fertilizer, irrigation under proper plant density (Boydak *et al.*, 2004).

Considering the above points an experiment was undertaken to study the responses of irrigation management, fertilizer doses and plant density on soybean with the following objectives:

Objectives:

I. To determine irrigation requirement for achieving higher yield of soybean,

II. To determine the appropriate fertilizer dose to achieve maximum yield of soybean,

III. To determine the proper plant density for achieving maximum yield of soybean,

IV. To evaluate the interaction effect of fertilize dose and irrigation on yield of soybean and

V. To find out the interaction effect of fertilizer dose, irrigation and plant density on yield of soybean.

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Soybean is becoming a popular crop in Bangladesh. It is one of the most oilseed and protein rich crops of the world. Although research work on soybean was started in 1961, little work has so far been done regarding its various aspects of management practices in Bangladesh. Studies on the effect of irrigation, fertilizer dose and plant density on the growth and yield of soybean are not adequate. Some of the findings pertinent to the present work have been reviewed in this chapter.

Effect of irrigation on growth parameters

Rabbani *et al.* (2004) studied 3 genotypes of soybean under different irrigation frequencies 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 irrigation at 20,40and 60 DAS. The highest numbers of branches were obtained with irrigation at 20, 40, 60 ,DAS and 20, 40, 60 and 80 DAS. The chlorophyll content increased whereas the number of empty pods decreased with increasing irrigation frequency.

Hao *et al.* (2003) conducted experiments to find out effects of irrigation and fertilizer on soybean cv. Bei during 1992-98 and 2000 in Heilongjing, China. They found that the effects of irrigation varied among the levels of fertilizer application and vice versa. The pods per plant, seeds per pod and 100 seed weight had positive correlation with soybean yield. Leaf area index and dry matter accumulation significantly increased with irrigation application.

Kazi *et al.* (2002) conducted an experiment to study the impact of irrigation frequencies on growth and yield of soybean cv. Bragg. The irrigation frequencies were 2, 3, 4, 5 and 6 irrigations. It was observed that the growth and yield components were significantly affected by irrigation frequencies. Maximum plant height, more branches plant^{-1}, pods plant^{-1}, harvest index and seed yield were found superior with the application of 6 irrigations followed by 5 irrigations , whereas, lowest number of irrigation decreased all the traits adversely.

Tokoyoda *et al.* (1999) conducted experiments and observed that plant height and number of tillers were generally greatest with normal irrigation and lowest in dry land conditions. Total plant dry weights at 86 days after sowing were highest with normal irrigation on soybean.

Effect of irrigation on yield and yield contributing characters

Irrigation is one of the most important factor that influenced yield and quality of soybean to a great extent. Soybean yield was reported to be increased when irrigation was scheduled throughout the whole growth period followed in order by irrigation at germination and flowering compared with irrigated control (Lago *et al*., 1981). It was reported that maximum seed yield was obtained in Lee–74 and improved Pelican variety of soybean with one irrigation after 30 or 45 days of sowing (Khair and Israil, 1977).

Constable and Heam (1980) reported that irrigations during late flower and pod filling in soybean were necessary to ensure maximum seed yield (up to 305 t ha^{-1}).

Martin *et al*. (1979) reported that yield of soybean cv. Ransom with irrigation after flowering and pod set began stages were 2.12 and 1.69 t ha^{-1}, respectively.

Shahidullah *et al.* (1979) reported that pod plant $^{-1}$ and seed yield $plot^{-1}$ were higher with single irrigation applied after 30 days of sowing.

Sweeney *et al.* (2003) carried out experiment to determine the effect of a single irrigation at different reproductive growth stages on yield and quality of soybean (Glycine max L.) from 1991 to 1994. They found that yields from a single irrigation at R1, R5 or R6 were similar and averaged approximately 20% .They added that irrigation at R 4 increased seeds $plant^{-1}$ whereas R 3 and R 6 irrigations increased seed weight -.Irrigation had minimal effect on seed protein and variable effect on oil content.

Sabev *et al.* (2003) reported that the optimum irrigation regimes with 40 and 20% reduced irrigation rates resulted in an increase of energy efficiency by 16.1 and 15.3% respectively, compared to non-irrigated treatment. Under disturbed irrigated regime, the coefficient of energy efficiency was highest for the treatment without first watering compared to the optimum one (1.3), followed by the treatments with application only of third, second and first watering . The energy difference had the highest values for the treatments with the optimum irrigation regimes with 20 and 40% reduced irrigation rates (24.28 and 23.87 MJ), followed by the treatments without first and second watering compared to the optimum treatment (17.97 and 16.24 MJ , respectively).

Kazi *et al* . (2002) stated that where irrigation frequencies were 2,3,4,5 and 6 irrigations, the growth yield components and oil content were significantly affected by irrigation frequencies . Maximum plant height, more branches $plant^{-1}$, pods $plant^{-1}$, seed index , seed yield (t ha^{-1}) and oil content (%) were found superior with the application of 6 irrigations followed by 5 irrigations . Whereas , lowest numbers of irrigations decreased all the traits adversely.

Sabbe and Delong (1998) conducted field traits with soybean at Marianna, Arkansas, USA in 1995, 97 and 1998. They used two irrigation treatments viz-no irrigation and irrigation and found drought in 1995 reduced un irrigated yields from 17.2 to 27.0 bushels acre^{-1} compared with 35.0 to 54.7 bushels acre^{-1} for irrigated crops . Corresponding yields for 1997 and 1998 were 27.9 -48.5 and 49.0-57.4 bushels acre^{-1} and 18.5 to 33.9 and 50.0-60.7 bushels acre^{-1}, respectively.

Sabbe and Delong (1996) observed that seed yields of the irrigated crops were 2 and 3 times greater than the rainfed craps at Marianna and Rohwer, respectively .

Gretzmacher and Wolfsberger (1991) reported that when irrigation given at flowering and pod set stages the average yields increase was 68 % from 1982 to 1989 with a maximum harvest of 3900 kg ha^{-1}. Rao and Reddy (1990) stated that irrigation at vegetative phase, vegetative +flowering stages , vegetative +flowering + pod formation stages or , vegetative +flowering + pod formation+seed development stages gave seed yields of 1.09, 1.15, 1.21 and 1.17 t ha^{-1}, resprctively.

Klik and Cepuder (1991) reported that a single irrigation either at flowering or 4 days later at the beginning of pod development gave a 14 % increase of yields over control. They also found 23 % increase of yields 3.38 t ha^{-1} with irrigation applied 4 times over non irrigation control.

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

Vasiliu (1988) reported that soybean seed yields ranged from 1.30 t ha^{-1}with no irrigation to 3.00 t ha^{-1} with irrigation to 50 % field capacity up to the maturity of the last pods.

Moraru et al . (1988)) reported that soybean seed yields were lowest with no irrigation and highest with irrigation at 70% of field capacity at 0-80 cm depth or at 50% of field capacity before and at flowering and or at 50% of field capacity at 0-80 cm depth.

Yazdi and Saadati (1978) stated that seed yield was 1.25 t ha^{-1} with one irrigation before flowering and upto (4.21 t ha^{-1}) with extra irrigation before and after flowering . Irrigation at the vegetative stage was important and at the end of flowering most important in increasing seed yields of soybean.

Stutte and Weiland (1981) stated that when soybean irrigated at late vegetative, flowering and early pod filling stages, seed yields of cv. Davis and Forrest were increased.

Matheny and Hunt (1981) reported that when soybean irrigated at late flowering stage, irrigation increased yields by 86% compared with control plants and maximum seed yield was recorded 3.10 t ha^{-1} in this treatment.

Effect of Fertilizer

Effect of Nitrogen

Osborne *et al.* (2006) observed that Nitrogen applied before planting could be beneficial to soybean nodules.

Peter *et al.* (2003) observed that soybean yield responses to nitrogen fertilizer were spread widely around Missouri.

Starling *et al.* (1998) observed that broadcast Nitrogen 50 kg ha^{-1} applied at planting time increased soybean seed yield of determinate stem-termination type by at least 8 %.

Mahmoud *et al.* (1998) observed that nitrogen application increased the stover production up to a certain level with different row spacing in soybean.

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

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

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

Leelavathi *et al*. (1991) conducted a field experiment and results showed that nitrogen application increased Stover yield of soybean to a certain level with different row spacing.

Jamro *et al*. (1990) observed that application of 0, 30, 60, or 90 kg N ha^{-1} in soybean cv. Bossier decreased nodule weight plant^{-1}with increasing N rate.

Joshi *et al.* (1989) observed that increasing N rates from 0-40 kg ha^{-1} increased seed yield of soybean.

Patel and Parnar (1986) observed that increasing N application to soybean from 0 - 45 kg ha^{-1} increased 1000 seed weight.

Effect of phosphorus

Aise *et al*. (2011) conducted an experiment on soybean and observed significant effect on higher leaf area, 1000- seed weight, pods per plant, seed yields of soybean under the condition of the proper application.

Shahid *et al*. (2009) observed that P was the essential constituent of plant tissue which significantly influences the plant height of soybean.

Alpha *et al*. (2007)) conducted an experiment and reported that proper P improved the shoot phosphorus uptake and increased shoot dry matter weight, 100 seeds weight , pods per plant and yield.

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

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

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

Giller *et al.* (1995) reported that soybean required P for adequate growth and N fixation and their effectiveness in soil improvement.

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

Navale *et al*. (2000) performed an experiment in Maharashtra, India during Kharif season and observed that seed yield increased with up to 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 phosphorous (60 kg P_2O_5 ha^{-1}) significantly increased grain yield of soybean.

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

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

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

Haque *et al.* (1988) found that increased doses of phosphorus increased the number of pods per $plant^{-1}$ of soybean.

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.

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 the highest seed yield of 1.77 and 2.02 t ha^{-1}in summer and monsoon season, respectively, by applying 120 kg P_2O_5 ha^{-1}.

Effect of Potassium

Jack *et al.* (2005) reported that K- deficient plants often had slow growth, poor drought resistance, week stems and were most susceptible to lodging and plant disease.

Noor *et al.* (1980) observed that K deficit caused lodging which could affect the growth, development and reduced yield by as much as 22%.

Effect of Plant Density

Epler *et al.* (2008) stated that Soybean yield and yield component responded to plant density.

Manhattan *et al.* (2005-2006) reported that plant height was affected by plant density at all location.

Ohdan *et al.* (2005) observed that the narrow row cultivation (high population density) decreased weeds emergence and the alternative application of herbicide to soil or foliage (Graminae weeds) could control weeds with labour saving and

stability.

Seiter *et al.* (2004) showed higher seed production in high populated soybean field followed by low plant density.

Bowers *et al.* (2000) showed that yield was most responsive to spacing when the total July August rainfall ranged from 100 -270 mm which varied plant population.

Saitoh *et al.* (1998) reported that dense planting has been reported to increase the node number, pod number and therefore seed yield without the consideration of lodging.

Miura *et al.* (1986) showed that the square or triangular planting increased the space occupied by plants than rectangular shape planting and promoted the development of branches thus increasing the seed yield.

Interaction Effect of Population density and Irrigation

Boydak *et al.* (2004) conducted two experiments to study the effect of density and irrigation intervals on yields, plant height, first pod height, branch plant^{-1}, pod number plant^{-1}, and seed yield plant^{-1}, for 2 years in Harran, Turkey, where four row spacing (50-30, 70-30, 80-10, and 70-70 cm) and four irrigation intervals (3,6,9, and 12 days intervals) were used. They observed that the seed yield plant^{-1}was reduced with decreasing row spacing but led to an increase in yield per hectare yields which were the highest (3752.6 kg ha^{-1}) at 50-30 cm row spacing and 6 days irrigation intervals (3744.1 kg ha^{-1}) but were the lowest (3096.6 kg ha^{-1}) at the 70 cm row spacing and 12 day irrigation intervals (2752.4 kg ha^{-1}) .

Boydak *et al.*(2002) conducted field experiments during 1998-1999 in Turkey to investigate the effect of different row spacing and irrigation methods on yield and yield components of soybean cv. A3935. They observed the variation in yields at different irrigation methods which was 28353 to 33238 kg ha^{-1}. The sprinkler irrigation produced the highest plant height, branch number plant-1, node number plant^{-1}, pod number plant^{-1}, and yield plant^{-1} than the drip irrigation method.

Paslawar *et al.* (1998) conducted a field experiment with soybean cv. PKV –I during 1995 in India. Sowing was done at densities of 2.2, 3.3 or 4.4 lakh plants ha^{-1} and irrigation was applied twice, no irrigation or protective irrigation. They reported that the yield increased with increasing density and were greater with irrigation than without irrigation.

Interaction Effect of Irrigation and Fertilizer

Hao *et al.* (2003) conducted an experiment to find out the effects of irrigation and fertilizer on soybean cv. Bei 92 -28 in 2000 at Heilongjiang, China. They found that the effects of irrigation varied among the levels of fertilizer application and vice versa. Pods $plant^{-1}$, seeds $pods^{-1}$, and 100- seed weight had positive correlations with soybean yield. Leaf area index and dry matter accumulation significantly increased when irrigated and supplied with fertilizer. Irrigation increased the absolute absorption of N, P and K in seeds, although differences in the accumulation rates were observed.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

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

3.1 Experimental site

The research work was carried out at the experiment field of She-e–Bangla Agricultural University, Dhaka during the period from December 2011 to April 2012. The experimental field belongs to the agro-ecological zone of the Madhupur Soil Tract (AEZ-28). For better understanding about the experimental site it has been shown in the map of AEZ of Bangladesh in Appendix-I

3.2 Climate

The climate of the study area was characterized by moderate temperature high humidity and moderate rainfall. The weather data during the growing period of experimentation has been shown in Appendix-II.

3.3 Soil

The land belongs to general soil type Shallow Red Brown Terrace Soil under Tejgaon soil series. The samples from 0 –15 cm depths were collected from the experimental field. The physical and chemical properties of the soil have been presented in Appendix-III.

3.4 Description of the cultivar

The variety of soybean used in this experiment was BARI Soybean-5. The seed of this variety was collected from Bangladesh Agricultural Research Institute, Joydbpur, Gazipur. This released variety has excellent seed quality and superior to existing other ones. BARI Soybean-5 was released by National Seed Board (NSB) during 2002. Its field duration was about 95-115 days. Plant height was about 40-60 cm. Flower colour was pinkish. Seed colour was cream. Seed size was medium. Seed yield was 1.6-2.0 t ha^{-1} (BARI, 2002).

