EFFECT OF IRRIGATION FREQUENCY ON GROWTH AND YIELD OF SOYBEAN

A THESIS

BY

BHUDEB CHANDRA SINHA

Student No.: 1505287

Session: Thesis Semester: July-Dec/2016

MASTER OF SCIENCE (M.S.)

IN

IRRIGATION AND WATER MANAGEMENT

DEPARTMENT OF AGRICULTURAL AND INDUSTRIAL ENGINEERING

HAJEE MOHAMMED DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

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DEDICATED TO MY

BELOVED PARENTS

AND

HONORABLE TEACHERS

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At first all sorts of praises are for God, the lord of universe, the great gracious and the great merciful, without whose help we could do nothing.

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ABSTRACT

Soybean (*Glycine max* L.) is one of the most nutritious crops in the world which is now a new prospective crop in Bangladesh. A field experiment was conducted at the research field, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200 during November 2015 to March 2016 with a view to find out the effect of irrigation frequency on the growth and yield of Soybean cv. BARI Soybean 6.The experiment was carried out with four (4) irrigation treatments viz, no irrigation (control), one time (at 20 DAS), two times (at 20 and 40 DAS), three times (at 20, 40, and 60 D AS). At 105 DAS the highest plant height (52.53cm) was found from I_2 treatment. On the other hand shortest plant (45.82 cm) was observed from I_0 treatment. The highest (5.91) leaf area index was obtained from the treatment of three irrigation (I_3) at 90 DAS and the lowest (5.1) leaf area index was recorded from the control (I_0). At the 90 DAS highest nodule number I_3 (9.208) and lowest nodule number I0 (6.459). The highest (90.09gm) fresh weight was obtained from the treatment I_2 at 90 DAS and the lowest (65.64gm) fresh weight was recorded in I_0. I_3 were produced higher amount of dry matter of (29.50g) and lower amount of dry matter production at harvest (20.67g) in I_0 treatment. Results showed that the highest seed yield was observed from I_2 (1.638 t ha^{-1}) which was statistically similar with I_3 whereas, the lowest was obtained from I_0 (1.075 t ha^{-1}). The highest Stover yield was obtained from I_3 (1.759 t ha^{-1} which is statistically similar to I_2 (1.754 t ha-1)) whereas the lowest was observed from I_0 (1.540 t ha^{-1}) which was statistically similar with I_1 (1.566 t ha^{-1}). The highest biological yield was found from I_2 (3.425 t ha^{-1}) which is statistically similar to I_3 and the lowest was obtained from I_0 (2.56 t ha^{-1}. The maximum harvest index was found from I_2 (47.71 %), the minimum was obtained from I_0 (40.81 %). I_2 treatment showed more significant results than the other treatment I_0, I_1 and I_3. So, two times irrigation had significant effect showing the highest yield of 1.638 t ha^{-1}.

ABBREVIATIONS

HSTU	:	Hajee Mohammad Danesh Science and Technology University
BARI	:	Bangladesh Agricultural Research Institute
RGR	:	Relative Growth Rate
RWE	:	Relative Water Content
AGR	:	Absolute Growth Rate
AEZ	:	Agro-ecological Zone
FAO	:	Food and Agricultural Organization
SRDI	:	Soil Resource and Development Institute
TGW	:	Thousand Grain Weight
DMRT	:	Duncan's Multiple Range Test
LAI	:	Leaf Area Index
HNN	:	Highest Nodule Number
LNN	:	Lowest Nodule Number
TDM	:	Total Dry Matter
TDW	:	Total Dry Weight
TSP	:	Triple Super Phosphate
MOP	:	Muriate of Pottash
EC	:	Electrolyte Conductivity
HI	:	Harvest Index
BY	:	Biological Yield
GY	:	Grain Yield
Cm	:	centimeter

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CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

Soybean (*Glycine max* L.) Merrill) belongs to the family Fabaceae and 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 consumed 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. It 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). Soybean occupies a unique position in science and agriculture, in addition of being a crop with enormous uses. Soybean is grown in almost all parts of the world for human consumption, industry and animal feed (Boydak *et al.*, 2002). It is the most important grain legume of the world and a new prospective crop for Bangladesh (Rahman *et al.,* 2011). It is classified more as an oil seed crop than as a pulse (Devi *et al.,* 2012). Soybean seed contains 40-45% protein, 20-22% oil, 20-26% carbohydrate and a high amount of Ca, P and vitamins (Rahman *et al.,* 2011). Soybean has 3% lesithine which is helpful for brain development. It accounts for approximately 50% of the total production of oil crops in the world. It has become the leading source of edible oils and fats, composing of about 20% of the world supply and more than any other single source of this essential food constituent (Singh *et al*., 1989). Malik *et al.* (2006) and Dugje *et al.* (2009) depicted that soybean oil is consisted of 85% cholesterol free unsaturated fatty acids Soybean protein contains essential amino acid in desired quantity. Hence, it is regarded as a well-balanced protein food.

Therefore, soybean has huge potential as healthy food. Due to its high nutritional value there is an increasing demand of soy food e.g. soymilk, soybean sprouts, soy nuts, several types of tofu, cottage cheese and curd (Rao *et al.,* 2002). It is a good source of isoflavones and therefore it helps in preventing heart diseases, cancer and HIVs (Kumar, 2007). Gesimba and Langart (2005) reported that, among seed oils, soybeans has had an extra-ordinary growth due to rising consumption of livestock products and concurrent rapid growth in meal demand; as well as the fact that it is a cheap source of proteins especially in developing nations. Soybean plant improves the soil fertility and productivity. Soybean, like other legumes, has the ability to fix atmospheric N though root nodule bacteria (*Bradyrhizobium japonicum*) and thus enrich the soil fertility (Mahabal, 1986). It fixes about 270 kg N ha-1 compared to 58 to 157 kg N ha-1 by other pulses (Hoque, 1978). This can compensate around 80-90% demand for nitrogen by the crops.

The crop is cultivated about 102.4 million hectares of land and annual production is approximately 261.6 metric tons in the world (FAOSTAT, 2012). As a grain legume crop it is gaining an important position in the agriculture of tropical countries including India, Sri Lanka, Thailand and Bangladesh. In Bangladesh, soybean is called the *Golden bean*. Now-a-days in Bangladesh, soybean production area is increasing day by day and in the year 2013 it reaches above 61,000 ha (Chowdhury *et al*., 2014). It is a good source of isoflavonoids and therefore it helps in preventing heart diseases, cancer and HIVs (Kumar, 2007).

Soybean is originating from the hot areas of South-East Asia, but more than 50% of its production today comes from the United States and South America. Per hectare yield of soybean in Bangladesh is only 1.2 t ha^{-1} (BARI, 2007) as compared to other soybean producing countries of the world like USA with seed yield of 3.5 t ha^{-1} (James *et al*., 1999). Yield of soybean is very low in Bangladesh and such low yield however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons, viz., unavailability of seeds of high yielding varieties with good quality, delayed sowing, fertilizer management, disease and insect infestation, improper or limited irrigation facilities, weeds and others stress condition. Among different factor, suitable variety and irrigation are the most important factor for low yield.

Soybeans respond well to irrigation during later growth stages where water stress may lead to a decrease in yield. Water stress imposed during pre-flowering and flowering stage reduced yield of soybean by 28% and 24%, respectively (Gunton and Evenson 1980). Similarly various soybean cultivars show varying sensitivity to drought at their different developmental stages (Momen *et al.,* 1979).

