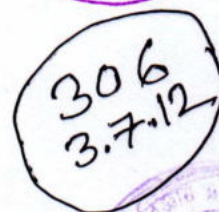


GROWTH, DEVELOPMENT AND YIELD OF MAIZE AS AFFECTED BY IRRIGATION LEVEL

A Thesis

By

**SABRINA SHARMIN
Student No. 1005087**



**MASTER OF SCIENCE (MS)
IN
Crop Physiology and Ecology**

**DEPARTMENT OF CROP PHYSIOLOGY AND ECOLOGY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
DINAJPUR**

WINTER 2011

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**Submitted to the
Department of Crop Physiology and Ecology
Hajee Mohammad Danesh Science and Technology University, Dinajpur
in partial fulfillment of the requirements for the degree of**

**MASTER OF SCIENCE (MS)
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Approved as to the style and content by

Professor Dr. Md. Maniruzzaman Bahadur
(Supervisor)

Professor Dr. Sripati Sikder
(Co-supervisor)

Professor Dr. Md. Maniruzzaman Bahadur
Chairman
Examination Committee

**DEPARTMENT OF CROP PHYSIOLOGY AND ECOLOGY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY
DINAJPUR**

WINTER 2011

*Dedicated to my
beloved parents*

ACKNOWLEDGEMENTS

All praises are due to the Almighty Allah Who has enabled me to complete this thesis for the degree of Master of Science (MS) in Crop Physiology and Ecology.

It is my pleasure to express my heartiest respect, sincere appreciation and immense indebtedness to my respectable teacher & research Supervisor Prof. Dr. Md. Maniruzzaman Bahadur, Chairman, department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his scholastic guidance during planning and execution of the research, valuable suggestions, continuous support and all hint of support and help throughout the period of research work and preparation of manuscript of the thesis.

Heartiest gratitude and deep sense of admiration to my respected co-supervisor Dr. Sripati Sikder, Professor, Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his valuable suggestions, sincere helps, scholar instructions and careful corrections of the manuscript of the thesis.

I recognize a profound thanks to Dr. Abu Hasan, Professor, Abu Khayer Md. Muktadirul Bari Chowdhury, Assistant Professor, Md. Hafizur Rahman Hafiz, Assistant Professor, Department of Crop Physiology and Ecology and Md. Rabiul Islam, Lecturer, Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur for their important suggestions, and all round help and kindly support for successful completion of the manuscript of the thesis.

I also extend gratitude to all the staffs of the Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur for their help & assistance during the period of the research.

I am very thankful and gratitude to all my friends Shika, Joya, Sojib, Jahangir, Ety, Ratan, Keka, Mow, Ruma, Rumana, Ela, Mira, Tasu, Shahjahan, Ruma sen, Habiba, Nilu and also existing colleagues as well wisher for their eagerness and direct and indirect helps during the period of research work.

I get pleasure to express my boundless gratitude and heartiest respect to my beloved parents, younger brother, and sisters for their great sacrifice and efforts during the whole study period in my life and other relatives who wished success through my academic career.