3.5 Experimental details

3.5.1 Treatments

Three sets of treatment (Factors) included in the experiment were as follows:

Factor A : Irrigation-2 (Main Plot)

I_0 = No irrigation

I_1=Irrigated

Factor B : Fertilizer level-2 (Sub-Plot)

Fr = Recommended dose of Urea, TSP and MP @ 60, 175 and 120 kg $ha^{-1,}$ respectively (BARI, 2005)

F-20 = Twenty percent lower Urea, TSP and MP from recommended dose

Factor C: Population Density -3 (Sub-Sub- Plot)

Dr = Recommended Population Density (Spacing 30 cm×7.5 cm ≈ 44 plants/m^2)

D_{-20}= Twenty percent less population than the recommended (Spacing 30 cm× 9 cm ≈ 36 plants/m^2)

D_{+20} = Twenty percent more population than the recommended (Spacing 30 cm× 6 cm ≈ 53 plants/m^2)

3.6 Design and Layout of the Experiment

The experiment was laid out following three factor split plot design with 3 replications. The field was divided into 3 blocks to represents 3 replications. Each block was divided into 2 main plots to accommodate the irrigation treatments and each main plot into 2 sub plots to accommodate the fertilizer treatments. These sub plots were then again sub divided into three to accommodate population density treatments. There were 36 plots in the experiment and the size of each unit plot was 2.5 m × 4 m. The distance between unit plots and blocks were 0.75 m and 1m, respectively.

3.7 Experimental procedure

3.7.1 Land preparation

The land was first opened on 7, November 2011 with a power tiller. Final land preparation was done by country plough on 20, November 2011. The land was thoroughly prepared by four ploughings and stubble were removed from the field. Final layout was done on 21, December, following the design adopted.

3.7.2 Fertilizer

The applied doses of fertilizer (urea, triple super phosphate and muriate of potash) were applied as per treatment. All the fertilizer were applied at the time of final land preparation .

3.7.3 Sowing of Seeds

Sowing was done on 21. November 2011. Seeds were sown in 30 cm apart rows and seed to seed distance of 9, 7.5 and 6 cm were maintained to conform the exact plant density of D -20, Dr and D+20, respectively. Furrows were made by hand rake and seeds were placed in the furrows by hand and then covered properly with soil.

3.8 Intercultural operation

The following Intercultural operations were done to ensure the normal growth of the plant.

3.8.1Thinning: Thinning was done as per required plant density within 15 DAS.

3.8.2Weeding

The crop was weeded twice. First weeding was done at 25 days after sowing (DAS) and second weeding was done at 45 DAS. Demarcation boundaries and drainage channels were also kept weed free.

3.8.3 Irrigation

Irrigation was done at 30 DAS after sowing (pre-flowering) stage and then at 60 DAS (pod formation stages)as per recommendation (BARI ,2005).

3.8.4 Mulching

After each irrigation the soils of the irrigation treated plots were loosen in between two rows by ploughing.

3.8.5 Plant protections

The soybean plants were infested by hairy caterpillars (*Dlaerisia oblique*) and cutworm at early growth stage which were controlled by applying Sumithion 50 EC @ 1.01 ha^{-1}. On the other hand picking of infested leaves withcaterpillar larvae was also done as a control measure.

3.8.6 General observation

The field was frequently observed to notice any change in plant characters from sowing till harvest.

3.8.7 Sampling and harvesting

Maturity of crop was determined when 95 % of the pods become brown in colour. Ten sample plants were collected from each plot before harvesting for taking yield attributes data. The plants of central 1 m^2 area were harvested by placing quadrates for recording yield data. Harvesting was done on 15, April , 2012. The harvested crops from each plot were tiedup into bundles separately, tagged and brought to the clean threshing floor .The same procedure was followed for sample plants.

3.8.8 Threshing

The crop bundles were sun dried for four days by spreading them on the threshing floor. Seeds were separated from the stover by hand machine or rubbing..

3.8.9 Drying

Seeds and stover were cleaned and dried in the sun for four consecutive days. After proper drying of seeds to a moisture content of 12 % were kept in polythene bags.

3.8.10 Cleaning and weighing

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

3.9 Collection of data

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

The following data were collected –

1. Plant height (cm)

2 Leaf area (cm)

3. Dry matter $plant^{-1}$ (g)

4. Pod length (cm)

5. Number of pods $plant^{-1}$

6. Number of seeds pod^{-1}

7. Weight of 1000-seeds (g)

8. Seed yield (g $plant^{-1}$)

9. Seed yield (ton ha^{-1})

10. Harvest index (%)

3.10 Methods of recording data

3 .10 .1 Plant height (cm)

The heights of 10 sample plants were measured from the ground level to the tip of the shoot. It was done at harvest. Then the data was averaged and expressed in cm.

3.10.2 Soil moisture : Soil moisture was measured through the machine..

3.10.3 Relative water content : The relative water content was measured to monitor the plant water status which was measured from the first fully expanded leaf of soybean plants in different treatments. The leaf samples were cut with a sharp knife with petiole and were put in a polythene bag treatment wise. Then the samples were brought in laboratory and their fresh weights were recorded immediately. The bags were kept on a tray and were wraped with a moist towel to avoid light and desiccation. The leaf samples were then dipped in water for 24 hours and their turgid weight were recorded after soaking the leaf surface by soaked towel. The samples were then oven dried to constant weight. The plant water status was measured using the following formulae;

Relative water content (RWC %) = [(Fresh weight – dry weight)/(Turgid weight – Dry weight))] ×100

3.10.4 Saturation water deficit:

Saturation water deficit was derivated from the data of relative water content (RWC) using the following formulae

Saturation water deficit = 100 - RWC

3.10.5 Exudation rate:

The exudation rate was measure from the stem at about 5 cm above from the ground. At first the dry cotton was weighed. A slanting cut on the stem was made with a sharp knife. Then the weighed cotton was placed on the cut surface. The exudation of the sap was collected from the stem for 1 hour at normal temperature. The final weight of the cotton with sap was taken. The exudation rate was calculated by deducting cotton weight from the sap containing cotton weight and was expressed per hour basis as follows;

Exudation rate = [(Weight of cotton + Sap) – (Weight of cotton)] / Time (Hours)

3. 10. 6 Dry weight plant^{-1} (g)

Five plants were collected randomly from each plot and dried separately for 48 hours in an electric oven set at 65 ° C. 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 g. Dry weight data were collected 5 times at 30, 45, 60 and 75 DAS and harvest.

3 .10.7 Pod lengths(cm)

The length of 10 pods taken from sample plants were measured and mean length was expressed in cm.

3. 10.8 Number of pods plant^{-1}

All the pods of the ten sample plants in each plot were counted and averaged them to have pods plant^{-1}.

3.10.9 Number of seeds pod $^{-1}$

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

3.10.10 Weight of seed per plant (g)

Seeds obtained from plant were dried in the sun and weighed out. The seed weight was expressed as gram on 12% moisture basis. Grain moisture content was measured by using digital moisture meter.

3.10.11 Weight of 1000-seed (g)

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

3.10.12 Seed yield (t ha^{-1}).

Seeds obtained from harvested area of each unit plot were dried in the sun and weighed . The seed weight was expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using digital moisture meter.

3.10.12 Harvest index (%)

Harvest index was calculated as the ratio of economic yield to biological yield and expressed as percentage. It was calculated by using following formula.

Harvest index (%) =Seed yield (t ha^{-1})/ Biological yield (t ha^{-1}) ×100

Where, Biological yield (t. ha^{-1}) = Seed yield (t. ha^{-1}) + Stover yield (t ha^{-1}).

3. 11 Statistical Analysis

The recorded data on various parameters were statistically analyzed by using MSTAT-C statistical package programme. The mean for all the treatments was calculated and analysis of variance for all the characters was performed by F-test. Difference between treatment means were determined by Least Significance Difference at 5% level of significance .

Chapter 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

Results obtained from the present study have been presented in different tables and figures and discussed in this chapter and possible interpretations are given under the following headings.

4.1 Soil moisture

4.1.1 Irrigation

Soil moisture of the experimental plot was measured at the time of seeding. It was evident from (Fig. 1) that the soil moisture affect the irrigation use efficiency. The maximum soil moisture (46.52%) was observed from I_1 (30DAS at flowering) treatment and the minimum soil moisture (33.86%) was observed from I_0 (no irrigation) treatment.

4.1.2 Effect of fertilizer

Soil moisture affect the fertilizer use efficiency(Fig. 1). The maximum soil moisture (41.08%) was found from F_{-20} (20% less than recommended dose of fertilizer) treatment. On the other hand the minimum soil moisture (39.30%) was observed from Fr (recommended dose of fertilizer) treatment.

4.1.3 Effect of population density

Population density had significant effect on soil moisture (Fig. 1). The maximum soil moisture (41.98%) was obtained from D_{-20} (30 cm×7.5 cm) treatment and the minimum soil moisture (37.7%) was obtained from D_{+20} (30 cm× 9 cm).

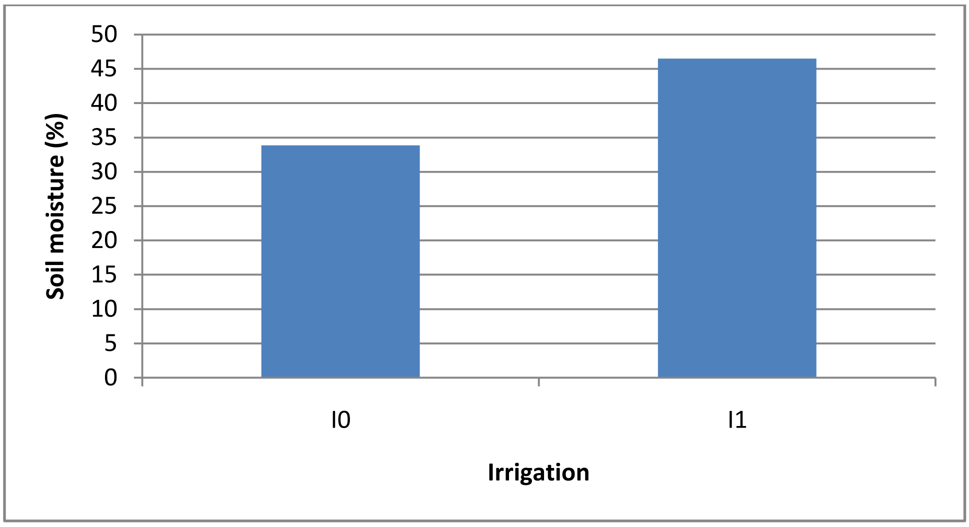

Fig. 1. Effect of irrigation on soil moisture of soybean (LSD $_{(0.05.)}$=7.17)

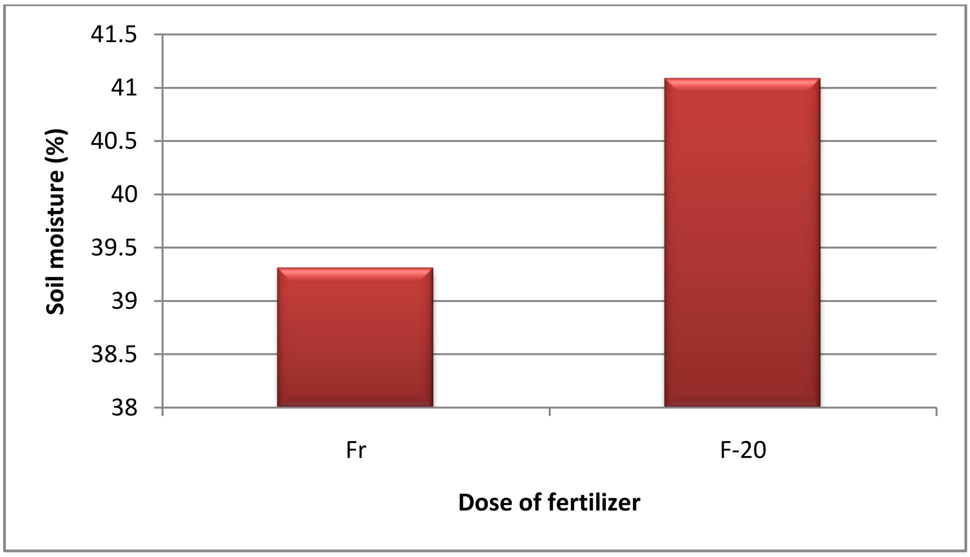

Fig. 2. Effect of fertilizer on soil moisture of soybean (LSD $_{(0.05.)}$=9.04)

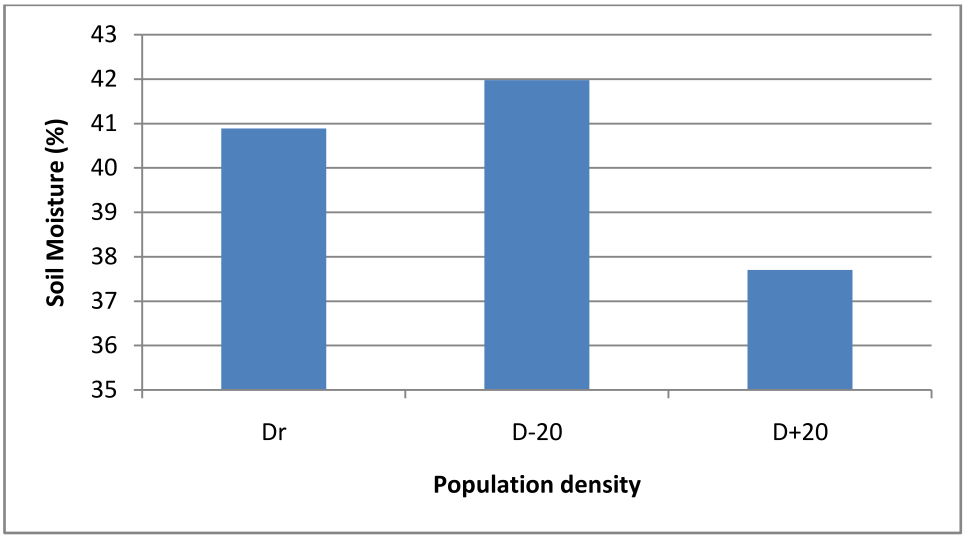

Fig. 3. Effect of population density on soil moisture of soybean (LSD $_{(0.05.)}$=7.47)

Table 1. Effect of irrigation, fertilizer and population density on Soil moisture, saturation water deficit, relative water content(%) and exudation rate of soybean