Irrigation and variety can play important role to increase yield of soybean. It may be observed that irrigation had significant effect showing the highest yield of soybean. Agronomic traits such as grain yield and its components are the major selection criteria for evaluating drought tolerance under field conditions. The most sensitive stages for soybean plants are pod development to seed filling. It needs adequate water in the soil to produce suitable yield. As the soybean plant develops from beginning bloom through seed enlargement, the ability of plant decrease to tolerate the water deficit and produce low yield. Water deficit stress occurrence during flowering and early pod development stage increases the rate of pod abortion, significantly (Liu *et al.,* 2003). Shortening of grain filling period due to water stress (Nakasathien *et al.,* 2000) and decrease of transferring assimilates into grains due to drought stress are two major reasons for reduction of soybean grain weight. Soybean seed protein and oil contents may be also influenced by water stress. Drought may reduce yield of soybean by about 40% (Specht *et al*., 1999). In Bangladesh, soybean is planted during post-monsoon when stored soil moisture rapidly declines and the crop encounters drought at the reproductive stage. Plant growth is affected by moisture stress including leaf expansion which is reduced due to sensitivity of cell growth to water stress. Reduction in leaf area reduces crop growth and thus affects biomass production (Brown and Caviness, 1985). The need for water in soybean increases with plant development, peaking during the flowering-grain filling stages (7-8 mm day^{-1}) and decreasing thereafter. The total water requirement for maximum productivity varies between 450 and 800 mm, depending on weather conditions, crop management practices and cycle timing (Embrapa, 2011; Farias *et al.*, 2007).

Under the above perspective and soybean situation the present experiment was conducted with different frequency of irrigation to achieve objectives:

i. To determine the effect of irrigation frequency on growth and development of soybean (BARI soybean-6)
ii. To determine the effect of irrigation frequency on yield and yield components of soybean (BARI soybean-6)

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Soybean is an important grain legume crop in the world. It is quite wide spread in different regions of the world and seems to grow well from the tropical and subtropical regions. Researches on irrigation of soybean have been carried out by a large number of researchers throughout the world. In Bangladesh, researches on irrigation of soybean are very few. However, some important findings have been reviewed in this chapter

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.

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).

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, respectively.

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-1with 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.

Lago *et al.*, 1981 reported that 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.

Khair and Israil, (1977) 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).

Specht, 2002. Reported Irrigation should not commence too early – thus during vegetative growth the plants can bestressed a bit otherwise a shallow root system and tall plants that fall over easily will develop. He also stated that soybean yield do not respond to irrigation during vegetative and early flowering stages, and that irrigation during these growth stages could lead to the plant being more susceptible to diseases. Irrigation in the early stages can be postponed if there was water stored in the soil profile before plant. He claims that in 15 years research, heavy irrigation (bringing the soil back to no less than 75% of field capacity on a weekly basis) at pod elongation has always resulted in a positive yield response. After this the irrigation can be reduced to 50% of field capacity on a weekly basis, but should not stop until all the beans have fully enlarged.

Mustapha *et al.* (2014) concluded that soybean genotypes under water deficit condition to evaluate the effects of water stress on yield components and yield of soybean genotype. They reported that the results show that yield components such as number of flowers, total number of pods, percentage aborted flowers, harvest index, biomass and grain yields were significantly reduced by water stress occurring at both vegetative and flowering stages, while post-flowering stress has no appreciable effects thereby suggesting that water stress occurring at post-flowering stage is not critical to grain yield in soybean. Amongst the investigated genotypes TGX 1817-12E was the most tolerant while 1485-1D was the least tolerant genotype.

Krivosudska and Filova (2013) conducted a field experiment with soybean genotypes to observe the evaluate the selected soybean genotypes (Glycine max L.) by physiological responses during water deficit condition. They reported that the drought stress had a negative impact on the relative water content in RWC plants, proline content, osmotic potential, SPAD, stress index as well as an amount of nodules on the roots by the all monitored varieties.

Jandong *et al.* (2011) conducted an experiment to study adaptation and stability of soybean varieties over six soil pH regimes. The genotypes, Kyado and TGX1448–2E were the most superior for seed yield plant-1 in 2004 and 2005 plantings, respectively while cultivar Gembu performed poorly in both years. Genotype Gembu was consistently poor in yield performance, hence the high stability observed.

Jamal *et al.* (2011) determined the effects of row spacing on yield components of three cultivars of winter canola and planting them in the test treatments and variety factorial experiment in randomized complete block design in three replicates in which the planting distance in 3 levels: 30, 40 and 50 cm in 3 levels and three varieties, including new lines. This experiment was carried out in 2010–11 crop season. The results showed that the Cultivar effect is significant on all traits measured in this paper. Simple variance analysis showed that was significant on plant height. In mean comparison the zarfam variety has maximum grain yield (2454 kg ha-1).

Shamsi and Kobraee (2009) to study the effect of different densities on the trend of growth, yield and its components of three varieties of soybean. Three varieties, i.e. Williams, Zan and Clark were assigned in this study. The highest dry weight was obtained from variety Clark. Comparison of changes in the relative growth rate (RGR) showed that variety Williams at density D3 (lowest) had the highest RGR among all the varieties and densities. In this study density increase caused an increase in plant height, the interface of the first sub–branch from soil surface, length of inter node, number of nodes in main branch, number of grain in pod plant-1 grain yield unit area-1, and biological yield performance.

Abayomi, 2008 stated that drought stress or drought badly affects the yield of different crops. It has been suggested that in many crops differences in sensitivity to drought stress occur at different growth stages.

Dogan *et al.* (2007) applied full irrigation during the vegetative stages where after the soybean plants were either not stress (control) or stressed at various reproductive stages (R1- R2; R3; R4; R5 and R6). The result of the stress was a reduction in yield for all the stressed treatments, with the highest reduction reported for stress at R6.

Okpara *et al.* (2007) conducted an experiment during the 2003 and 2004 cropping seasons at Umudike, Southeastern Nigeria, to assess the effect of liming on the performance of four high yielding soybean [Glycine max (L.) Merril] varieties (early maturing TGX 1485–1D, TGX 1799–8F, TGX 1805–8F and medium maturing TGX 1440–1E). The medium maturing TGX 1440–1E gave, on the average, significantly higher number of leaves and number of pods plant–1 and grain yield than other varieties. There were generally no significant effects of lime and crop variety interactions on soybean growth and yield.n should be irrigated until seeds have reached their full size before irrigation should be stopped. Constable and Hearn (1980) found that plant available water should be kept above 60% during pod fill but could be depleted below 60% during the vegetative growth stage.

Eck *et al.* (1987) subjected soybeans to water stress during different reproductive stages. This resulted in a 9-13% reduction in seed yield when stress initiated during R1/R2 were extended to R3. When this stress was extended further to R4.5, the yield reduced by 46%, while if the stress only started at R3 to R4.5, the yield reduction was only 19%. When stress started at R5 but was relieved at R6 the yield decrease was between 15 and 46% over two seasons, while stressing it from R5 throughout R6 (5 weeks total) increased the yield decrease to between 45 and 88% for the two seasons. When the stress was only applied throughout R6 (3 weeks total) the yield decrease was between 21 and 65% for the two seasons. The main difference between the seasons was that the first received a higher rainfall than the second season. This answers the question as to when to stop irrigating. If producers stop too early, it can have as ubstantial effect on the final yield.

Specht (2002) stated that if irrigation is stopped too early, it hastens maturity and results in lower yields as the individual seeds cannot reach their maximum potential (size).

Klocke *et al.* (1989) did a trial with indeterminate soybean cultivars in Nebraska. They advocate that soybean should be irrigated according to growth stages. In doing so, one need to give attention to the soil water holding capacity, climatic factors and the irrigation system itself. They recommend that in the warmer and dryer production areas, irrigation to meet evaporative demand should be applied from the beginning of the season (thus vegetative growth stage), while in moist areas, it can be delayed until the flowering stage. But even in the latter case the soil should have a good water holding capacity and be filled to field capacity before planting.

Specht (2002) has suggested. Their research, however, indicated that rainfall supplemented with irrigation from flowering in most cases resulted in better yields than waiting till pod fill. In these cases, irrigation at flowering often resulted in similar yields than where full irrigation from start to end of season was applied.

Sweeney and Granade (2002) reported an increased in yield with applying irrigation duringR1 to R2 (beginning to full bloom), at R4 (full pod), or at R6 (full seed). They stated that while R1/R2 or R4 irrigations had a positive effect on number of seeds, irrigation at R6 in addition increased individual seed mass.

Shaw and Laing (1966); Shipley and Regier (1970); Dusek *et al*. (1971); Doss *et al.* (1974); Sionit and Kramer (1977); Constable and Hearn (1980); Korte *et al*. (1983a, 1983b); and Stegman *et al.* (1990) all stated that soybean seed yield is least sensitive to water deficits during the vegetative stage, more sensitive during flowering and pod set, and most sensitive during pod fill.