Winter, 2011

Sabrina Sharmin

GROWTH, DEVELOPMENT AND YIELD OF MAIZE AS AFFECTED BY IRRIGATION LEVEL

ABSTRACT

The study was conducted in Crop Physiology and Ecology Research Field and Laboratory, Hajee Mohammad Danesh Science and Technology University during the period of November 2010 to June 2011 to investigate the growth, development and yield of maize as affected by irrigation level. Three maize varieties (V_1 = NK 40, V_2 =Hybrid 981 and V_3 = BHM 11) and three levels of irrigation (I_0 = no irrigation, I_1 = 300 mm irrigation in total life span and I_2 = 450 mm irrigation in total life span at different days after sowing) were included as experimental treatments. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Maize variety NK 40 required maximum days to attain the most of the phenological stages. The duration of tasseling, cob initiation, silking, pollen shading and maturity required the highest days in NK 40. Present study also revealed that differences in variety significantly influenced TDM, LAI, LAD, CGR, RGR and NAR. Irrigation levels also influenced the above growth parameters significantly. The results revealed that maize variety NK 40 with I_2 (450 mm) irrigation treatment gave the highest values of all the growth parameters. Relative leaf water content (RLWC) and moisture retention capacity (MRC) influenced due to variation in maize variety NK 40 gave the highest values of RLWC and MRC. Irrigation frequency also significantly influenced the RLWC and MRC. RLWC and MRC increased with the increasing irrigation level. Significantly higher plant height, cob length, cob diameter, number of cobs plant⁻¹, number of grain rows cob⁻¹, number of grains row⁻¹, and number of grains cob⁻¹ and 100-grain weight was recorded in variety NK 40. The highest yield (5.48 t ha⁻¹) and harvest index (32.89%) was found in NK 40 (V_1) and the lowest yield (4.84 t ha⁻¹) and harvest index (31.28%) was obtained from V_2 (Hybrid 981). Irrigation levels also significantly influenced yield and yield attributes of maize. The highest yield (5.95 t ha⁻¹) was obtained from the plant growing with I_2 (450 mm) treatment while the lowest yield (4.20 t ha⁻¹) was found from I_0 (no irrigation). The interaction between variety and irrigation levels showed a significant variation among the growth, yield and yield attributes of maize. It is indicated that NK 40 with 450 mm irrigation showed the best performance in respect of growth, development, yield attributes, yield and harvest index of maize.

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CHAPTER 1

INTRODUCTION

Maize (*Zea mays* L.) is a cereal crop that is grown widely throughout the world in a range of agroecological environments. Maize was introduced into Africa in the 1500s and has since become one of Africa's dominant food crops. More maize is produced annually than any other grain. About 50 species exist and consist of different colors, textures and grain shapes and sizes. White, yellow and red varieties are the most common types. The white and yellow varieties are preferred by most people depending on the region.

Maize is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America. All parts of the crop can be used for food and non-food products. In industrialized countries, maize is largely used as livestock feed and as a raw material for industrial products. Maize accounts for 30–50% of low-income household expenditures in Eastern and Southern Africa. A heavy reliance on maize in the diet, however, can lead to malnutrition and vitamin deficiency diseases such as night blindness and kwashiorkor.

Worldwide production of maize is 785 million tons, with the largest producer, the United States, producing 42%. Africa produces 6.5% and the largest African producer is Nigeria with nearly 8 million tons, followed by South Africa. Africa imports 28% of the required maize from countries outside the continent. At present maize is major crop among the cereals of Bangladesh because of it's the highest yield potentiality and use. Maize is well suited to the existing agro-climate condition and cropping pattern of Bangladesh. The production area of maize is increasing day by day. Presently the crop covers an area of

about 0.375 million acres and produces 0.887 million metric ton in this country (BBS 2010). In our country maize production gradually increased (Appendix 1).

A loamy soil with nearly neutral pH is most suitable for this crop. Maize grows well on a fine sandy-loam to heavy clay-loam soil with a moderately acid (pH 5.0) to a moderately alkaline (pH 8.5) soils. It is a fast growing crop. Moderate temperature and optimum supply of water are favorable for its growth, temperature of about 24° to 30°C and well distributed rainfall of about 800 mm are sufficient for the growth of maize. The major pest and diseases infestation is less in case of maize compared to other cereals.

Due to urbanization and industrialization the cultivable land decreases day by day. On the other hand, the population is increasing day by day. Bangladesh is facing problem of malnutrition due to her high population growth and low productivity of crops. The traditional crop including rice and wheat seem quite unable to meet up the nutritional requirements to the increasing population. So, it is a time demand to new crop like maize to the existing cropping pattern of our country. Maize can be a potential grain crop for nutritional support to country population. The grains are rich in vitamins A, C and E, carbohydrates, and essential minerals, and contain 9% protein. They are also rich in dietary fiber and calories which are a good source of energy. On the view point of nutrition, it is richer in protein, fats, vitamins and minerals than rice and wheat (Appendix II).