Treatment	Soil moisture (%)	Saturation water deficit (%)	Relative water content(%)	Exudation rate (g/ha.)
I_0	33.855	0.524	89.34	0.034
I_1	46.524	0.737	89.224	0.057
LSD	**7.17**		**3.59**	**0.064**
CV%	**12.44**	**52.01**	**2.81**	**97.22**
F_r	39.302	0.631	89.422	0.052
F_{-20}	41.077	0.64	89.142	0.039
LSD	**9.04**	**0.15**	**1.80**	**0.029**
CV%	**24.32**	**27.45**	**2.19**	**68.75**
D_r	40.89	0.64	89.29	0.048
D_{-20}	41.98	0.6517	89.58	0.054
D_{+20}	37.7	0.60	88.97	0.036
LSD	**7.47**	**0.09**	**1.96**	**0.027**
CV%	**21.55**	**16.62**	**2.53**	**68.75**

Here,

I_0 = No irrigation

I_1=Irrigated

Fr = Recommended dose of Urea, TSP and MP @ 60, 175 and 120 kg $ha^{-1,}$ respectively (BARI, 2005)

F-20 = Minus Twenty kg of Urea, TSP and MP from recommended dose

Dr = Recommended Population Density (Spacing 30 cm×7.5 cm ≈ 44 plants/m^2)

D_{-20}= 20% less population than the recommended (Spacing 30 cm×6 cm ≈ 36 plants/m^2)

D_{+20} = 20% more population than the recommended (Spacing 30 cm× 9 cm ≈ 53 plants/m

Table 2. Interaction effect of irrigation × fertilizer, irrigation × population density, fertilizer × population density and irrigation × fertilizer × population density on Soil moisture, water saturation deficit, relative water content (%) and exudation rate of soybean

Treatment	Soil moisture (%)	Water saturation deficit (%)	Relative water content (%)	Exudation rate (g/ha.)
I_0Fr	33.08	0.51	89.21	0.041
I_0F_{-20}	34.63	0.54	89.05	0.027
I_1Fr	45.52	0.7267	89.63	0.063
I_1F_{-20}	47.53	0.7467	89.24	0.051
$LSD_{(0.05)}$	**12.79**	**0.228**	**2.551**	**0.0416**
CV%	**24.32**	**27.45**	**2.19**	**68.75**
I_0 Dr	36.44	0.5067	88.64	0.050
I_0 D_{-20}	34.01	0.5483	88.46	0.022
I_0 D_{+20}	31.12	0.5183	89.55	0.030
I_1 Dr	45.34	0.7733	89.42	0.057
I_1 D_{-20}	49.96	0.755	89.62	0.049
I_1 D_{+20}	44.28	0.6817	89.95	0.066
LSD $_{(0.05)}$	**10.6**	**0.128**	**2.768**	**0.0387**
CV%	**21.55**	**16.62**	**2.53**	**68.75**
Fr Dr	39.28	0.63	89.86	0.065
Fr D_{-20}	40.83	0.6383	89.18	0.037
FrD_{+20}	35.5	0.625	89.23	0.055
F_{-20} Dr	42.5	0.65	88.73	0.042
F_{-20} D_{-20}	43.13	0.665	88.76	0.035
F_{-20} D_{+20}	39.9	0.575	89.94	0.041
LSD $_{(0.05)}$	**10.6**	**0.128**	**2.768**	**0.0387**
CV%	**21.55**	**16.62**	**2.53**	**68.75**

Here,

Non Significant data did not lettering

Table 2.(contd.)

Treatment	Soil moisture (%)	Water saturation deficit (%)	Relative water content (%)	Exudation rate (g/ha.)
I_0FrDr	36.22	0.4667	87.81	0.070
I_0FrD_{-20}	33.46	0.54	88.74	0.020
I_0FrD_{+20}	29.57	0.6	90.12	0.034
$I_0F_{-20}Dr$	36.66	0.5467	88.93	0.030
$I_0F_{-20}D_{-20}$	34.56	0.5567	89.1	0.024
$I_0F_{-20}D_{+20}$	32.67	0.4367	89.11	0.027
I_1FrDr	42.33	0.7933	88.41	0.060
I_1FrD_{-20}	47.12	0.7133	88.54	0.054
I_1FrD_{+20}	41.43	0.65	88.33	0.077
$I_1F_{-20}Dr$	48.34	0.7533	90.76	0.054
$I_1F_{-20}D_{-20}$	47.11	0.7733	90.56	0.045
$I_1F_{-20}D_{+20}$	52.8	0.7367	90.97	0.054
LSD $_{(0.05)}$	**14.99**	**0.182**	**3.91**	**0.055**
CV%	**21.55**	**16.62**	**2.53**	**68.75**

4.1.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on soil moisture was found significant (Table 2). The maximum soil moisture (47.53%) found from the $I_{1F\text{-}20}$ treatment and the minimum soil moisture (33.08%) was found from the I_0Fr.

4.1.5 Interaction effect of irrigation and population density

Soil moisture was significantly affected by the interaction between irrigation and population density (Table 2). The maximum soil moisture (49.96) was found from I_1D_{-20} and the minimum (31.12%) from $I_0D_{+20.}$

4.1.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on soil moisture showed significant variation among treatment combination (Table 2). The maximum soil moisture (43.13) was produced from $F_{-20}D_{-20}$ treatment and the minimum soil moisture (35.50 %) was produced from FrD_{+20} treatments.

4.1.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 2), it was found that although soil moisture was significant. The maximum soil moisture (52.80%) obtained from $I_1F_{-20}D_{+20}$ treatments and the minimum soil moisture (29.57%) plant was observed from I_0FrD_{+20}.

4.1.2 Water saturation deficit

4.2.1 Irrigation

There was the effect on water saturation deficit due to the application of fertilizer given on (Fig. 4). The maximum water saturation deficit (0.74%) was observed from I_1 treatment and the minimum water saturation deficit (0.52%) was observed from I_0 treatment.

4.2.2 Effect of fertilizer

There was effect on water saturation deficit due to the application of fertilizer (Fig. 5). The maximum water saturation deficit (0.64%) was found from F_{-20} treatment. On the other hand the minimum water saturation deficit (0.631%) was observed from Fr treatment.

4.2.3 Effect of population density

Population density had insignificant effect on water saturation deficit (Fig. 6). The maximum water saturation deficit (0.651%) was obtained from D_{-20} treatment and the minimum water saturation deficit (0.60%) was obtained from D_{+20}.

4.2.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on water saturation deficit was found insignificant (Table 2). The maximum water saturation deficit (0.75%) found from the I_1F_{-20} treatment and the minimum water saturation deficit (0.51%) was found from the I_0Fr.

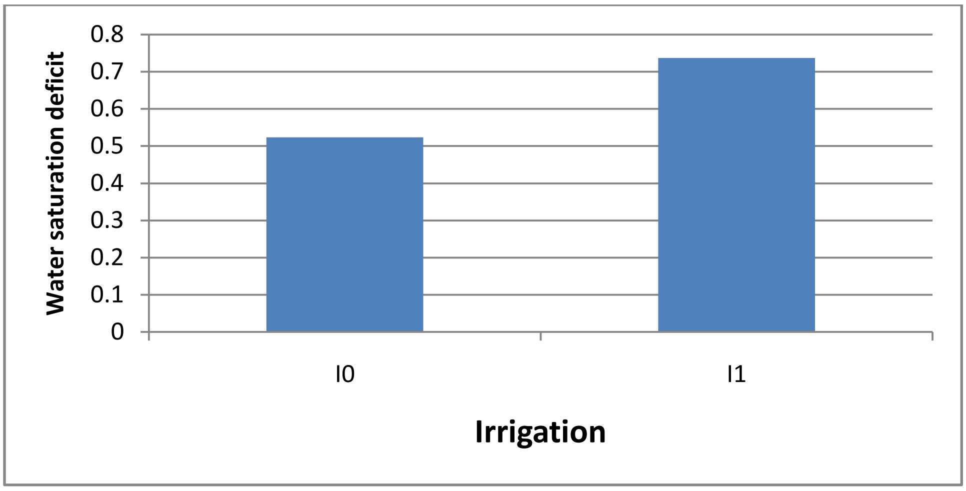

Fig. 4 Effect of irrigation on water saturation deficit **(LSD $_{(0.05.)}$=0.47)**

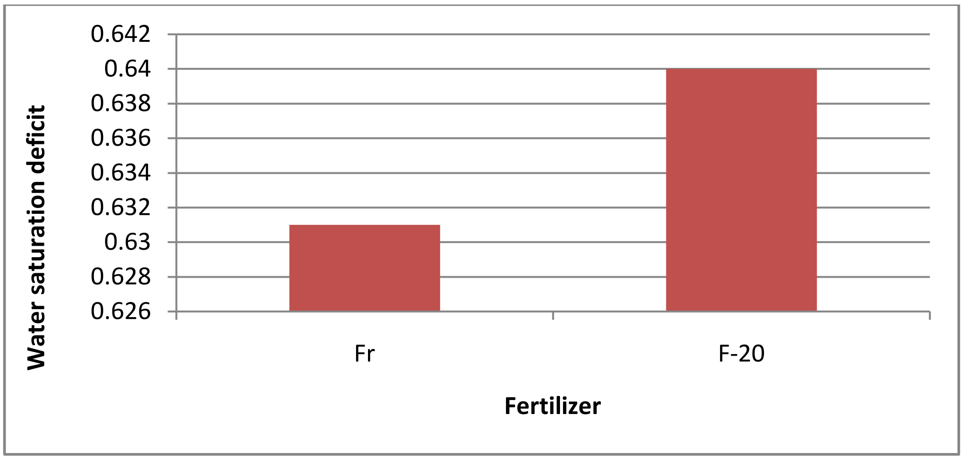

Fig. 5 Effect of fertilizer on water saturation deficit (LSD $_{(0.05.)}$=0.15)

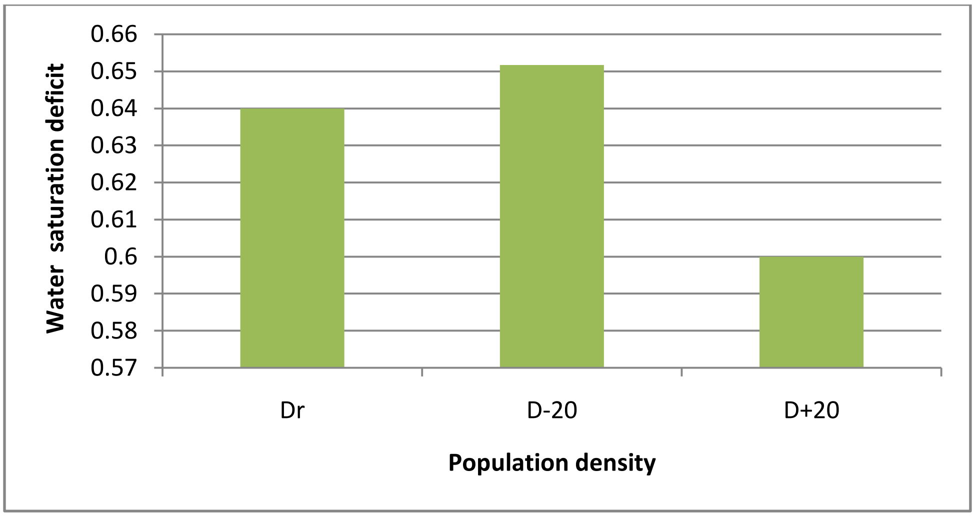

Fig. 6 Effect of population density on water saturation deficit (LSD $_{(0.05.)}$=0.04)

4.2.5 Interaction effect of irrigation and population density

Water saturation deficit was insignificantly affected by the interaction between irrigation and population density (Table 2). The maximum water saturation deficit (0.77%) was found from I_1Dr and the minimum (0.51%) from I_0Dr .

4.2.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on water saturation deficit show insignificant variation among treatment combination. The maximum water saturation deficit (0.67%) was produced from $F_{-20}D_{-20}$ treatment and the minimum water saturation deficit (0.58%) was produced from $F_{-20}D_{+20}$ treatments.

4.2.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 2), it was found that although water saturation deficit was significant. The maximum water saturation deficit (0.79%) obtained from I_1FrDr treatment and the minimum water saturation deficit (0.44%) plant was observed from $I_0F_{-20}D_{+20}$.

4.3 Relative water content

4.3.1 Irrigation

Relative water content was evident from (Fig. 7) that the relative water content was influenced by irrigation. The maximum relative water content (89.34%) was observed from I_1 treatment and the minimum relative water content (89.24%) was observed from I_0 treatment.

4.3.2 Effect of fertilizer

There was effect on relative water content due to the application of fertilizer (Fig. 8). The maximum relative water content (89.44%) was found from F_{-20} treatment. On the other hand the minimum relative water content (89.12%) was observed from Fr treatment.

4.3.3 Effect of population density

Population density had insignificant effect on relative water content (Fig. 9). The maximum relative water content (89.58%) was obtained from D_{-20} treatments and the minimum relative water content (88.97%) was obtained from D_{+20}.

4.3.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on relative water content was found insignificant (Table 2). The maximum relative water content (89.63%) found from the I_1Fr treatment and the minimum relative water content (89.05%) was found from the I_0F_{-20}.