Krote *et al*. (1983); Westgate and Peterson (1993); and Liu *et al*. (2003) all reported more pod abortion if the plants are stressed during flowering and early pod growth, leading to lower yields.

Demirtas *et al.* (2010) withhold water during six growth stages (during vegetative growth V5 (fifth trifoliate), flowering (R2), podding (R4), seed fill (R6), full bloom + podding (R2 + R4), and podding + seed fill (R2 + R6)), with a fully irrigated and a dryland treatment included as controls. Their data (averaged over two years) indicated a decrease in yield from 3.79 t ha-1 for the well irrigated control to 2.81 t ha-1 for the treatment stressed during pod growth and seed fill (R2 + R6). As expected, water use efficiency (WUE) under dryland conditions (T8) was the best for all the treatments while it decreased with between 0.14 and 0.11 kg m-3 when the plants did not receive water during R6 (T5), R2 + R4 (T6) and R2 + R6 (T7). Irrigation water use efficiency was also severely negatively affected by withholding irrigation during R6 (T5) and R2 + R6 (T7).

Sutherland and Danileson (1980) showed that water stress during flowering followed by full irrigations increases yield. Water stress imposed on soybeans throughout the growing stages reduces vegetative growth and affects flowering and yield .Water stress during reproductive development often decreases the seed size in soybean.

Sionet and Kramer, 1977; Momen *et al.*, 1979; Kadhem *et al.*, 1985a; 1985b). Meckel *et al.* (1984) ascribe this to a shortening in the length of the seed filling period, rather than reduced seed growth rate.

Malek *et al.* (2012) explained by the results from They investigated absolute growth rate (AGR), LA and LAI of field grown soybean and reported that for all the genotypes tested, the growth rate was slowest during the vegetative phase leading to a smaller portion of total dry mass produced before flower initiation, and the bulk thereafter. Due to the plants reaching maximum LA and LAI during the pod fill stage, AGR was at its maximum. Taking this into account, it could explain why yield reacted more positively to irrigation during the reproductive than vegetative growth stages. They observed that irrigation at R4 increased the number of seeds, while irrigation at the other two stages increased the seed mass.

De Costa and Shanmugathasan (2002) measured numerous growth related characteristics of the soybean plant in relation to its response to withholding of irrigation during certain growth stages. By withholding water during V1 – R1, R1 – R4 and R4 –R8, the following was reported. LAI, radiation interception and biomass increased with more growth stages being irrigated, but the singular growth stage showing the highest positive reaction to this was the vegetative growth stage. Radiation use efficiency was most positively affected by irrigation during flowering and pod fill stages, while for pod number, and harvest index it was at the flowering stage. Mean pod growth rate during pod filling exceeded corresponding overall crop growth rate of all treatments indicating translocation of reserves.

Comlekcioglu and Simsek (2011) was conducted effects of the water deficit on yield and yield components of soybean in semi-arid conditions. This research was carried out at the Agricultural Experimental Field of the Harran University (Sanliurfa, Turkey) on clay soil during the growth periods of 2006 and 2007. The irrigation treatments were 33% (I33), 67% (I67), 100% (I100) and133% (I133) ratios of total irrigation water applied (IW)/cumulative pan evaporation (CPE) with four day irrigation interval. The average amount of irrigation water applied to treatments (I133, I100, I67 and I33) was 1058, 795, 533 and 263 mm and 1094, 823, 551 and 272 mm for Toyokomachi and Toyohomare cultivars, respectively. The maximum green pod yields were 20.6 and 29.1 t ha-1 with 997 and 922 mm water consumption for Toyohomare and Toyokomachi, respectively in I133 treatments. Yield response factor (*ky*) values of I100, I67 and I33 treatments were determined as 2.17, 0.92 and 0.59 for Toyohomare and 3.50, 0.61 and 0.61 for Toyokomachi, respectively. The results of the study implied that at least equal (I100) or excess of the evaporated water amount is required to produce high yield in soybean. Differences of yield between cultivars in response to irrigation levels make it necessary to select less sensitive cultivars to water stress especially in semi-arid and arid areas. Varietal characteristics must be considered for successful growing of soybean.

Gaballah and Samiha (2008) were conducted at Giza Agricultural Research Station, Agricultural Research Center, Egypt during 2005 and 2006 growing seasons. The aim of the experiment was to determine the effect of water stress on the yield soybean/maize under different intercropping patterns and their water use efficiency. Intercropping patterns were: 1:1, 1:2, 2:1 and 2:2 soybean/maize. Irrigation treatments consisted of: irrigation using 1.2 pan evaporation coefficient (control), irrigation using 1.0 pan evaporation coefficient (about 7% reduction in irrigation water than the control) and irrigation using 0.8 pan evaporation coefficient (about 14% reduction in irrigation water than the control). The yield of soybean and maize under intercropping was changed to units of cereal to simplify the comparison between different intercropping patterns. Water use efficiency values were calculated for the different treatments by dividing yield in cereal units by consumptive water use. Results showed that the highest yield was obtained under 1:2 soybean/maize intercropping pattern and using irrigation with evaporation pan coefficient equaled to 1.2, compared with either sole maize or sole soybean planting. Furthermore, the highest amounts of irrigation water were applied to 1:2 soybean/maize intercropping pattern for the three irrigation treatments in both growing seasons.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

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

3.1 Experimental Site

A field experiment was conducted at Research Field and Laboratory of the Department of Agricultural and Industrial Engineering at Hajee Mohammed Danesh Science and Technology University, Dinajpur during the period of November, 2015 to March, 2016. The experimental area was located on latitude 25°38' N and longitude 88°41' E and at the elevation of 34.4 m above the sea level. The experimental site was medium high land and belonging to the Agro-ecological Zone-1 (AEZ-1) named Old Himalayan Piedmont Plain (FAO and UNDP 1988).

3.2 Soil

The soil of the research field is slightly acidic in reaction with low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The experimental plot was also high land, having pH 5.8. The soil was sandy loam. Irrigation facilities and drain out system of excess water was well developed. Soil characteristics of experiment site at a depth of 0-15 cm were analyzed at the Regional Laboratory of Soil Resources Development Institute (SRDI), Dinajpur. The physiochemical property and nutrient status of soil of the experimental plots are given in Appendix I

3.3 Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 1987). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The weather data during the study period at the experimental site are shown in Appendix II.

3.4 Plant materials and features

The variety of soybean used in this experiment was BARI Soybean-6. The seed of this variety was collected from Bangladesh Agricultural Research Institute, Joydbpur, Gazipur. Its field duration was about 100-110 days. Its height is about 50-55 cm. BARI Soybean-6 contains 20-21% oil and 42-44% protein. Seed yield is about 1.80-2.10 t ha-1 (BARI, 2011).

3.5 Experimental treatments

The experiment consisted single factor as mentioned below:

Factor A: Irrigation

a) $\mathbf{I_0}$ = No irrigation

b) $\mathbf{I_1}$= One irrigation at 20 DAS

c) $\mathbf{I_2}$= Two irrigation at 20 DAS and 40 DAS

d) $\mathbf{I_3}$= Three irrigation at 20 DAS and 40 DAS and 60DAS

3.6 Design and layout

The experiment was laid out in a split plot design with four replications. The size of the individual plot was 4 m × 2.5 m and total numbers of plots were 16. There were 4 treatments and 4 replications combinations. Each block was divided into 4 unit plots. Layout of the experiment was done on November 15, 2015 with inter plot spacing of 0.50 m and inter block spacing of 0.75 m. A layout of the experimental plot is given in Fig. 1.