Yield is the cumulative effect of variety with its inherent characteristics, environmental condition in which it is grown and management practices. Variety is one of the most important factor for increasing yield. In general, it is understood that there are differences in morpho-physiological aspects among the traditional and modern varieties. Such as ear length, ear diameter, number of earplant⁻¹, number of grainsrowsear⁻¹, number of grains

row, number of grain per ear⁻¹ and 100-grain weight. Yield of maize also depends on different growth processes such as days to tasseling, cob initiation, silking, pollen shading and maturity which occur in the ontogeny of wheat plant.

Proper growth and development of maize needs favorable soil moisture in root zone. The moisture content in the soil gradually decreases with the passing of time during dry season. Limited water supply during the growing season results in soil and plant water deficits and reduces maize yields (Gordon *et al.* 1995, Patel *et al.* 2006). In areas that are poor in precipitation, irrigation guarantees yield. Irrigation in general, especially in cases of drought, highly increases the yield of maize. Proper time and supplemental irrigation should be realized in irrigation scheduling for the most effective use of available water in optimizing maize production. Water deficit has little effect on timing of emergence, number of leaves per plant but delayed tasseling initiation and silking, reduced plant height and vegetation growth of maize (Abrecht and Carberry, 1993, Singh *et al.* 2007). Heading to milking stage is the most important sensitive period of water stress and has ultimate impact on grain yield (Shaozong and Mingannang 1992, Hussain *et al.* 2008).

Improper scheduling of irrigation results not only in wastage of water but decrease the crop growth and yield. Irrigation found to be significant for ear length, ear diameter, number of barren per plants, plant yield, grain yield and biological yield (Khalil and Samia 2006). Growth parameter, i.e. plant height and leaf area index, which ultimately resulted in higher grain and straw yield significantly increased by irrigation (Singh and Sudhanshu 2005). Proper phenological development takes place with the application of optimum water and also increased accumulation of TDM, maximum RGR, NAR and yield (YaJun *et al.* 2006).

The moisture and temperature plays an important role in movement of ions and nutrients. Irrigation water dissolved the fertilizers and made available to the crop for proper growth and development. The irrigation and fertilizer research results of Nagy (1995, 1997, 1999) have indicated that irrigation improves the efficiency of fertilization and there is a strong correlation between fertilizer utilization and the water supply of a plant. The irrigation and fertilization experiment results of Hank and Frank (1951) have proved that irrigation increases the efficiency of fertilization. The efficiency of fertilizers also depends on agro-ecological conditions (Láng 1981).

The choice of high yielding varieties is very important for maximum production as well as better agronomic practices directly correlated with yield. For maximum production of maize, new promising HYV is prior concern. On the other hand, proper irrigation scheduling is necessary for securing good yield of maize. Therefore, keeping the view in mind, to increase the yield of maize through improved management practices the present investigation would be framed with the following objectives.

- i) To know the effect of irrigation on some morpho-physiological and growth parameters of maize.
- ii) To evaluate yield components and yield of maize varieties under different irrigation levels.

CHAPTER 2

REVIEW OF LITERATURE

Proper growth and development of maize needs favorable soil moisture in root zone. The moisture content in the soil gradually decreases with the passing of time during dry season. Water stress on maize has a profound effect on growth and yield of the crop. Limited water supply during the growing season results in soil and plant water deficits and reduces maize yields (Gordon *et al.* 1995, Patel *et al.* 2006). Proper time and supplemental irrigation should be realized in irrigation scheduling for the most effective use of available water in optimizing maize production. In this regard many researchers throughout the world have made several observations on the effect of water stress on maize. But there is very little information on its availability in Bangladesh. However, here is some of the information on the morpho-physiological characters affected by irrigation. In maize along with other related crops have been reviewed below.