4.3.5 Interaction effect of irrigation and population density

Relative water content was insignificantly affected by the interaction between irrigation and population density (Table 2). The maximum relative water content (89.95%) was found from I_1D_{+20} and the minimum (88.46%) from $I_0D_{-20.}$

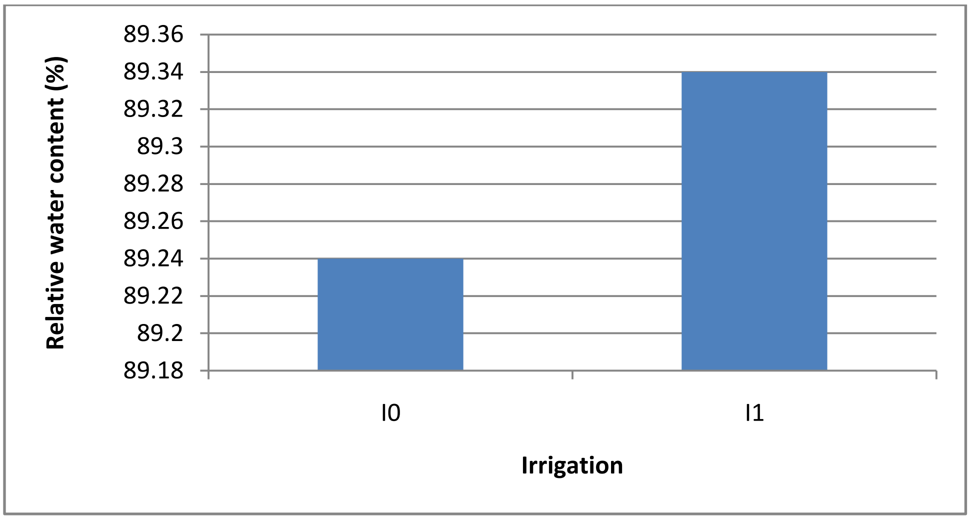

Fig. 7 Effect of irrigation on relative water content (LSD $_{(0.05.)}$=3.59)

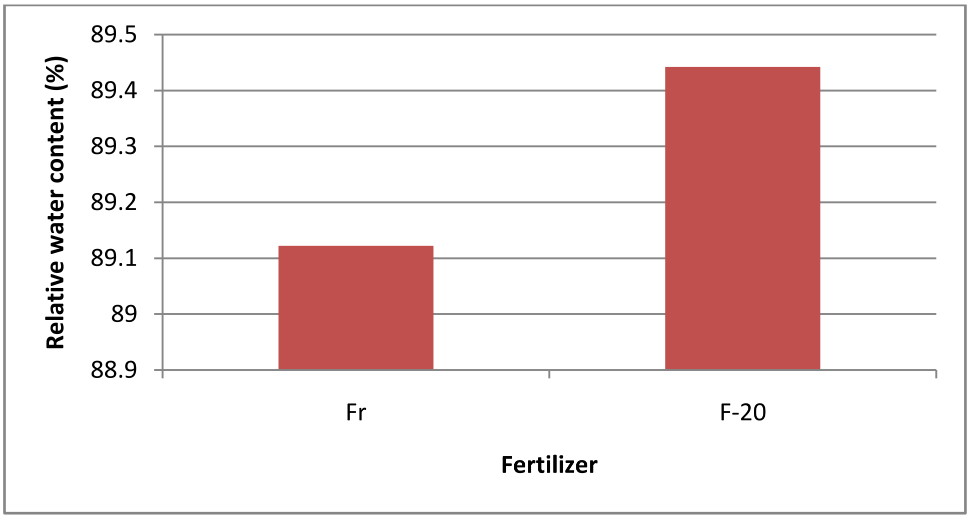

Fig. 8 Effect of fertilizer on relative water content (LSD $_{(0.05.)}$=1.80)

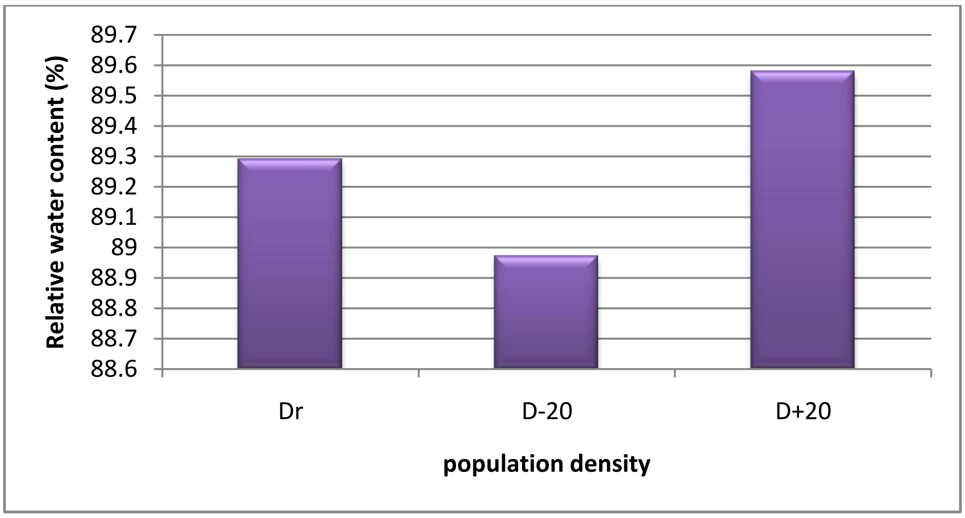

Fig. 9 Effect of population density relative water con tent (LSD $_{(0.05.)}$=1.96)

4.1.1.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on relative water content show insignificant variation among treatment combination. The maximum relative water content (89.94%) was produced from $F_{-20}D_{+20}$ treatments and the minimum relative water content (88.73%) was produced from F_{-20}Dr treatment.

4.1.1.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 2), it was found that although saturated water deficit was significant. The maximum saturated water deficit (90.97%) obtained from $I_1F_{-20}D_{+20}$ treatments and the minimum saturated water deficit (87.81%) plant was observed from I_0FrDr.

4.4 Exudation rate

4.4.1 Effect of Irrigation

Exudation rate was evident from (Fig. 10) that the exudation rate deficit was influenced by irrigation. The maximum exudation rate (0.057 g/hr) was observed from I_1 treatment and the minimum exudation rate (0.034 g/hr) was observed from I_0 treatment.

4.4.2 Effect of fertilizer

There was effect on exudation rate due to the application of fertilizer (Fig. 11). The maximum exudation rate (0.052 g/hr) was found from F_{-20} treatment. On the other hand the minimum exudation rate (0.039 g/hr) was observed from Fr treatment.

4.4.3 Effect of population density

Population density had insignificant effect on exudation rate (Fig. 12). The maximum exudation rate (0.058 g/hr) was obtained from D_{-20}. Treatment and the minimum exudation rate (0.034 g/hr) was obtained from D_{+20}.

4.4.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on exudation rate was found insignificant (Table 2). The maximum exudation rate (0.063 g/hr) found from the I_1Fr treatment and the minimum exudation rate (0.027 g/hr) was found from I_0F_{-20}.

4.4.5 Interaction effect of irrigation and population density

Exudation rate was insignificantly affected by the interaction between irrigation and population density (Table 2). The maximum exudation rate (0.066 g/hr) was found from I_1D_{+20} and the minimum (0.022 g/hr) from I_0D_{-20}.

4.4.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on exudation rate show insignificant variation among treatment combination. The maximum exudation rate (0.065 g/hr) was produced from FrDr treatment and the minimum exudation rate (0.035 g/hr) was produced from $F_{-20}D_{-20}$ treatment.

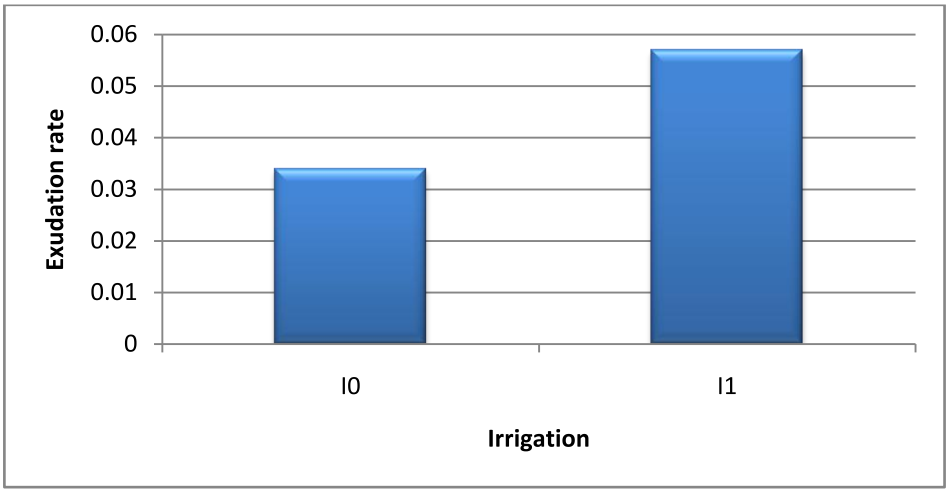

Fig. 10 Effect of irrigation on exudation rate (LSD $_{(0.05.)}$=0.064)

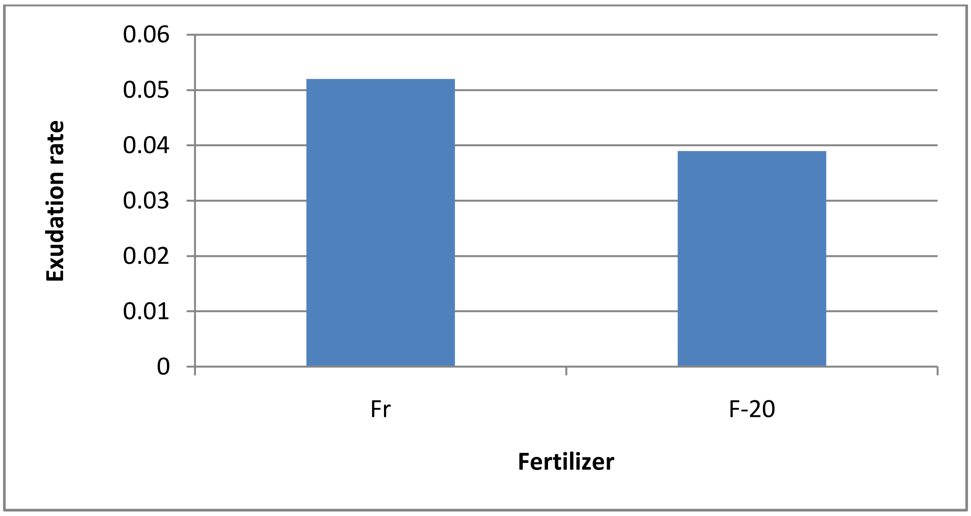

Fig. 11 Effect of fertilizer on exudation rate (LSD $_{(0.05.)}$=0..29)

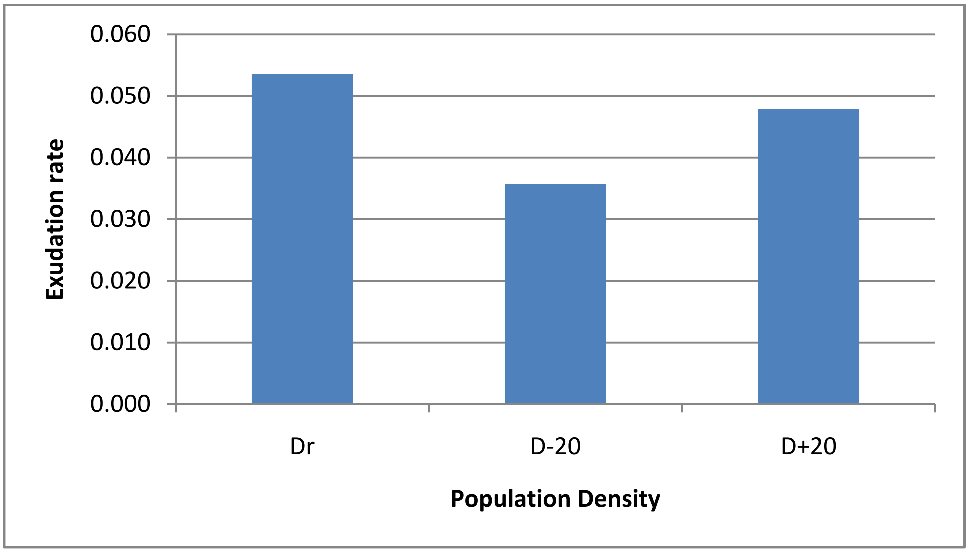

Fig. 12 Effect of population density on exudation rate (LSD $_{(0.05.)}$=0.029)

4.4.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 2), it was found that although exudation rate was significant. The maximum exudation rate (0.077 g/hr) obtained from I_1FrD_{+20} treatments and the minimum exudation rate (0.020 g/hr) plant was observed from I_0FrD_{-20}.

4.5 Plant height

4.5.1 Irrigation

Plant height of the soybean was measured at maturity. It was evident from (Fig. 13) that the height of the plant was influenced by irrigation. At harvest I_1 produced the taller plant (36.78 cm) and I_0 produced shorter (32.052 cm). Kazi *et al.* (2002) conducted an experiment to study the impact of irrigation frequencies and observed that the growth and yield components were significantly affected by irrigation frequencies. Maximum plant height and more branches plant^{-1} were found with the application of 6 irrigations followed by 5 irrigations, whereas, lowest number of irrigation decreased the traits adversely.

4.5.2 Effect of fertilizer

There was effect on plant height due to the application of fertilizer (Fig 14). The tallest plant (34.65cm) was found from F_{-20} treatment. On the other hand shortest plant (34.18 cm) was observed from Fr treatment.

4.5.3 Effect of population density

Population density had no significant effect on plant height (Fig. 15). At harvest, numerically the tallest plant (34.68 cm) was obtained from D_{-20} treatment and the shortest plant (34.24 cm) was obtained from D_{+20}.

4.5.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on plant height was found significant at harvest (Table 4). The tallest plant (36.81 cm) found from the I_1F_{-20} treatment which was statistically similar with the I_0F_{-20} and shortest plant (31.61 cm) was found from the I_0Fr.

4.5.5 Interaction effect of irrigation and population density

Plant height was significantly affected by the interaction between irrigation and population density (Table 4). The tallest plant (37.33 cm) was found from I_1Dr and shortest plant (31.33 cm) from I_0D_{-20}.

4.5.6 Interaction effect of fertilizer and population density

Interaction effect of fertilizer and population density on plant height was found significant at harvest (Table 4). The tallest plant (35.08 cm) found from the $F_{-20}Dr$ treatment which was statistically similar with the FrD_{-20} and shortest plant (33.58 cm) was found from the $F_{-20}D_{-20}$.

4.5.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 4), it was found that although plant height was significant at harvest. The tallest plant height (38.53 cm) obtained from $I_1F_{-20}D_{+20}$ treatment and the Shortest (30.79 cm) plant was observed from $I_0F_{-20}D_{+20}$.