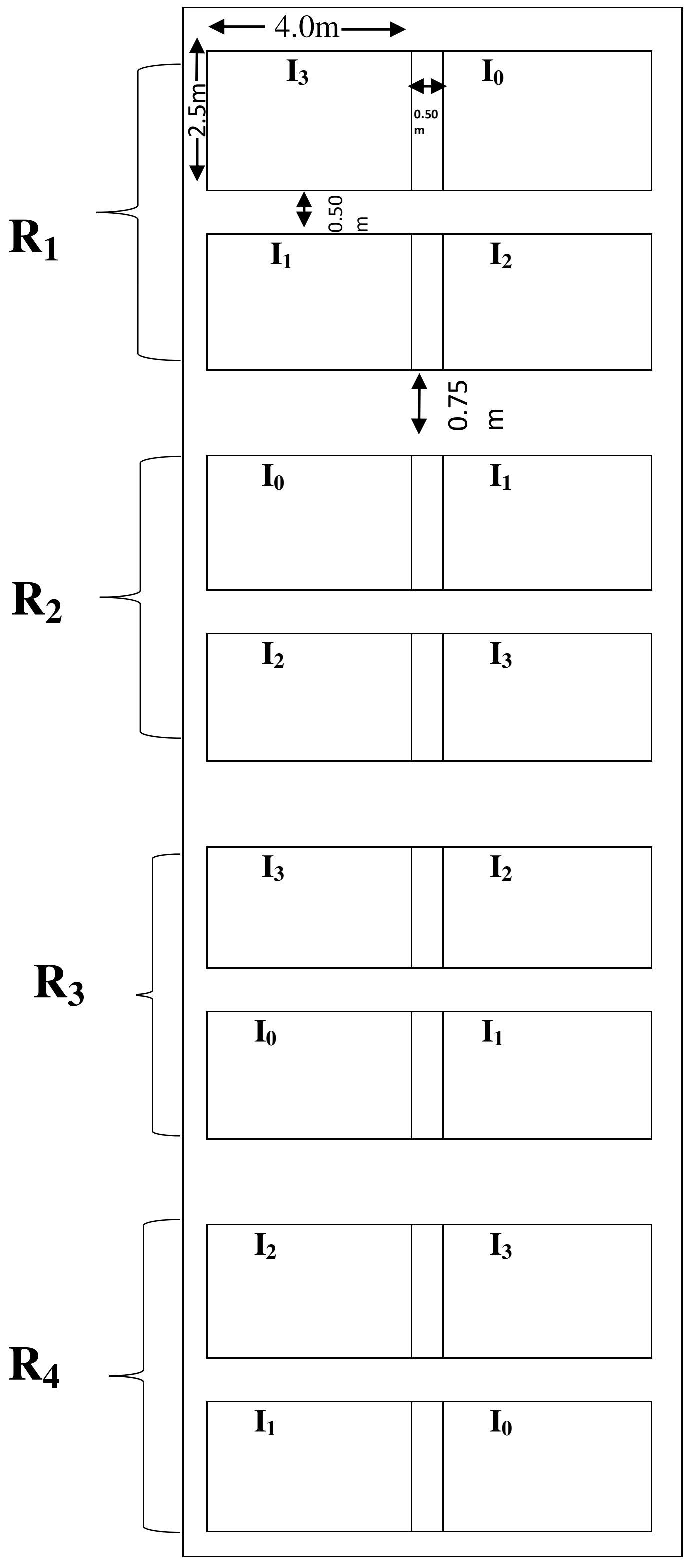

Figure 1: A layout of the experimental plot

3.7 Land preparation

The land of the experimental field was first opened on November 10, 2015 with a power tiller. Then it was exposed to the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of the crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field.

3.8 Fertilizer application

All the fertilizers were applied at BARI recommended dose as 60 kg ha-1 Urea, 175 kg ha-1 TSP, 120 kg ha-1 MOP, 115 kg ha-1 Gypsum (BARI Krishi Projucti Hatboi). All the fertilizers were applied at the time of final land preparation.

3.9 Seed treatment

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

3.10 Seed sowing

Seeds were sown as per treatments of the experiment in 10 cm apart rows and seeds were sown continuously in rows. Furrows were made by hand rake and seeds were placed in the furrows by hand and then covered properly with soil.

3.11 Intercultural operations

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

3.11.1 Thinning

After 15 DAS, excess plants were thinned out and maintained plant to plant distance 5cm.

3.11.2 Weeding

Weed control methods are followed as per treatments as mentioned in section 3.5.

3.11.3 Irrigation

Irrigation are followed as per treatments as mentioned in section 3.5.

Proper drainage system was also made for draining out excess water.

3.11.4 Plant protections

The soybean plants were infested by hairy caterpillars (*Dlaerisia oblique*) and cutworm at early growth stage which was controlled by applying Sumithion 50 EC @1.01 ha-1. On the other hand picking of infested leaves with caterpillar larvae was also done as a control measure. Diseased or off type plants were uprooted as and when required.

3.12 General observations of the experimental field

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

3.13 Sampling

Five sample plants were collected randomly from each plot. These 5 plants were used for taking yield attributes data.

3.14 Harvest and post-harvest operation

Maturity of crop was determined when 95 % of the pods become brown in color. The plants of central 1 m^2 area were harvested by placing quadrate for recording yield data. Harvesting was done on 15 March, 2016. The harvested crops from each plot were tied up into bundles separately, tagged and brought to the clean threshing floor. The same procedure was followed for sample plants.

3.14.1 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 and rubbing.

3.14.2 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.

3.14.3 Cleaning and weighing

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

3.15 Collection of weed and crop characters data

Ten plants in each plot were selected and tagged. All the growth data (except dry weight) were recorded from those three selected plants. The following data were recorded during the experimentation.

A. Crop growth parameters

i. Plant height (cm) at 30, 45, 60, 75, 90 and 105 DAS.

ii. Leaf area index at 30, 45, 60, 75, 90 and 105 DAS.

iii. Number of Nodule plant-1 30, 60, 90 and 120 DAS.

iv. Fresh weight of plant-1 at 30, 60, 90 DAS.

v. Dry weight of plant-1 at 30, 60, 90 DAS.

B. Yield contributing characters

i. Number of pods plants-1

ii. Filled pod

iii. Pod length (cm)

iv. Number of seeds plant-1

v. Weight of 1000 seeds (g)

C. Yield and harvest index

i. Seed yield (t ha-1)

ii. Stover yield (t ha-1)

iii. Biological yield (t ha-1)

iv. Harvest index (%

A. Crop growth parameters

i. Plant height (cm)

The height of the soybean plants was recorded at 30, 45, 60, 75, 90 and 105 DAS. The heights of 3 pre-selected sample plants were measured from the ground level to the tip of the shoot. Then the data was averaged and expressed in cm.

ii. Leaf area index (LAI)

Total leaf area index was taken at 30, 45, 60, 75, 90 and 105 DAS. All the leaf area present on 3 pre-selected sample plants were counted and averaged them to have. Leaf area index were estimated measuring the length and width of leaf and multiplying by a factor of 0.75.

ii. Fresh weight of plant^{-1}

The fresh weight of soybean plants was recorded at 30, 60, 90 DAS. Three plants were collected randomly from the inner rows of each plot. The fresh weight of the samples was taken using a sensitive digital electric balance. The mean weight was calculated and the weight was expressed in g plant-1.

iv. Dry weight of plant^{-1}

The dry weight of soybean plants was recorded at30, 60, 90 DAS. Three plants were collected randomly from the inner rows of each plot and dried separately for 72 hours in an electric oven set at 60^0C. The dry weight of the samples was taken using a sensitive digital electric balance. The mean weight was calculated and the weight was expressed in g plant-1.

v) Number of Nodule plant-1

Number of nodule of soybean plants was recorded at 30, 60, 90 and 120 DAS. Three plants were collected randomly from the inner rows of each plot. Then count carefully the number of nodule per plant.

B. Yield contributing characters

i. Filled pods plants-1

All the pods of the preselected 3 sample plants in each plot were counted and averaged them to have pods plant-1.

iii. Pod length

The length of 10 randomly selected pods was taken from sample plants were measured. Mean data was expressed in centimeter (cm).

iv. Number of seeds plant-1

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

v. Weight of 1000 grains (g)

One thousand sun dried cleaned seeds were counted randomly 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.