2. 1 Phenological, morphological and growth parameters

A pot experiment was conducted by JinFeng *et al.* (2006) to investigate the effects of controlled alternate partial root zone irrigation on soil microorganism and growth of maize. The treatments include: (1) conventional irrigation (sufficient); (2) fixed partial root zone irrigation (mild deficiency); and (3) alternate partial root zone irrigation (severe deficiency). Data on the quantity of soil microorganism, plant height, stalk diameter, leaf area, dry biomass and irrigation amount were recorded. They found that, under fixed partial irrigation, plant soil microorganisms were not significantly inhibited and their growth quantity was at times higher than that of sufficient irrigated treatment. The soil microorganisms were evenly distributed under alternate partial root zone irrigation.

Results indicated the superiority of alternative partial root zone irrigation. The highest dry biomass was recorded in conventional irrigation. The best water use efficiency was observed under alternate partial root zone irrigation.

A pot experiment and a field experiment were conducted by YaJun *et al.* (2006) in the southern Loess Plateau (China) to investigate effects of water supply levels in different growth stages on maize yield under different fertilizer levels. They reported that, Maize yield of LL was significantly lower than that of NL, regardless of soil water content. Maize yield of NL increased continuously with increasing soil water content in the range 45-105%. However, the yield of LL increased with increasing soil water content, and decreased when soil water content was more than 90% at seedling stage, tasselling stage and filling stage. In the internode elongation stage, the yield of both LL and NL increased continuously with the increase of soil water content in the range of 45-105%. Maize yield increased with the increase of relatively soil water content in the range 45-90%, but this was changed by fertilizer supply and different stages of maize growth. The increase of maize yield was more affected by fertilizer than by water.

An experiment was carried out by Singh and Sudhanshu (2005) to examine the influence of mulching and irrigation on hydrothermal regime of soil with reference to growth and yield of winter maize. Altogether three mulch treatments and three irrigation levels were introduced. The type of mulches were polyethylene sheet 500 gauge (M_2), rice straw at 5 tha^{-1} (M_1) and unmulched (M_0) and the levels of irrigation were 12 $IWCPE^{-1}$ (I_3), 0.9 $IWCPE^{-1}$ (I_2) and 0.6 IW/CPE^{-1} (I_1) ratio. The recommended dose of fertilizers was applied. They observed that, the growth parameter, i.e. plant height and leaf area index, which ultimately resulted in higher grain and straw yield was significantly increased. The highest mean value of growth parameter was observed in M_2I_3 combination and lowest in

M_0I_1 . The sequence of mean value of yields were $M_2 > M_1 > M_0$, whereas the sequence of level of irrigation were $I_3 > I_2 > I_1$. The effect of mulching for increasing the growth parameter and yield was significant, however the effect of irrigation was significant for increasing the leaf area index and yield but for increasing the plant height it was found at par.

The effect of water stress caused by alternate furrow irrigation (AFI) on the yield of maize may be alleviated by applying every-furrow irrigation (EFI) at stress sensitive growth stages. This research was conducted in two different areas with deep and shallow water tables to examine the amount of water used, yield, yield components and water use-efficiency of maize under AFI at 7-day intervals supplemented with EFI at different stages by Sepaskhah and Parand (2006). They observed that AFI resulted in significant reduction in grain yield and in both Bajgah and the Kooshkak areas with deep and shallow water tables, respectively. This occurred due to probable water stress and reduction in 1000-grain weight. However, under AFI supplemented with EFI once or twice at the tasseling or silking stage grain yields were statistically equal to those obtained in EFI although the amount of water used was about 30% smaller in both Bajgah (deep water table) and Kooshkak areas (shallow water table). In both areas the water-use efficiency for grain yield under these irrigation treatments was 1.04 and 0.97 kg grain per m³ of water, respectively.