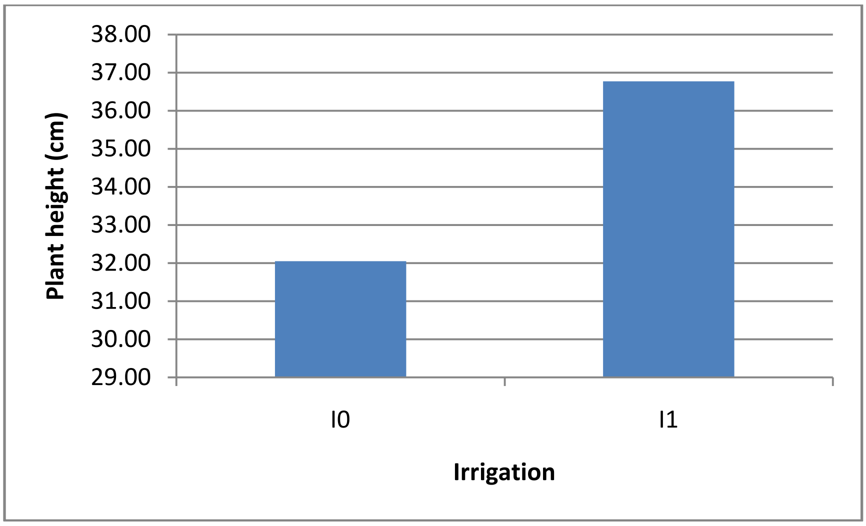

Fig. 13 Effect of irrigation on plant height of soybean (LSD $_{(0.05.)}$=5.82)

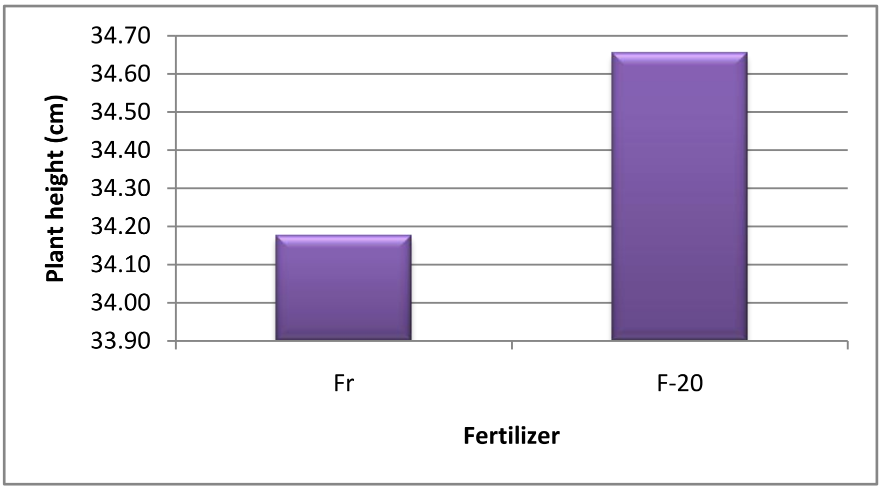

Fig. 14 Effect of fertilizer on plant height of soybean (LSD $_{(0.05.)}$=2.05)

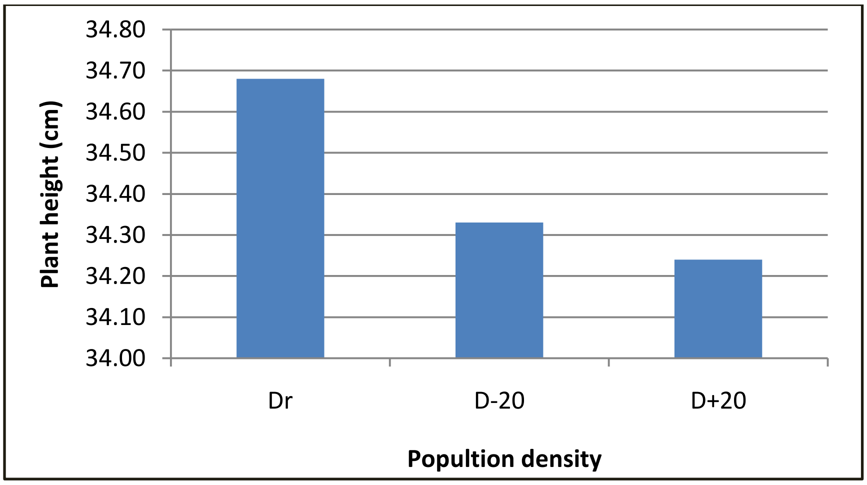

Fig. 15 Effect of population density on plant height of soybean (LSD $_{(0.05.)}$=2.31)

4. 6 Leaf Area

4.6.1 Effect of irrigation

Leaf area or the surface area of green leaves produced by soybean plants per unit area of land was taken as an index of leaf area development. The leaf area of plant is one of the major determinants of its growth. The leaf area (LA) was affected by irrigation (Table 3). The maximum LA (124.42 cm^2) was found in I_1 treatment. The lowest LA (118.27 cm^2) was found in I_0 treatment. This result agrees well with Hao *et al.* (2003) who reported that the leaf area index significantly increased with irrigation application.

4.6.2 Effect of fertilizer

Fertilizer had remarkable influence on leaf area (Table 3). The maximum leaf area (125.00 cm^2) was obtained from F_{-20} treatment. Minimum leaf area (117.69 cm^2) was counted Fr.

4.6.3 Effect of population density

Population density had significant effect on LA (Table 3). Numerically the maximum LA (125.40 cm^2) was obtained from Dr Treatment and the lowest LA (115.20 cm^2) was obtained from D_{+20}.

Table 3.Effect of irrigation, fertilizer, population density on plant height, leaf area, dry wt./plant, No. of pod/plant, pod length, No. of seed / pod of soybean.

Treatments	Plant height (cm)	Leaf area/plant (cm^2)	Dry wt./plant (g)	No. of pod/plant	Pod length (cm)
I_0	32.05	118.27	5.41	6.43	2.69
I_1	36.78	124.42	6.09	9.61	2.87
LSD(0.05)	**5.82**	**16.63**	**3.12**	**0.63**	**0.48**
CV%	**11.83**	**9.56**	**38.50**	**5.45**	**12.14**
Fr	34.18	117.70	4.93	7.91	2.74
F_{-20}	34.65	125.00	6.57	8.13	2.83
LSD(0.05)	**2.05**	**26.39**	**1.63**	**1.03**	**0.23**
CV%	**6.47**	**23.51**	**31.12**	**13.77**	**9.06**
Dr	34.33	125.40	6.38	7.56	2.79
D_{-20}	34.68	123.40	5.32	8.00	2.69
D_{+20}	34.24	115.20	5.56	8.50	2.88
$LSD_{(0.05)}$	**2.313**	**20.55**	**1.43**	**1.505**	**0.087**
CV%	**7.79**	**19.57**	**29.35**	**21.47**	**8.92**

Table 4. Interaction effect of irrigation × fertilizer, irrigation × population density, fertilizer × population density and irrigation × fertilizer × population density on leaf area, table dry wt/plant, No. of pod/plant, pod length, No. of seed / pod of soybean

Treatments	**Plant height (cm)**	**Leaf area (cm^2)**	**Dry wt./plant (g)**	**No. of pod/plant**	**Pod length (cm)**
I_0Fr	31.61	109.00	4.85	5.85	2.65
I_0F_{-20}	32.49	126.40	5.97	7.00	2.74
I_1Fr	36.74	122.40	5.01	9.26	2.83
I_1F_{-20}	36.81	127.60	7.18	9.96	2.92
LSD $_{(0.05)}$	**2.90**	**37.34**	**2.298**	**1.46**	**0.33**
CV%	**6.47**	**23.51**	**31.12**	**13.77**	**9.06**
I_0 Dr	32.51	125.30	6.28	5.67	2.59
I_0 D_{-20}	31.33	115.70	5.55	6.28	2.77
I_0 D_{+20}	32.32	113.90	4.84	7.33	2.73
I_1 Dr	37.33	137.00	6.45	9.67	2.81
I_1 D_{-20}	36.84	121.50	5.09	8.83	2.78
I_1 D_{+20}	36.16	114.80	6.30	10.33	3.03
LSD$_{(0.05)}$	**3.27**	**29.07**	**2.08**	**2.13**	**0.30**
CV%	**7.79**	**19.57**	**29.35**	**21.47**	**8.92**
Fr Dr	34.38	124.60	5.36	8.22	2.67
Fr D_{-20}	35.08	122.50	4.83	7.94	2.71
Fr D_{+20}	34.50	105.90	4.59	7.17	2.84
F_{-20} Dr	35.08	126.20	7.39	8.33	2.72
$F\text{-}_{20}$ D_{-20}	33.58	124.20	6.05	7.78	2.86
$F\text{-}_{20}$ D_{+20}	33.97	124.50	6.29	8.67	2.92
LSD ($_{0.05)}$	**3.27**	**29.07**	**2.08**	**2.13**	**0.30**
CV%	**7.79**	**19.57**	**29.35**	**21.47**	**8.92**

Table 4 (contd.)

Treatments	Plant height (cm)	Leaf area/plant (cm^2)	Dry wt./plant (g)	No. of pod/plant	Pod length (cm)
I_0FrDr	32.00	125.60	4.56	5.33	2.57
I_0FrD_{-20}	31.63	122.10	6.08	7.11	2.61
I_0FrD_{+20}	33.84	96.39	4.40	8.56	2.72
$I_0F_{-20}Dr$	33.02	102.10	7.95	6.00	2.66
$I_0F_{-20}D_{-20}$	31.02	128.40	6.69	5.45	2.88
$I_0F_{-20}D_{+20}$	30.79	134.90	6.83	6.11	2.73
I_1FrDr	36.76	126.80	5.11	10.22	2.84
I_1FrD_{-20}	37.16	115.50	4.78	10.44	2.94
I_1FrD_{+20}	35.16	114.10	4.65	8.78	2.80
$I_1F_{-20}Dr$	36.92	147.10	4.58	8.78	2.78
$I_1F_{-20}D_{-20}$	36.13	116.70	5.40	8.89	2.76
$I_1F_{-20}D_{+20}$	38.53	126.30	8.00	10.55	3.11
$LSD_{(0.05)}$	**4.63**	**41.11**	**2.87**	**3.01**	**0.43**
CV%	**7.79**	**19.57**	**29.35**	**21.47**	**8.92**

4.6.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on LA was found significant at harvest (Table 4). The maximum LA (127.6 cm^2) found from the I_1F_{-20} treatment which was statistically similar with the I_0F-20 and shortest plant (109.00 cm^2) was found from the I_0Fr.

4.6.5 Interaction effect of irrigation and population density

Lead area was significantly affected by the interaction between irrigation and population density (Table 4). The maximum LA (137.00 cm^2) was found from I_1Dr and lowest LA (113.90 cm^2) from I_0D_{+20} which was statistically similar to $I_1D_{+20,}$ I_0D_{-20}.

4.6.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on LA show significant variation among treatment combination. The highest LA (126.20 cm^2) was produced from F_{-20}Dr treatment and the lowest LA (105.90 cm^2) was produced from FrD_{+20} treatment.

4.6.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 4), it was found that although LA was significant. The highest LA (147.1 cm^2) obtained from I_1F_{-20}Dr treatment and the lowest (96.39 cm^2) plant was observed from I_0FrD_{+20}.

4.7 Total dry matter production

4.7.1 Effect of irrigation

Dry matter is the material which was dried to a constant weight. Total dry matter (TDM) production indicates the production potential of a crop. A high TDM production is the first perquisite for high yield. TDM of roots, leaves, stem and or pods of used varieties data were measured at harvest. (Table 3) shows that at I_1 were produced higher amount of dry matter of (6.09g) and lower amount of dry matter production at harvest (5.41) in I_0 treatment. Hao *et al* (2003) conducted experiments to find out effects of irrigation and found that dry matter accumulation significantly increased with irrigation application.

4.7.2 Effect of fertilizer

Dry matter production was influenced by fertilizer application (Table 3). The maximum TDM was (6.57 g) plant^{-1} recorded form F_{-20} at maturity. On the other hand lower amount of TDM (4.93g) was produced by Fr treatment.

4.7.3 Effect of population density

The TDM production was unaffected at harvest by the population density of Soybean (Table 3). Maximum (6.38g) TDM was found from the Dr treatment at harvest. The minimum TDM (5.32g) was observed from D_{-20} treatment.

4.7.4 Interaction effect of irrigation and fertilizer

Total dry matter production was insignificantly affected due to the interaction of irrigation and fertilizer at harvest (Table 4). The maximum (7.18 g) TDM was found from the combination of I_1F_{-20} and the minimum (4.85 g) was found from I_0Fr.

4.7.5 Interaction effect of irrigation and population density

The (Table 4) revealed that interaction of irrigation and population density on TDM production insignificantly affected at harvest. At harvest numerically maximum (6.45 g) TDM was found from I_1Dr and minimum (4.84 g) was observed from I_0D_{+20}.

4.7.6 Interaction effect of fertilizer and population density

It was observed from the (Table 4) that interaction effect of fertilizer and population density forms showed significant in TDM production at harvest. At harvest maximum (7.39 g) TDM was found from $F_{-20}Dr$ treatment and minimum (4.59 g) from the FrD_{+20}treatment.

4.7.7 Interaction effect of irrigation, fertilizer and population density

From the (Table 4) it was observed that the interaction of irrigation, fertilizer and population density on TDM production had significant effect at harvest. The numerically maximum (8.00 g) TDM found from the combination of $I_1F_{-20}D_{-20}$ and minimum (4.40 g) from the combination of I_0FrD_{+20}.

4.8 Number of pod per plant

4.8.1 Irrigation

Number of pod per plant was influenced by irrigation. The maximum number of pod per plant (9.61) was found from I_1 treatment and the minimum number of pod per plant (6.43) was produced from I_0 treatment. Kazi *et al.*(2002) conducted an experiment to study the impact of irrigation frequencies and found that the Maximum pods plant $^{-1}$was found with the application of 6 irrigations followed by 5 irrigations , whereas, lowest number of irrigation decreased all the trait adversely.

4.8.2 Effect of fertilizer

There was effect on number of pod per plant due to the application of fertilizer (Table 3). The maximum number of pod per plant (8.13) was found from F_{-20} treatment. On the other hand shortest plant (7.91) was observed from Fr treatment.

4.8.3 Effect of population density

Population density had no significant effect on number of pod per plant (Table 3). The maximum number of pod per plant (8.50) was obtained from D_{+20} treatment and the minimum number of pod per plant (7.56) was obtained from Dr.

4.8.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on number of pod per plant was found insignificant (Table 4). The maximum number of pod per plant (9.96) found from the I_1F_{-20} treatment and the minimum number of pod per plant (5.85) was found from the I_0Fr.

4.8.5 Interaction effect of irrigation and population density

Number of pod per plant was significantly affected by the interaction between irrigation and population density (Table 4). The maximum number of pod per plant

(10.33) was found from I_1Dr and the minimum number of pod per plant (5.67) from I_0Dr.

4.8.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on plant number of pod per plant show significant variation among treatment combination. The maximum number of pod per plant (8.67) was produced from $F_{-20}D_{+20}$ treatments and the minimum number of pod per plant (7.17) was produced from $F_{-20}D_{-20}$ treatment.

4.8.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 4), it was found that although number of pod per plant was significant. The maximum number of pod per plant (10.55) obtained from $I_1F_{-20}D_{+20}$ treatments and the minimum number of pod per plant (5.33) plant was observed from I_0FrDr.