C. Yield and harvest index

i. Seed yield

Seeds obtained from harvested 1.0 m^2 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.

ii. Stover yield

The stovers obtained from the harvested 1.0 m^2 area of each unit plot were dried separately and weights were recorded. These weights were converted to t ha-1.

iii. Biological yield Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

iv. Harvest index (%)

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

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

3.16 Statistical analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package programme. The significant differences among the treatment means were compared by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from a study to investigate the influence of irrigation frequency on the growth, development and yield of soybean as influenced by irrigation frequency. The results of the crop characters as influenced by irrigation have also been presented and discussed in this chapter.

4.1 Crop growth parameters

4.1.1 Plant height

The significant result was found in plant height of soybean by the irrigation date at different growth stages (Fig. 2). Plant height of the soybean was measured at maturity. It was evident from (Fig. 2) that the height of the plant was influenced by irrigation. At 30DAS I2 produced the taller plant (14.20 cm) and I0 produced smaller one (12.34cm). At 105 DAS I2 produce taller plant (52.35cm) and I0 produce lowest plant height (45.82 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.

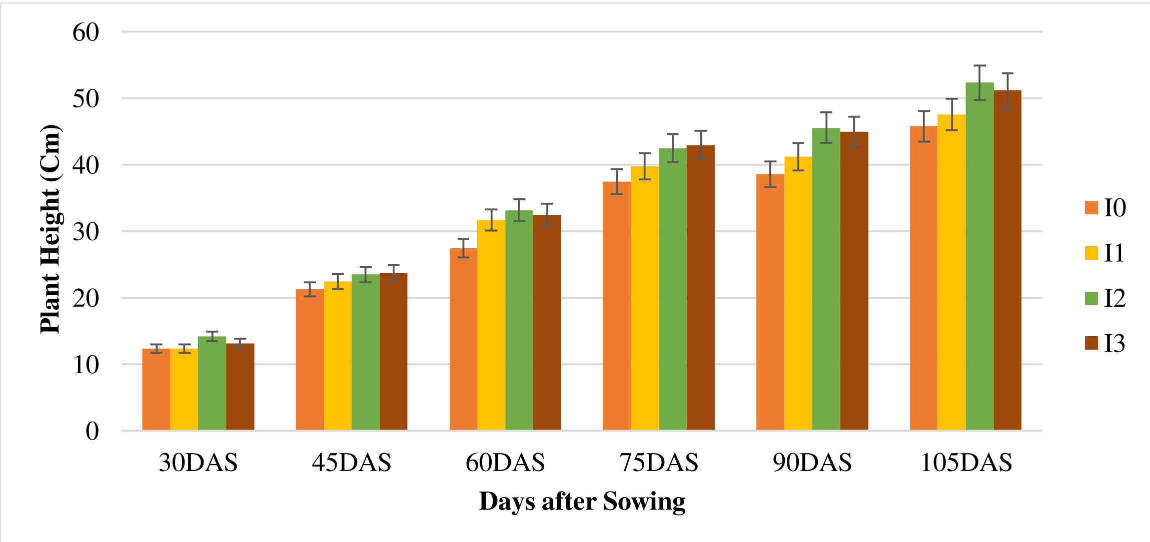

Figure 2. Effect of irrigation on plant height (cm) of soybean at different days after sowing.

(SE =0.3464, 0.7321, 0.8827, 1.411, 1.465 and 4.342 at 30, 45, 60, 75, 90 and 105 DAS, respectively)

I0 = No irrigation, **I1**= One irrigation at 20 DAS.**I2**= Two irrigation at 20 DAS and 40 DAS, **I3**= Three irrigation at 20 DAS and 40 DAS and 60DAS

4.1.2 Leaf Area Index

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 (I). Leaf area index of soybean varied significantly due to irrigation treatments at different days after sowing (Figure 3). The highest (5.91) leaf area index was obtained from the treatment of three irrigation (I3) at 90 DAS and the lowest (5.1) leaf area index was recorded from the control (I0). This result agrees well with Hao *et al.* (2003) who reported that the leaf area index significantly increased with irrigation application.

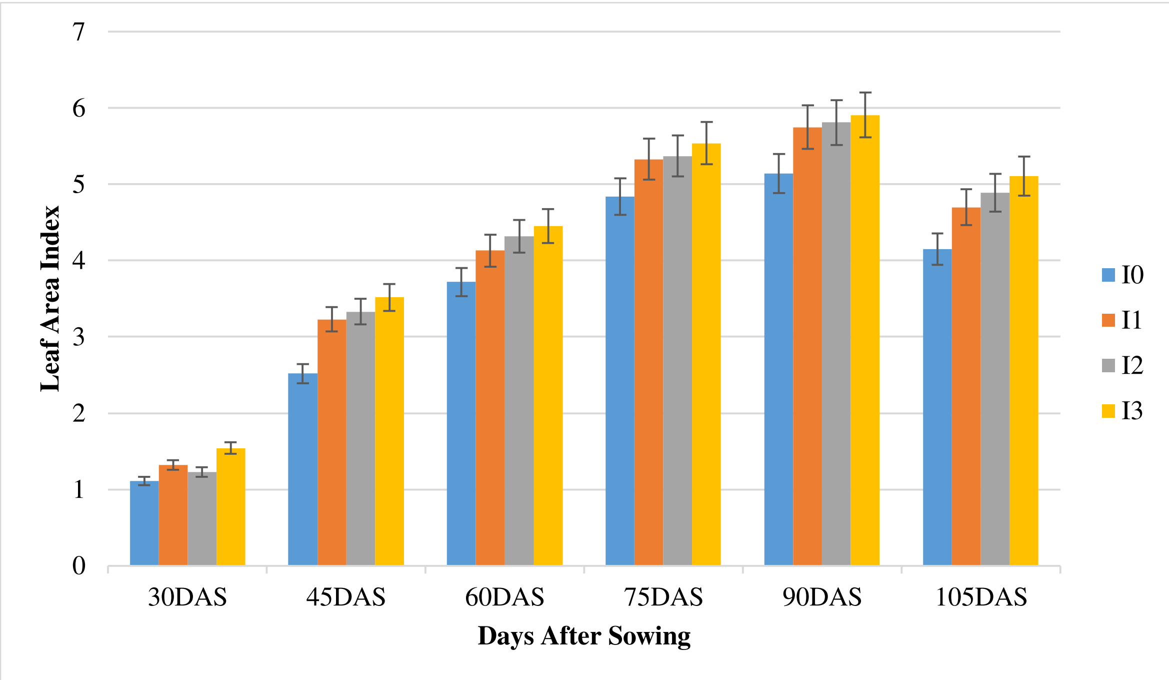

Figure 3. Effect of irrigation on leaf area index of soybean at different days after sowing.

(SE =0.08175, 0.08566, 0.1032, 0.09047, 0.07350 and 0.1156 at 30, 45, 60, 75, 90 and 105 DAS, respectively)

4.1.3 Nodule production

At the 90 DAS number of nodule is increased at the highest pick. Again during harvest time it reduces to the starting level. In 30DAS highest nodule number I_2 (3.41) which is statistically similar to I_3, I_1 and lowest nodule number in I_0 (2.035). In 90 DAS nodule number I_3 (9.208) and lowest nodule number I0 (6.459).) This result agrees well with Rabbani *et al*. (2004 who reported that the nodules number significantly increased with irrigation application

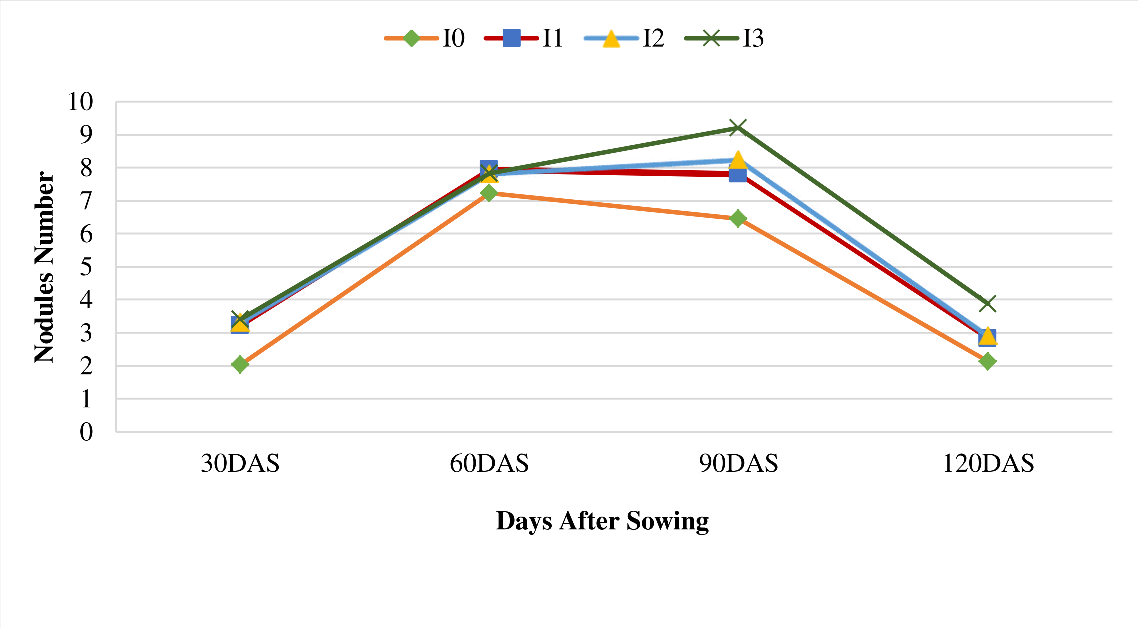

Figure 4. Effect of irrigation on nodule production of soybean at different days after sowing.

(SE =0.3040, 0.6936, 0.6774, 0.3277at 30, 60, 90 and 120 DAS, respectively).

4.1.4 Fresh Weight

Effect of Irrigation methods had significant influence on the fresh weight at different days after sowing (Figure 5). In 30 DAS the fresh weight obtained from all the treatment was statistically same. In 60 DAS the highest value of the fresh weight obtained in I_3 (25.56gm). The highest (90.09gm) fresh weight was obtained from the treatment I2 at 90 DAS and the lowest (65.64gm) fresh weight was recorded in I0. This result supported well with Sahidullah *et al*. (1979) who reported that the nodules number significantly increased with irrigation application.

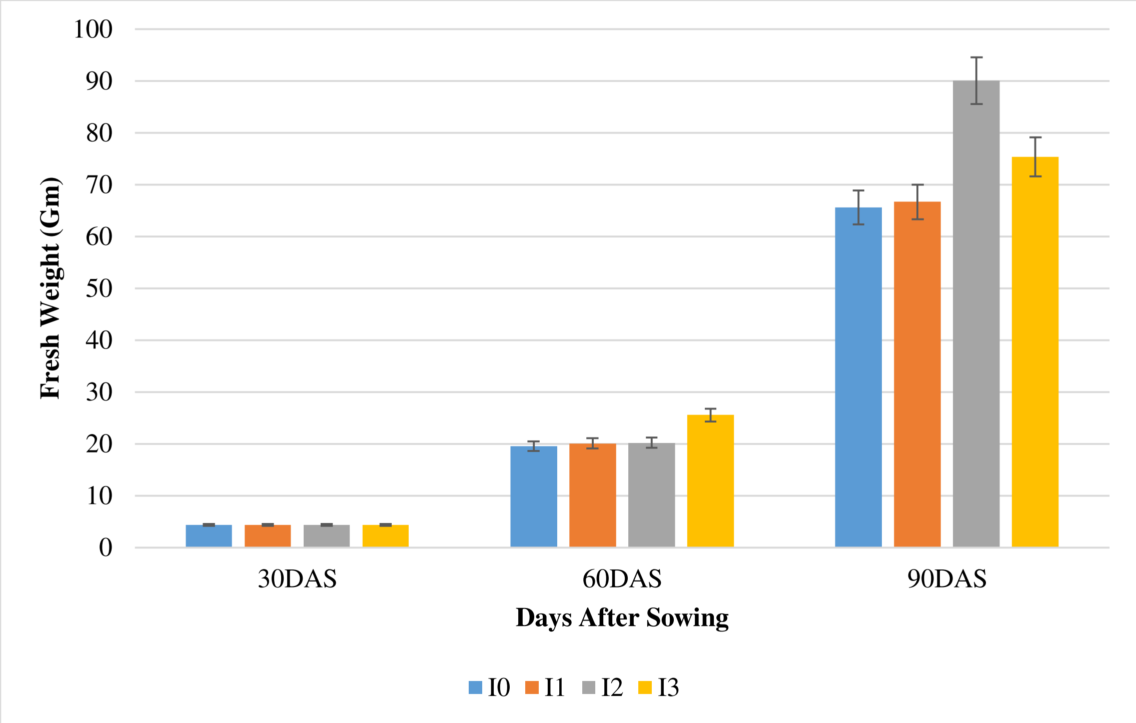

Figure 5. Effect of irrigation on fresh weight (g) of soybean at different days after sowing

(SE =0.2191, 2.087, 6.865 at 30, 60 and 90 DAS, respectively).

4.1.5 Total dry matter production

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. Figure 6 shows that at 30 DAS the dry weight obtained from all the treatment was statistically same. In 60 DAS the highest value of the dry weight obtained in I_3 (8.57gm) and the lowest dry weight obtained from I_0 (6.56gm). At 90 DAS I3 were produced higher amount of dry matter of (29.50g) and lower amount of dry matter production at harvest (20.67g) in I0 treatment. Hao *et al.* (2003) conducted experiments to find out effects of irrigation and found that dry matter accumulation significantly increased with irrigation application.

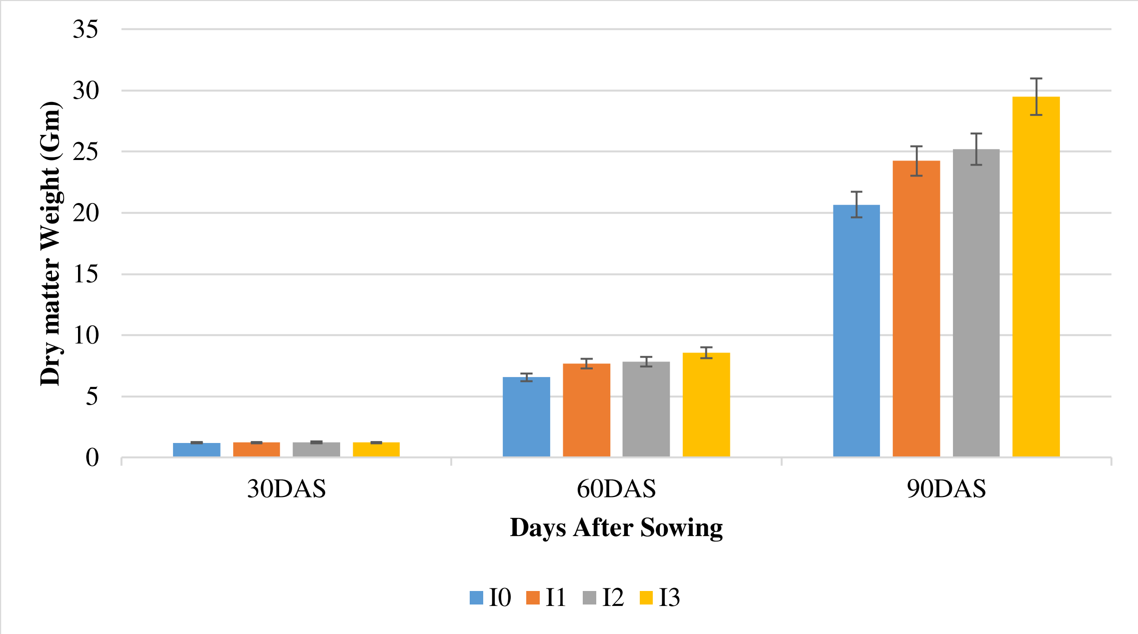

Figure 6. Effect of irrigation on total dry weight (g plant-1) of soybean at different days after sowing.

(SE value=0.05916, 0.6199, 2.306 at 30, 60 and 90 DAS, respectively).