4.9 Pod length

4.9.1 Effect of irrigation

The pod length varied due to irrigation shown in (Table 3). It was observed that I_1 treatment produced longer (2.87 cm) pod and the I_0 treatment was produced shorter (2.69 cm) pod.

4.9.2 Effect of fertilizer

The longest (2.83cm) and shortest (2.74 cm) pod length was observed in F_{-20} and Fr, respectively though the value did not differ significantly (Table 3).

4.9.3 Effect of population density

Pod length was statistically unaffected by population density (Table 3). Longest (2.88 cm) pod was produced due to D_{+20} treatment and shortest pod length (2.69 cm) was produced in D_{-20} treatment.

4.9.4 Interaction effect of irrigation and fertilizer

Pod length was significantly affected by the interaction of irrigation and fertilizer (Table 4). Longest (2.92 cm) pod length was observed from the combination I_1F_{-20} treatment and lowest (2.65 cm) was found from the combination I_0Fr treatment.

4.9.5 Interaction effect of irrigation and population density

Pod length was statistically influenced by the interaction of irrigation and population density (Table 4). The longest pod (3.03 cm) was found from I_1D_{+20} treatments. The shortest pod (2.59 cm) was observed from I_0Dr treatment.

4.9.6 Interaction effect of fertilizer and population density

Interaction of fertilizer and the fertilizer exerted statistically non significant influence on pod length (Table 4). However, in the present experiment numerically the longest pod (2.92 cm) was obtained in the treatment combination of $F_{-20}D_{+20}$ treatments and the shortest pod length (2.67 cm) was found in FrDr treatment.

4.9.7 Interaction effect of irrigation, fertilizer and population density

From the (Table 4) it was observed that interaction effect of irrigation, fertilizer and population density had significant effect on pod length. Highest (3.11 cm) pod length was observed from the combination $I_1F_{-20}D_{+20}$ treatments and the lowest

(2.57 cm) from I_0FrDr. It might be due to inherent characters of the variety that might not be much changed by cultural treatment although there were numerical variations.

4.10 Number of seed per pod

4.10.1 Irrigation

Number of seed per pod was influenced by irrigation. The maximum number of seed per pod (2.05) was found from I_1 treatment and the minimum number of seed per pod (1.74) was produced from I_0 treatment.

4.10.2 Effect of fertilizer

There was effect on number of seed per pod due to the application of fertilizer (Table 5). The maximum number of seed per pod (1.93) was found from F_{-20} treatment. On the other hand minimum number of seed per pod (1.87) was observed from Fr treatment.

4.10.3 Effect of population density

Population density had no significant effect on number of seed per pod (Table 5). The maximum number of seed per pod (1.98) was obtained from D_{+20} treatment and the minimum number of pod per plant (1.75) was obtained from D_{-20}.

4.10.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on number of seed per pod was found insignificant (Table 6). The maximum number of seed per pod (2.07) found from the I_1F_{-20} treatment and the minimum number of seed per pod (1.70) was found from the I_0Fr.

4.10.5 Interaction effect of irrigation and population density

Number of seed per pod was significantly affected by the interaction between irrigation and population density (Table 6). The maximum number of seed per pod (2.17) was found from I_1D_{+20} and the minimum number of seed per pod (1.61) from I_0Dr.

4.10.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on number of seed per pod show significant variation among treatment combination. The maximum number of seed per pod (2.06) was produced from $F_{-20}D_{+20}$ treatment and the minimum number of seed per pod (1.72) was produced from FrDr treatment.

4.10.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 6), it was found that although number of seed per pod was significant. The maximum number of seed per pod (2.29) obtained from $I_1F_{-20}D_{+20}$ treatment and the minimum number of pod per plant (1.44) plant was observed from IoFrDr.

4.11 Weight of seeds per plant

4.11.1 Effect of Irrigation

Weight of seed per plant was influenced by irrigation. The maximum weight of seed per plant (1.38 g) was found from I_1 treatment and the minimum number of seed per pod (0.94 g) was produced from I_0 treatment.

4.11.2 Effect of fertilizer

There was effect on weight of seed per plant due to the application of fertilizer (Table 5). The maximum weight of seed per plant (1.24 g) was found from F_{-20}

treatment. On the other hand the minimum weight of seed per plant (1.08 g) was observed from Fr treatment.

4.11.3 Effect of population density

Population density had no significant effect on weight of seed per plant (Table 5). The maximum weight of seed per plant (1.23 g) was obtained from D_{+20} treatment and the minimum weight of seed per plant (1.04g) was obtained from D_{-20}.

4.11.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on weight of seed per plant was found significant (Table 6). The maximum weight of seed per plant (1.47 g) found from the I_1F_{-20}treatment and the minimum weight of seed per plant (0.85 g) was found from the I_0Fr.

4.11.5 Interaction effect of irrigation and population density

Weight of seed per plant was insignificantly affected by the interaction between irrigation and population density (Table 6). The maximum weight of seed per plant (1.42 g) was found from I_1D_{+20} and the minimum weight of seed per plant (0.72 g) was observed from I_0D_{-20}.

4.11.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on weight of seed per plant show insignificant variation among treatment combination. The maximum weight of seed per plant (1.29 g) was produced from $F_{-20}D_{+20}$ treatment and the minimum weight of seed per plant (1.01 g) was produced from FrDr treatment.

Table 5. Effect of irrigation, fertilizer, population density on no. of seed /pod, seed wt./plant, thousand seed wt., seed weight/ha harvest index of soybean

Treatment	Seed / Pod(no.)	Seed wt./Plant (gm)	Thousand seed wt. (j)	Seed weight t/ha	Harvest index (%)
I_0	1.74	0.94	94.33	0.66	27.76
I_1	2.05	1.38	104.59	0.97	34.15
LSD	**0.48**	**0.559**	**1.38**	**0.304**	**14.07**
CV%	**17.96**	**30.75**	**11.96**	**26.06**	**32.65**
Fr	1.87	1.08	99.45	0.81	28.54
F_{-20}	1.93	1.24	99.47	0.82	33.37
LSD	**0.21**	**0.32**	**13.7**	**0.12**	**7.70**
CV%	**11.77**	**27.09**	**14.76**	**16.02**	**27.77**
Dr	1.97	1.21	99.53	0.80	33.35
D_{-20}	1.75	1.04	98.72	0.79	22.92
D_{+20}	1.98	1.23	100.10	0.85	36.60
$LSD_{(0.05)}$	**0.23**	**0.27**	**11.64**	**0.171**	**7.89**
CV%	**13.87**	**24.94**	**13.41**	**24.26**	**30.06**

Table 6. Interaction effect of irrigation × fertilizer, irrigation × population density, fertilizer × population density and irrigation × fertilizer × population density on no. of seed /pod, seed wt./plant, thousand seed wt., seed weight/ha harvest index of soybean

Treatment	No. of seed / pod	Seed wt./plant (gm)	Thousand seed wt. (g)	Seed weight t/ha (t)	Harvest index (%)
I_0Fr	1.70	0.85	94.24	0.67	30.58
I_0F_{-20}	1.78	1.02	94.42	0.64	24.94
I_1Fr	2.04	1.30	104.50	0.96	36.17
I_1F_{-20}	2.07	1.47	104.70	0.98	32.13
$LSD_{(0.05)}$	**0.29**	**0.45**	**19.38**	**0.17**	**10.89**
CV%	**11.77**	**27.09**	**14.76**	**16.02**	**27.77**
I_0 Dr	1.61	1.05	94.29	0.54	3.92
I_0 D_{-20}	1.83	0.72	93.52	0.72	18.68
I_0 D_{+20}	1.78	1.04	95.17	0.70	30.17
I_1 Dr	2.11	1.37	104.80	0.98	36.52
I_1 D_{-20}	1.89	1.36	103.90	0.90	27.16
I_1 D_{+20}	2.17	1.42	105.10	1.04	38.78
LSD $_{(0.05)}$	**0.32**	**0.39**	**16.46**	**0.24**	**11.16**
CV%	**13.87**	**24.94**	**13.41**	**24.26**	**30.06**
Fr Dr	1.72	1.01	102.70	0.77	21.30
Fr D_{-20}	1.94	1.03	89.96	0.83	30.89
Fr D_{+20}	2.00	1.17	105.70	0.85	35.80
F_{-20} Dr	1.89	1.41	96.36	0.78	30.18
$F_{-20}D_{-20}$	1.78	1.05	91.74	0.81	24.53
$F_{-20}D_{+20}$	2.06	1.29	110.30	0.86	43.01
LSD $_{(0.05)}$	**0.32**	**0.39**	**16.46**	**0.24**	**11.16**
CV%	**13.87**	**24.94**	**13.41**	**24.26**	**30.06**

Here,

Non Significant data did not lettering

Table 6 (contd.)

Treatment	No. of seed / pod	Seed wt./plant (gm)	Thousand seed wt. (g)	Seed weight/ha (t)	Harvest index (%)
I_0FrDr	1.44	1.19	97.29	0.50	39.22
I_0FrD_{-20}	2.00	0.66	85.85	0.73	17.46
I_0FrD_{+20}	1.89	1.22	100.10	0.77	35.06
$I_0F_{-20}Dr$	1.67	0.92	91.29	0.71	29.61
$I_0F_{-20}D_{-20}$	1.78	0.78	86.91	0.58	19.90
$I_0F_{-20}D_{+20}$	1.67	0.86	104.50	0.64	25.29
I_1FrDr	2.11	1.41	108.10	0.96	25.15
I_1FrD_{-20}	2.22	1.48	116.10	0.91	36.48
I_1FrD_{+20}	2.11	1.36	94.08	0.89	36.55
$I_1F_{-20}Dr$	2.11	1.10	101.40	1.00	30.75
$I_1F_{-20}D_{-20}$	2.00	1.32	96.57	1.03	29.17
$I_1F_{-20}D_{+20}$	2.29	1.63	116.15	1.04	46.80
LSD $_{(0.05)}$	**0.45**	**0.55**	**23.27**	**0.34**	**15.79**
CV	**13.87**	**24.94**	**13.41**	**24.26**	**30.06**

4.11.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 6), it was found that although weight of seed per plant was significant. The maximum weight of seed per plant (1.63g) obtained from $I_1F_{-20}D_{+20}$ treatment and the minimum weight of seed per plant (0.66 g) plant was observed from I_0FrD_{-20}.

4.12 1000 seed weight

4.12.1 Effect of Irrigation

1000 seed weight was influenced by irrigation. The maximum 1000 seed weight (104.59 g) was found from I_1 treatment and the minimum 1000 seed weight (94.33 g) was produced from I_0 treatment.

4.12.2 Effect of fertilizer

There was effect on 1000 seed weight due to the application of fertilizer (table 5). The maximum 1000 seed weight (99.47 g) was found from F_{-20} treatment. On the other hand the minimum 1000 seed weight (99.45 g) was observed from Fr treatment.

4.12.3 Effect of population density

Population density had no significant effect on 1000 seed weight (Table 5). The maximum 1000 seed weight (100.10 g) was obtained from D_{+20} treatment and the minimum 1000 seed weight (98.72g) was obtained from D_{-20}.

4.12.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on 1000 seed weight was found significant (Table 6). The maximum 1000 seed weight (104.72 g) found from the I_1F_{-20} treatment and the minimum 1000 seed weight (94.24 g) was found from the I_0Fr.

4.12.5 Interaction effect of irrigation and population density

1000 seed weight was significantly affected by the interaction between irrigation and population density (Table 6). The maximum 1000 seed weight (105.10 g) was found from I_1D_{+20} and the minimum 1000 seed weight (93.52 g) was observed from I_0D_{-20}.

4.12.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on 1000 seed weight show insignificant variation among treatment combination. The maximum 1000 seed weight (110.30g) was produced from $F_{-20}D_{+20}$ treatment and the minimum 1000 seed weight (89.96g) was produced from FrD_{-20} treatment.

4.12.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 6), it was found that although 1000 seed weight was significant. The maximum 1000 seed weight (116.15g) obtained from $I_1F_{-20}D_{+20}$ treatment and the minimum 1000 seed weight (85.85 g) plant was observed from I_0FrD_{-20}.

4.13 Seed yield (t/ha)

4.13.1 Effect of Irrigation

Grain yield was influenced by irrigation. The maximum yield of soybean (0.97 t/ha) was found from I_1 treatment and the minimum yield of soybean (0.66 t/ha) was produced from I_0 treatment. Kazi *et al.*(2002) also reported that the maximum seed yield were found superior with the application of 6 irrigations followed by 5 irrigations , whereas, lowest number of irrigation decreased all the traits adversely. Constable and Heam (1980) reported that irrigations during late flowering and pod filling in soybean was necessary to ensure maximum seed yield (up to 305 t ha^{-1}).

4.13.2 Effect of fertilizer

There was effect on yield of soybean due to the application of fertilizer (Table 5). The maximum yield of soybean (0.82 t/ha) was found from F_{-20} treatment. On the other hand the minimum yield of soybean (0.81 t/ha) was observed from Fr treatment. Rani and Kodandardmaiah (1997) stated that seed yield of soybean was increased by 1.89 t ha^{-1} with application of 90 kg ha^{-1} compared to 1.50 t ha^{-1} without applied N . Singh *et al.* (1992) in a field trial of soybean with 0-50 kg N ha^{-1} obtained the highest seed yield from 30 kg N ha^{-1}, although there were not significant differences between the treatments. Alpha *et al* .(2007)) conducted an experiment and reported that proper P improved the shoot phosphorus uptake and increased shoot dry matter weight, 100 seeds weight , pods per plant and yield. Tomar and Singh (2004) conducted an experiment in Modhya Pradesh ,India during Kharif season and observed that stover yield increased with the increase of phosphorus application for 3 genotypes of soybean.

4.13.3 Effect of population density

Population density had significant effect on yield of soybean (Table 5). The maximum yield of soybean (0.85 t/ha) was obtained from D_{+20} treatment and the minimum yield of soybean (0.79 t/ha) was obtained from D_{-20}. Bowers *et al.* (2000) reported that the environmental condition along with population density affected soybean yields. They showed that yield was most responsive to spacing when the total July August rainfall ranged from 100 -270 mm which varied plant population. Saitoh *et al.*(1998) reported that dense planting has been reported to increase the node number, pod number and therefore seed yield without the consideration of lodging .