4.2 Yield contributing characters

Table 1. Effect of irrigation on yield contributing characters of soybean

Treatment	Filled Pods Plant-1	Length of Pod (cm)	No. of Seed Pod-1	1000-seed weight
I_0	12.83 b	3.027 a	15.75 c	99.69 b
I_1	13.87 b	3.032 a	18.50 b	102.5 a
I_2	19.98 a	3.057 a	31.87 a	102.8 a
I_3	20.67 a	3.045 a	32.30 a	103.9 a
LSD	1.078	0.1045	1.856	1.535
CV%	43.78	21.46	45.38	12.20

4.2.1 Filled Pods Plant^{-1}

Irrigation had significant effect on the number of filled pod per plant. The highest number of filled pod plant^{-1}(20.67) was observed from I3 which is statistically same to I_2 and the lowest was found from I0 (12.83) that is statistically same to I_1. Kazi *et al.* (2002) conducted an experiment to study the impact of irrigation frequencies and observed that the Filled Pods Plant^{-1} significantly affected by irrigation frequencies.

4.2.2 Length of Pod

The pod length varied due to irrigation shown in (Table 1). It was observed that I2 treatment produced longer (3.057cm) pod and which is statistically similar with I0, I1 and I3 treatment.

4.2.3 Number of seeds plant^{-1}

Number of seed per plant was influenced by irrigation. The maximum number of seed pod^{-1} (32.30) was found from I3 treatment which was statistically similar with I2 treatment and the minimum number of seed plant-1 (15.75) was produced from I0 treatment. Hao *et al.* (2003) conducted experiments to find out effects of irrigation and found that Number of seeds plant^{-1} significantly increased with irrigation application.

4.2.4 1000-seed weight (g)

1000 seed weight was influenced by irrigation. The maximum 1000 seed weight (103.9gm) was found from I3 treatment and the minimum 1000 seed weight (99.69gm) was produced from I0 treatment.

4.3 Yield and harvest index

4.3.1 Seed yield

Seed yield was influenced by irrigation. The maximum yield of soybean (1.638 t/ha) was found from I2 treatment and the minimum yield of soybean (1.075 t/ha) was produced from I0 treatment.

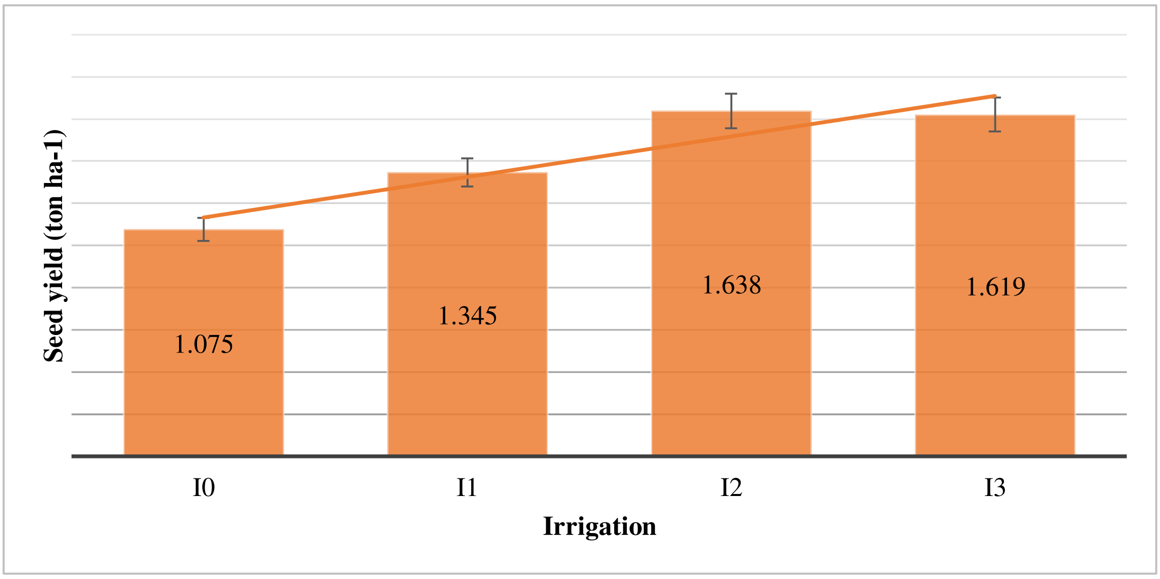

Figure 7. Effect of irrigation on seed yield (t ha-1) of soybean at different days after sowing.

Kazi *et al.* (2002) also reported that the maximum seed yield were found superior with the application of 3 irrigations followed by 2 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).

4.3.2 Stover yield

Irrigation had significant effect on Stover yield of soybean .The highest Stover yield was obtained from I3 (1.759 t ha-1 which is statistically similar to I2 (1.754 t ha-1)) whereas the lowest field was observed from I0 (1.540 t ha-1) which was statistically similar with I1 (1.566 t ha-1)

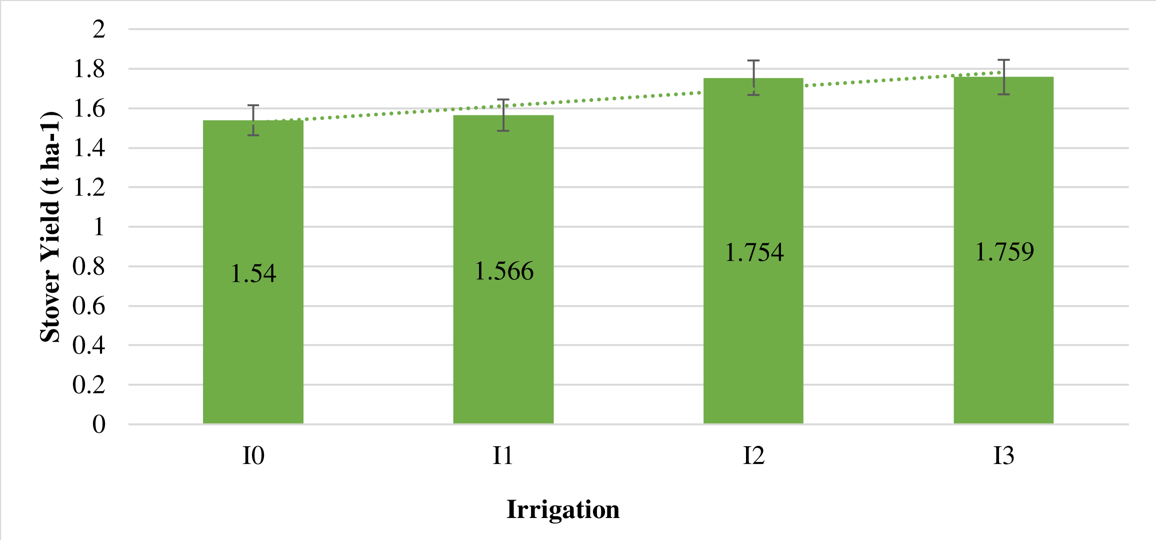

Figure 8. Effect of irrigation on Stover yield (t ha-1) of soybean at different days after sowing.

It might be the results of higher Stover yield which resulted evidently due to the optimum frequency of irrigation.

4.3.3 Biological yield

Irrigation frequency had significant effect on biological yield of soybean. The highest biological yield was found from I2 (3.425 t ha-1) which is statistically similar to I_3 and the lowest was obtained from I0 (2.56 t ha-1). Sahidullah *et al*. (1979) who reported that biological yield significantly increased with optimum irrigation frequency.