4.13.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on yield of soybean was found significant (Table 6). The maximum yield of soybean (0.98 t/ha) found from the I_1F_{-20} treatment and the minimum yield of soybean (0.64 t/ha) was found from the I_0F_{-20}. Hao *et al.* (2003) found that the effects of irrigation varied among the levels of fertilizer application and vice versa. Pods plant^{-1}, seeds pods^{-1}, and 100- seed weight had positive correlations with soybean yield. Leaf area index and dry matter accumulation significantly increased when irrigated and supplied with fertilizer. Irrigation increased the absolute absorption of N, P, and K in seeds, although differences in the accumulation rates were observed.

4.13.5 Interaction effect of irrigation and population density

Yield of soybean was significantly affected by the interaction between irrigation and population density (Table 6). The maximum yield of soybean (1.04 t/ha) was found from I_1D_{+20} and the minimum yield of soybean (0.54 t/ha) was observed from I_0Dr. Boydak *et al.* (2004) observed that the seed yield of soybean was affected by the interaction of irrigation and density. They observed that the seed yield plant^{-1} was reduced with decreasing row spacing but led to an increase in yield per hectare yields which were the highest (3752.6 kg ha^{-1}) at 50-30 cm row spacing and 6 days irrigation intervals (3744.1 kg ha^{-1}) but were the lowest (3096.6 kg ha^{-1}) at the 70 cm row spacing and 12 day irrigation intervals (2752.4 kg ha^{-1}) .

4.13.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on yield of soybean show insignificant variation among treatment combination. The maximum yield of soybean (0.86 t/ha) was produced from $F_{-20}D_{+20}$ treatment and the minimum yield of soybean (0.77 t/ha) was produced from FrDr treatment.

4.3.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 6), it was found that although yield of soybean was significant. The maximum yield of soybean (1.04 t/ha) obtained from $I_1F_{-20}D_{+20}$ treatment and the minimum yield of soybean (0.50 t/ha) plant was observed from I_0FrDr.

4.14 Harvest Index

4.14.1 Effect of irrigation

It was found from (Table 5) that irrigation had effect on harvest index. From the results it is evident that I_1 treatment produced the higher (34.15%) harvest index than I_0 (27.76%). Low HI in I_0 was caused by poor grain yield.

4.14.2 Effect of fertilizer

Fertilizer variation had significant effect on harvest index (Table 5). However, F_{-20} produced the maximum (33.37%) harvest index. On the other hand, the minimum (28.54%) harvest index was obtained from Fr Treatment.

4.14.3 Effect of population density

Population density had exerted significant variation on harvest index (Table 5) and it was 36.6 % in D_{+20} treatment and 22.92% in D_{-20} treatment.

4.14.4 Interaction effect of irrigation and fertilizer

Interaction effect of irrigation and fertilizer on harvest index was found significant (Table 6). The maximum harvest index (36.17%) found from the I_1Fr treatment and the minimum harvest index (24.94%) was found from the I_0F_{-20}.

4.14.5 Interaction effect of irrigation and population density

Harvest index was significantly affected by the interaction between irrigation and population density (Table 6). The maximum harvest index (38.78 %) was found from I_1D_{+20} and the minimum harvest index (18.68%) was observed from I_0D_{-20}.

4.14.6 Interaction effect of fertilizer and population density

It was revealed that interaction of fertilizer and population density on harvest index show significant variation among treatment combination. The maximum harvest index (43.01%) was produced from $F_{-20}D_{+20}$ treatment and the minimum harvest index (21.3%) was produced from FrDr treatment.

4.14.7 Interaction effect of irrigation, fertilizer and population density

From the interaction data of irrigation, fertilizer and population density (Table 6), it was found that although harvest index was significant. The maximum harvest index (46.80%) obtained from $I_1F_{-20}D_{+20}$ treatments and the minimum harvest index (17.46%) plant was observed from I_0FrD_{-20}.

Chapter 5

Summary and conclusion

Chapter V

SUMMARY AND CONCLUSION

An experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka- 1207 during the period from December, 2011 to April 2012 to study the responses of different levels of irrigation, fertilizer dose and plant density on the growth and yield of soybean. The objectives of the study were to determine the effect of irrigation level for achieving higher yield in soybean, to determine the appropriate fertilizer dose to achieve maximum yield of soybean, to determine the proper plant density for achieving maximum yield of soybean, to evaluate the interaction effect of fertilize dose and irrigation on yield of soybean and to find out the interaction effect of fertilizer dose , irrigation and plant density on yield of soybean.

The research work was carried out at the Field of She-e-Bangla Agricultural University, Dhaka during the rabi season from December 2011 to April 2012. The climate of the experimental site was characterized by moderate temperature high humidity and moderate rainfall. The variety of soybean used in this experiment was BARI soybean-5.

The experiment was laid out following three factor split plot design with 3 replications. Three sets of treatment (Factors) were included in the experiment which were; I=Irrigation, F=fertilizer, D=Density. The Factor A was Irrigation set in the Main Plot (I_0=No irrigation, I_1=irrigated). Factor B was Fertilizer doses set in the Sub-Plot (Fr = Recommended dose (Urea, TSP and MP @ 60, 175 and 120 kg ha^{-1}, respectively), F_{-20}= Minus Twenty kg of Urea, TSP and MP from recommended dose). Factor C was Population Density set in the sub-sub-plots (Dr=Recommended Population Density (44 plants/m^2), D_{-20} =20% less population than the recommended, D $_{+20}$=20% more population than the recommended). Sowing was done on November 21, 2011.

Data were taken on different parameters. Results showed that the maximum soil moisture (46.52% was observed from I_1 (30 DAS at flowering) treatment and the minimum soil moisture (33.86%) was observed from I_0 (no irrigation) treatment. The maximum soil moisture (41.08%) was found from F_{-20} (20% less than recommended dose of fertilizer) treatment. On the other hand the minimum soil moisture (39.30%) was observed from Fr (recommended dose of fertilizer) treatment. The maximum soil moisture (41.98%) was obtained from D_{-20} (30 cm × 6 cm) treatment and the minimum soil moisture (37.7%) was obtained from D_{+20} (30 cm × 9 cm). The maximum soil moisture (47.53%) found from the I_1F_{-20} treatment and the minimum soil moisture (33.08%) was found from the I_0Fr. The maximum soil moisture (49.96) was found from I_1D_{-20} and the minimum (31.12%) from I_0D_{+20} .The maximum soil moisture (43.13) was produced from $F_{-20}D_{-20}$ treatment and the minimum soil moisture (35.50 %) was produced from FrD_{+20} treatment. The maximum soil moisture (52.80%) obtained from $I_1F_{-20}D_{+20}$ treatments and the minimum soil moisture (29.57%) plant was observed from I_0FrD_{+20}.

The maximum water saturated deficit (0.74%) was observed from I_1 treatment and the minimum water saturated deficit (0.52%) was observed from I_0 treatment. The maximum water saturated deficit (0.64%) was found from F_{-20} treatment. On the other hand the minimum water saturated water deficit (0.63%) was observed from Fr treatment. The maximum water saturated deficit (0.65%) was obtained from D_{-20} treatment and the minimum water saturated deficit (0.60%) was obtained from D_{+20}. The maximum water saturated deficit (0.75%) found from the I_1F_{-20} treatment and the minimum water saturated deficit (0.51%) was found from the I_0Fr. The maximum water saturated deficit (0.77%) was found from I_1Dr and the minimum (0.51%) from I_0Dr . The maximum water saturated deficit (0.67%) was produced from $F_{-20}D_{-20}$ treatment and the minimum water saturated deficit (0.578%) was produced from $F_{-20}D_{+20}$ treatment. The maximum saturated water deficit (0.79%) obtained from I_1FrDr treatment and the minimum water saturated deficit (0.46%) plant was observed from I_0FrDr.

The maximum relative water content (89.34%) was observed from I_1 treatment and the minimum relative water content (89.24%) was observed from I_0 treatment. The maximum relative water content (89.44%) was found from F_{-20} treatment. On the other hand the minimum relative water content (89.14%) was observed from Fr treatment. The maximum relative water content (89.58%) was obtained from D_{-20} treatments and the minimum relative water content (88.97%) was obtained from D_{+20}. The maximum relative water content (89.63%) found from the I_1Fr treatment and the minimum relative water content (89.05%) was found from the I_0F_{-20}. The maximum relative water content (89.95%) was found from I_1D_{+20} and the minimum (88.46%) from $I_oD_{-20.}$ The maximum relative water content (89.94%) was produced from $F_{-20}D_{+20}$ treatment and the minimum relative water content (88.73%) was produced from $F\text{-}_{20}$Dr treatment. The maximum relative water content (90.97%)

obtained from $I_1F_{-20}D_{+2}$ treatment and the minimum relative water content (87.81%) was observed from I_0FrDr

The maximum exudation rate (0.057 g/hr) was observed from I_1 treatment and the minimum exudation rate (0.034 g/hr) was observed from I_0 treatment. The maximum exudation rate (0.052 g/hr) was found from Fr treatment. On the other hand the minimum exudation rate (0.039 g/hr) was observed from F_{-20} treatment. The maximum exudation rate (0.058 g/hr) was obtained from D_{-20} treatment and the minimum exudation rate (0.034 g/hr) was obtained from D_{+20}. The maximum exudation rate (0.063 g/hr) found from the I_1Fr treatment and the minimum exudation rate (0.027 g/hr) was found from the I_0F_{-20}. The maximum exudation rate (0.066 g/hr) was found from I_1D_{+20} and the minimum (0.022 g/hr) from I_0D_{-20}.The maximum exudation rate (0.065 g/hr) was produced from FrDr treatment and the minimum exudation rate (0.035 g/hr) was produced from $F_{-20}D_{-20}$ treatment. The maximum exudation rate (0.077 g/hr) obtained from I_0FrD_{+20} treatment and the minimum exudation rate (0.020 g/hr) plant was observed from I_0FrD_{-20}.

At harvest I_1 produced the taller plant (36.78 cm) and I_0 produced shorter (32.052 cm). The tallest plant (34.65 cm) was found from F_{-20} treatment. On the other hand shortest plant (34.18 cm) was observed from Fr treatment. At harvest, numerically the tallest plant (34.68 cm) was obtained from Dr Treatment and the shortest plant (34.24 cm) was obtained from D_{+20}. The tallest plant (36.81 cm) found from the I_1F_{-20} treatment which was statistically similar with the I_1Fr and shortest plant (31.61 cm) was found from the I_0Fr. The tallest plant (37.33 cm) was found from I_1Dr and shortest plant (31.33 cm) from I_0D_{-20}.The tallest plant (35.08cm) was produced from F_{-20}Dr treatment and the shortest plant height (33.58 cm) was produced from $F_{-20}D_{-20}$ treatment. The tallest plant height (38.53 cm) obtained from $I_1F_{-20}D_{+20}$ treatment and the Shortest (30.79 cm) plant was observed from I_0F_{-20} D_{+20}.

The maximum leaf area (LA) (124.42 cm^2) was found in I_1 treatment. The lowest LAI (118.27 cm^2) was found in I_0 treatment. The maximum leaf area (125.01 cm^2) was obtained from F_{-20} treatment. Minimum leaf area (117.69 cm^2) was counted Fr. Numerically the maximum LA (125.40 cm^2) was obtained from Dr treatment and the lowest LA (115.20 cm^2) was obtained from D_{+20}. The maximum LA (127.6 cm^2) found from the I_1F_{-20} treatment which was statistically similar with the I_0F_{-20} and shortest plant (109.00 cm^2) was found from the I_0Fr. The maximum LA (137.00 cm^2) was found from I_1Dr and lowest LA (113.90 cm^2) from I_0D_{+20} which was statistically similar to $I_1D_{+20,}$ I_0D_{-20}. The highest LA (126.20 cm^2) was produced from F_{-20}Dr treatment and the lowest LA (105.90 cm^2) was produced from FrD_{+20} treatment. The highest LA (147.1 cm^2) obtained from I_1F_{-20}Dr treatment and the lowest (96.39 cm^2) plant was observed from I_0FrD_{+20}.

The maximum TDM was 6.09 g $plant^{-1}$ recorded form I_1 at maturity. On the other hand lower amount of TDM (5.41 g) was produced by I_o treatment. The maximum TDM was 6.57 g $plant^{-1}$ recorded form F_{-20} at maturity. On the other hand lower amount of TDM (4.93 g) was produced by Fr treatment. Maximum (6.38 g) TDM was found from the Dr treatment at harvest. The minimum TDM (5.18 g) was observed from D_{-20} treatment. The maximum (7.18 g) TDM was found from the combination of I_1F_{-20} and the minimum (4.85 g) was found from I_0Fr. At harvest numerically maximum (6.45 g) TDM was found from I_1Dr and minimum (4.84 g) was observed from I_0D_{+20}.At harvest maximum (7.39 g) TDM was found from F_{-}

$_{20}$Dr treatment and minimum (4.59 g) from the FrD$_{+20}$ treatments. The numerically maximum (8.00 g) TDM found from the combination of I$_1$F$_{-20}$D$_{+20}$ and minimum (4.58 g) from the combination of I$_o$F$_{-20}$Dr.

The maximum number of pod per plant (9.61) was found from I$_1$ treatment and the minimum number of pod per plant (6.43) was produced from I$_0$ treatment. The maximum number of pod per plant (8.13) was found from F$_{-20}$ treatment. On the other hand shortest plant (7.91) was observed from Fr treatment. The maximum number of pod per plant (8.50) was obtained from D$_{+20}$ treatment and the minimum number of pod per plant (7.56) was obtained from Dr. The maximum number of pod per plant (9.96) found from the I$_1$F$_{-20}$ treatment and the minimum number of pod per plant (5.85) was found from the I$_0$Fr The maximum number of pod per plant (10.33) was found from I$_1$D$_{+20}$ and the minimum number of pod per plant (7.17) from I$_0$D$_{+20}$.The maximum number of pod per plant (8.67) was produced from F$_{-20}$D$_{+20}$ treatment and the minimum number of pod per plant (5.67) was produced from FrDr treatment. The maximum number of pod per plant (10.55) obtained from I$_1$F$_{-20}$D$_{+20}$ treatments and the minimum number of pod per plant (5.33) plant was observed from I$_0$FrDr.