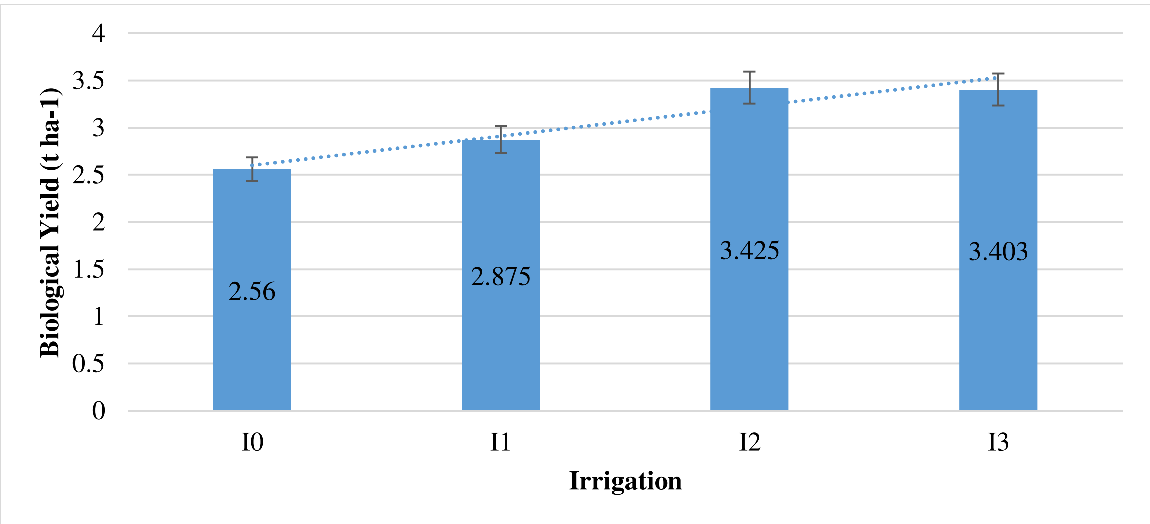

Figure 9. Effect of irrigation on biological yield (t ha-1) of soybean at different days after sowing

I0 = No irrigation, **I1**= One irrigation at 20 DAS, **I2**= Two irrigation at 20 DAS and 40 DAS, **I3**= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

4.3.4 Harvest index

Irrigation showed significant effect on harvest index of soybean. Numerically the highest harvest index was observed from I2 (47.71 %) which is statistically similar with I3and the lowest was found from I0 (40.81 %).

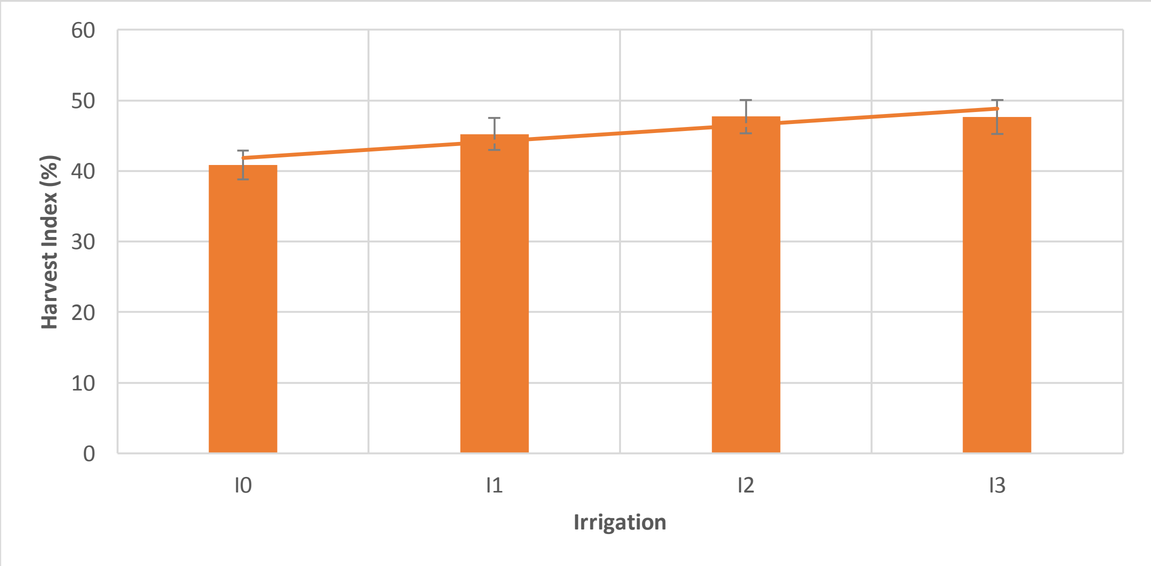

Figure 10. Effect of irrigation on harvest index (%) of soybean at different days after sowing.

I0 = No irrigation, **I1**= One irrigation at 20 DAS, **I2**= Two irrigation at 20 DAS and 40 DAS, **I3**= Three irrigation at 20 DAS and 40 DAS and 60DAS

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the research field, Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period from November 2015 to March 2016 to investigate the influence of on the growth and yield of soybean under the Agro-ecological Zone-1 (AEZ-1) named Old Himalayan Piedmont Plain. 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-6. The experiment was carried out with four (4) irrigation treatments viz, no irrigation (control), one irrigation (at 20 DAS), two irrigation (at 20 and 40 DAS), three irrigation (at 20, 40, and 60 D AS) with four replications. The size of the individual plot was 4.0 m x 2.5 m and total numbers of plots were 16. The experiment was laid out following single factor randomized complete block design with 4 replications. The objectives of the study were to determine the effect of irrigation frequency for achieving higher yield in soybean. The data on crop growth characters like plant height, leaf area index, nodule production, fresh weight (gm), and dry weight plant^{-1} were recorded at different growth stages. Yield and yield contributing parameters like, Filled pod, number of pods plant-1, pod length, number of seeds plant-1, 1000-seed weight, seed yield, stover yield, biological yield and harvest index were recorded after harvest. Data were analyzed using MSTAT-C computerized package program. The mean differences among the treatments were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance. The tallest plant (52.53cm) was found from I_2 treatment. On the other hand shortest plant (45.82 cm) was observed from I_0 treatment at 105 DAS. The highest (5.91) leaf area index was obtained from the treatment of three irrigation (I_3) at 90 DAS and the lowest (5.1) leaf area index was recorded from the control (I_0). At the 90 DAS highest nodule number I_3 (9.208) and lowest nodule number I0 (6.459). The highest (90.09gm) fresh weight was obtained from the treatment I_2 at 90 DAS and the lowest (65.64gm) fresh weight was recorded in I_0. I_3 were produced higher amount of dry matter of (29.50g) and lower amount of dry matter production at harvest (20.67g) in I_0 treatment. Results showed that the highest seed yield was observed from I_2 (1.638 t ha-1) which was statistically similar with I_3 whereas, the lowest was obtained from I_0 (1.075 t ha-1). The highest Stover yield was obtained from I_3 (1.759 t ha-1 which is statistically similar to I2

(1.754 t ha-1)) whereas the lowest was observed from I_0 (1.540 t ha-1) which was statistically similar with I_1 (1.566 t ha-1). The highest biological yield was found from I_2 (3.425 t ha-1) which is statistically similar to I_3 and the lowest was obtained from I_0 (2.56 t ha-1.The maximum harvest index was found from I_2 (47.71 %), the minimum was obtained from I_0 (40.81 %). It may be summarized that two times irrigation had significant effect showing the highest yield of 1.638 t ha-1.

Based on the experimental results, it may be concluded that

i. Irrigation has positive effect on growth, yield attributes and yield of soybean.

ii. Two irrigation are the best suited for obtaining maximum grain yield of soybean.

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APPENDICES

APPENDICES

Appendix I: Soil properties in the experimental sites of the study area during 2014-2015 (before sowing of soybean)

Soil depth (cm)	p^H	OM (%)	Total N (%)	P (ug/gm soil)	K (meq/100g soil)	S (ug/gm soil)	Zn (ug/gm soil)	B (ug/g m soil)
0-10	6.2	2.33	0.12	36.47	0.19	10.81	0.80	0.22
10-20	6.83	1.49	0.08	23.99	0.12	12.16	0.68	0.28
20-30	7	1.60	0.08	13.93	0.14	12.76	0.57	0.23
Avg	6.68	1.81	0.09	24.8	0.15	11.91	0.68	0.25

Appendix II: Average monthly rainfall, temperature, humidity and evaporation (2010-2014)

Month	**Rainfall (mm)**	**Temperature ^{0}c**	**Humidity (%)**	**Evaporation (mm)**
January	5.20	16.79	84	51
February	13,08	20.80	76	62
March	7.86	24.43	65	78
April	58.92	27.64	61	96
May	185.76	24.48	71	106
June	369.40	28.78	85	100
July	318.40	29.68	84	98
August	281.40	29.19	86	82
September	261.80	28.21	87	89
October	100.44	26.90	83	53
November	0.86	22.24	79	49
December	0.08	18.85	85	44