It was observed that I$_1$ treatment produced longer (2.87 cm) pod length and the I$_0$ treatment was produced shorter (2.69 cm) pod. The longest (2.83cm) and shortest (2.74 cm) pod length was observed in F$_{-20}$ and Fr, respectively though the value did not differ significantly. Longest (2.88 cm) pod was produced due to D$_{+20}$ treatment and shortest pod length (2.69 cm) was produced in D$_{-20}$ treatment. Longest (2.92 cm) pod length was observed from the combination I$_1$F$_{-20}$ treatment and lowest (2.65 cm) was found from the combination I$_0$Fr treatment. The longest pod (3.03

cm) was found from I_1D_{+20} treatment. The shortest pod (2.59 cm) was observed from I_0Dr treatment. Interaction of fertilizer and the population density exerted statistically non significant influence on pod length. Highest (3.11 cm) pod length was observed from the combination I_1F_{-20} D_{+20} treatment and the lowest (2.57 cm) from I_0FrDr. It might be due to inherent characters of the variety that might not be much changed by cultural treatment although there were numerical variations.

The maximum number of seed per pod (2.05) was found from I_1 treatment and the minimum number of seed per pod (1.74) was produced from I_0 treatment. The maximum number of seed per pod (1.93) was found from F_{-20} treatment. On the other hand minimum number of seed per pod (1.87) was observed from Fr treatment. The maximum number of seed per pod (1.98) was obtained from D_{+20} treatment and the minimum number of pod per plant (1.75) was obtained from D_{-20}. The maximum number of seed per pod (2.07) found from the I_1F_{-20} treatment and the minimum number of seed per pod (1.70) was found from the I_0Fr. The maximum number of seed per pod (2.17) was found from I_1D_{+20} and the minimum number of seed per pod (1.61) from I_0Dr.The maximum number of seed per pod (2.06) was produced from $F_{-20}D_{+20}$ treatment and the minimum number of seed per pod (1.72) was produced from FrDr treatment. The maximum number of seed per pod (2.29) obtained from $I_1F_{-20}D_{+20}$ treatments and the minimum number of pod per plant (1.44) plant was observed from I_0FrDr.

The maximum weight of seed per plant (1.38 g) was found from I_1 treatment and the minimum number of seed per pod (0.94 g) was produced from I_0 treatment. The maximum weight of seed per plant (1.24 g) was found from F_{-20} treatment. On the other hand the minimum weight of seed per plant (1.08 g) was observed from Fr treatment. The maximum weight of seed per plant (1.23 g) was obtained from D_{+20} treatment and the minimum weight of seed per plant (1.04 g) was obtained from D_{-20}. The maximum weight of seed per plant (1.47 g) found from the I_1F_{-20} treatment and the minimum weight of seed per plant (0.85 g) was found from the I_0Fr. The maximum weight of seed per plant (1.42 g) was found from I_1D_{+20} and the minimum weight of seed per plant (0.72 g) was observed from I_0D_{-20}. The maximum weight of seed per plant (1.29 g) was produced from $F_{-20}D_{+20}$ treatment and the minimum weight of seed per plant (1.01 g) was produced from FrDr treatment. The maximum weight of seed per plant (1.63 g) obtained from $I_1F_{-20}D_{+20}$ treatment and the minimum weight of seed per plant (0.66 g) plant was observed from I_0FrD-20.

The maximum 1000 seed weight (104.59 g) was found from I_1 treatment and the minimum 1000 seed weight (94.33 g) was produced from I_0 treatment. The maximum 1000 seed weight (99.47 g) was found from F_{-20} treatment. On the other hand the minimum 1000 seed weight t (99.45 g) was observed from Fr treatment. The maximum 1000 seed weight (100.10 g) was obtained from D_{+20} treatments and the minimum 1000 seed weight (98.72g) was obtained from D-20. The maximum 1000 seed weight (104.70 g) found from the I_1F_{-20} treatment and the minimum 1000 seed weight (94.24 g) was found from the I_0Fr. The maximum 1000 seed weight (105.10 g) was found from I_1D_{+20} and the minimum 1000 seed weight (93.52 g) was observed from I_0D_{-20}.The maximum 1000 seed weight (110.30g) was produced from $F_{-20}D_{+20}$ treatment and the minimum 1000 seed weight (89.96 g) was produced from FrD_{-20} treatment. The maximum 1000 seed weight (116.15 g) obtained from $I_1F_{-20}D_{+20}$ treatment and the minimum 1000 seed weight (85.85 g) plant was observed from I_0FrD_{-20}.

The maximum yield of soybean (0.97 t/ha) was found from I_1 treatment and the minimum yield of soybean (0.66 t/ha) was produced from I_0 treatment. The maximum yield of soybean (0.82 t/ha) was found from F_{-20} treatment. On the other hand the minimum yield of soybean (0.81 t/ha) was observed from Fr treatment. The maximum yield of soybean (0.85 t/ha) was obtained from D_{+20} treatment and the minimum yield of soybean (0.79 t/ha) was obtained from D_{-20}. The maximum yield of soybean (0.98 t/ha) found from the I_1F_{-20} treatment and the minimum yield of soybean (0.64 t/ha) was found from the I_0F_{-20}. The maximum yield of soybean (1.04 t/ha) was found from I_1D_{+20} and the minimum yield of soybean (0.54 t/ha) was observed from I_0Dr.The maximum yield of soybean (0.86 t/ha) was produced from $F_{-20}D_{+20}$ treatment and the minimum yield of soybean (0.77 t/ha) was produced from FrDr treatment. The maximum yield of soybean (1.04 t/ha) obtained from $I_1F_{-20}D_{+20}$ treatment and the minimum yield of soybean (0.50 t/ha) plant was observed from I_0FrDr.

From the results it is evident that I_1 treatment produced the higher (34.15%) harvest index than I_0 (27.76%). Low HI in I_0 was caused by poor grain yield. F_{-20} produced the maximum (33.38%) harvest index. On the other hand, the minimum (28.54%) harvest index was obtained from Fr Treatment. Population density had exerted significant variation on harvest index (Table 5) and it was 36.6 % in D_{+20} treatment and 22.92% in D_{-20} treatment. The maximum harvest index (36.17%) found from the I_1Fr treatment and the minimum harvest index (24.94%) was found from the

I_0F_{-20}. The maximum harvest index (38.78 %) was found from I_1D_{+20} and the minimum harvest index (18.68%) was observed from I_0D_{-20}.The maximum harvest index (43.01%) was produced from $F_{-20}D_{+20}$ treatment and the minimum harvest index (21.3%) was produced from FrDr treatment. The maximum harvest index (46.80%) obtained from $I_1F_{-20}D_{+20}$ treatment and the minimum harvest index (17.46%) plant was observed from I_0FrD_{-20}.

It may be summarized that irrigation had significant effect showing the highest yield of 970 kg/ha. But different doses of fertilizer and population density did not have significant effect on seed yield. The seed yield also did not vary due the interaction of irrigation and fertilizer; fertilizer and population density. But interaction effect of irrigation at all levels of population density showed significantly higher values in most of the parameters at around the recommended density level. There was significantly higher soil moisture in the irrigated-fertilized (47.53%), irrigated with lower to recommended density plots (49.96%) and irrigated-fertilized plots having higher density plots (52.8%) in comparison to the that in the non irrigated plots (33.85%). Significantly the highest exudation rate was obtained in the irrigated-fertilized with the highest populated plots (0.077 g/hr) in comparison to the lowest of non irrigated-fertilized recommended density plots (0.02 g/hr). Irrigated-fertilized plots having lower to recommended density showed highest plant height (37 cm), leaf area (147 cm^2/plant), dry weight (6-8 g/plant) and No. of pods/plant (8-10). Significantly the highest seed yield of 1.00-1.04 t/ha were obtained in irrigated-fertilized plots having recommended or higher density.

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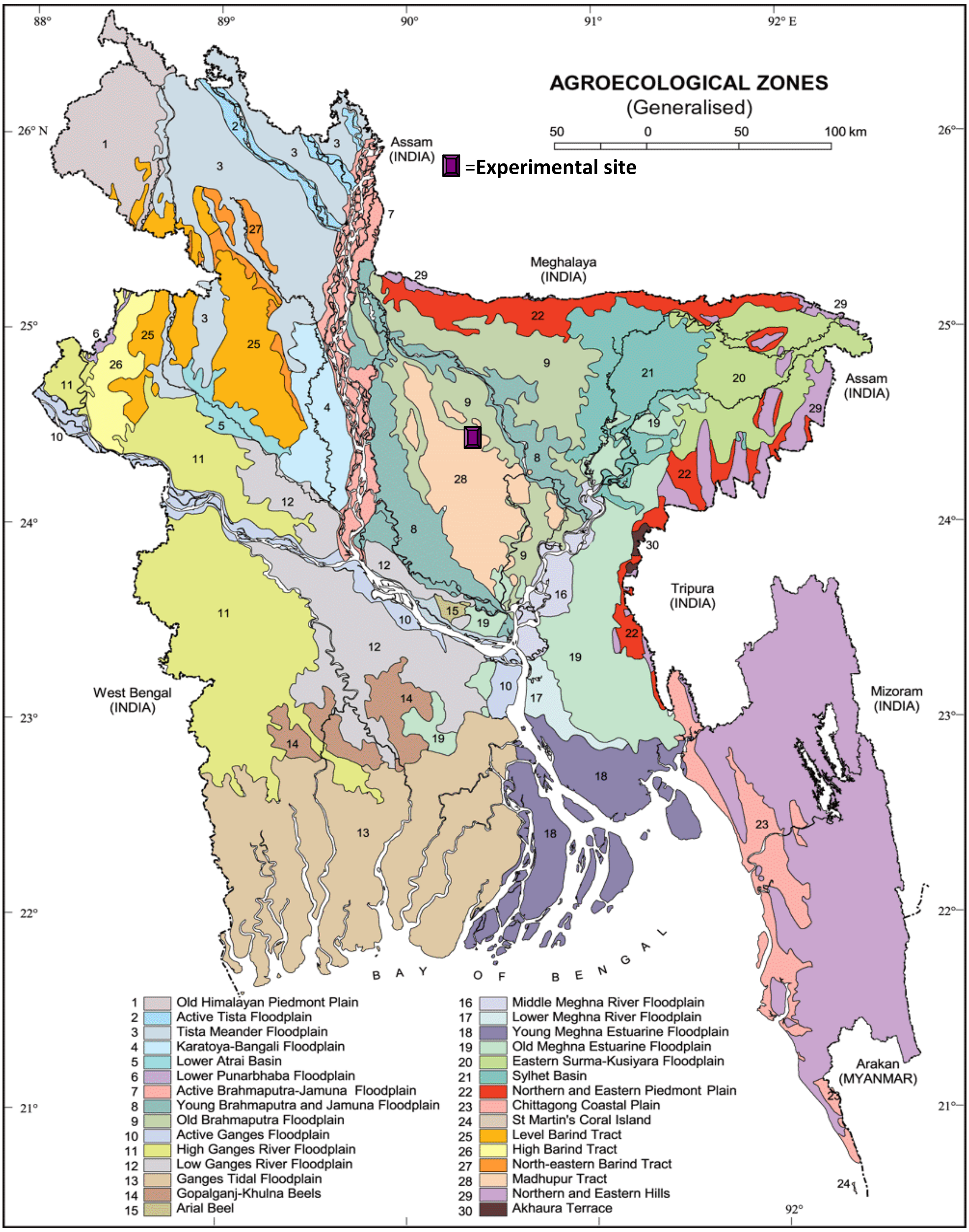
Appendices

APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



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

(0-15 cm depth)

Physical composition :

Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	**Value**
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.07
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Magnesium	1.00 meq/100 g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Zinc	3.32 µg/g soil
Potassium	0.30 µg/g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix III. Analysis of variance of the data on Soil moisture, saturated water deficit, relative water content (%) and exudation rate of soybean as influenced by irrigation, fertilizer and population density

Source	Degrees of freedom	Mean square			
		Soil moisture (%)	Saturated water deficit (%)	Relative water content(%)	Exudation rate
Replication	2	653.516	0.029	26.747	0
Irrigatina (A)	1	1444.507	0.405	0.12	0.005
Error	2	24.981	0.108	6.273	0.002
Fertilizer (B)	1	28.373	0	0.706	0.002
AB	1	0.467	0.004	0.822	0
Error	4	95.547	0.03	3.807	0.001
Populatin density (C)	2	59.458	0.009	1.127	0.001
AC	2	37.841	0.008	4.106	0.001
BC	2	38.305	0.005	2.571	0
ABC	2	31.192	0.023	9.746	0.001
Error	16	75	0.011	5.116	0.001

*significant at 5% level of probability,

NS- Non signficant

Appendix IV. Analysis of variance of the data on plant height, leaf area, dry wt/plant, No. of pod/plant, pod length, No. of seed / pod of soybean as influenced by irrigation, fertilizer, population density

Source	Degrees of freedom	Mean square					
		Plant height (cm)	Leaf area/plant (cm^2)	Dry wt./plant (g)	No. of pod/plant	Pod length (cm)	No. of seed / pod
Replication	2	6.93	961.411	8.881	11.441	0.128	0.057
Irrigatina (A)	1	268.031	340.526	8.161	61.387	0.045	1.113
Error	2	16.452	134.495	4.726	0.195	0.113	0.114
Fertilizer (B)	1	0.153	480.34	0.563	0.151	0.02	0.003
AB	1	19.906	1149.662	14.491	5.191	0	0.077
Error	4	4.917	813.755	3.087	1.244	0.063	0.049
Populatin density (C)	2	0.963	349.574	1.082	1.715	0.149	0.115
AC	2	0.927	652.653	0.472	2.116	0.054	0.058
BC	2	0.776	286.349	0.19	0.789	0.069	0.317
ABC	2	4.61	838.284	3.73	4.602	0.014	0.003
Error	16	7.142	563.995	2.746	3.025	0.061	0.068

*significant at 5% level of probability,

NS- Non significant

Appendix V. Analysis of variance of the data on no. of seed /pod, seed wt./plant, thousand seed wt., seed weight/ha harvest index of soybean as influenced by irrigation, fertilizer, population density

		Mean square			
Source	Degrees of freedom	Seed wt./Plant (gm)	Thousand seed wt. (g)	Seed weight/ha (t)	Harvest index (%)
Replication	2	0.477	247.424	0.236	179.475
Irrigatina (A)	1	1.322	1117.342	0.766	224.101
Error	2	0.152	0.922	0.045	96.21
Fertilizer (B)	1	0.068	545.222	0.012	1.681
AB	1	1.166	8.9	0.012	591.138
Error	4	0.118	219.228	0.017	69.623
Populatin density (C)	2	0.006	708.11	0.01	55.263
AC	2	0.348	3.586	0.012	99.001
BC	2	0.071	1535.088	0.009	61.181
ABC	2	0.113	1.197	0.039	90.524
Error	16	0.1	180.768	0.039	83.198

*significant at 5% level of probability,

NS- Non significant