A field test was carried out by ChunYan *et al.* (2004) with sweetcorn cv. Fenghuang No. 1 in Nanning, Guangxi, China, in which high (0.15 g N + 0.10 g P₂O₅ + 0.15 g K₂O kg⁻¹ soil) and low (0.075 g N + 0.05 g P₂O₅ + 0.075 g K₂O kg⁻¹ soil) fertilizer treatments were applied. The three irrigation treatments involved were conventional irrigation (CI) for the whole root-zone, alternate half root-zone irrigation, and continuous half root-zone drying.

The effects were investigated of PRI on photosynthesis, leaf area, dry matter accumulation and water use efficiency (WUE) of the sweetcorn. Results indicate that PRI increased canopy water use efficiency at the high fertilizer level. Therefore, PRI should be combined with rational fertilizer and irrigation application to exert its best water-saving effects.

A field trial was conducted by Kusaksz and Kusaksz (2005) on maize cultivars Maverick, Brasco, C-955, Dracma, Doge, Tietar and Vero. Result revealed that, significant differences were found among the cultivars for plant height, number of green leaves per plant, stem diameter, dry matter content (%), dry matter yield and herbage yield. Plant height of maize genotypes varied between 155.18 and 206.75 cm; number of green leaves per plant between 10.9 and 13.6; stem diameter between 2.06 and 2.38 cm; dry matter (%) between 27.60 and 35.01%; dry matter yield between 16.27 and 23.14 tha^{-1} ; and herbage yield between 55.98 tha^{-1} and 72.97 tha^{-1} . It was concluded that C-955 cultivar was superior to other cultivars for dry matter yield and herbage yield.

A pot experiment was conducted by Iqbal *et al.* (2003) to evaluate the effect of mulch and irrigation level on biomass and water use efficiency of forage maize using clay and loam soils in autumn 2002. Two mulch levels, 0 (control) and 6.7 Mg ha^{-1} , and three irrigation levels 100, 80 and 60% of total crop water requirement (CWR), were used. They observed that maximum plant growth was noted in the case of I_0 (100% CWR), followed by I_2 (60% CWR) and I_1 (80% CWR) in most of the cases for all the growth parameters studied. Interactions between mulch and soil texture was found statistically significant as increase in parameters such as leaf area index, water use efficiency and decreased in biomass were observed.

- ✓ The effects of different irrigation (flood, furrow or alternate furrow irrigation) and nitrogen application methods (broadcast or band placement) on the agro-physiological

characters of maize hybrid R-2205 were determined in a field experiment conducted by Riaz *et al.* (2002) in Faisalabad, Pakistan during the autumn of 2001. Result showed that furrow irrigation and nitrogen band placement resulted in the highest leaf area per plant, seasonal crop growth rate (CGR), average net assimilation rate (NAR), number of grains per cob, 1000-grain weight and grain yield of maize. The interaction effects of irrigation and nitrogen application methods had no significant effects on the leaf area per plant, seasonal CGR, average NAR and number of grains per cob but had significant effects on 1000-grain weight and grain yield.

Maize cv. AMC-1 (Akola maize Composite-1) was tested by Jiotode *et al.* (2002) for its growth responses and water use influenced by irrigation levels at 40, 60 or 80 mm CPE and irrigation as per the critical growth stages of the crop, and three row spacing of 30, 45 and 60 cm during the rabi seasons of 1996-97 in Akola, Maharashtra, India. They found that irrigation at 40 mm CPE recorded the highest values in terms of all the growth parameters as well as consumptive use, potential evapotranspiration, soil moisture depletion, absolute water use rate and relative water use rate. However, water use efficiency was highest in the case of irrigation as per the critical growth stages of the crop and at 60-cm row spacing.

- ✓ A field experiment was conducted by Singh *et al.* (2000) with 3 levels of water management practices (rainfed with and without drainage, and irrigation with drainage) and 5 cropping systems (maize, groundnuts, turmeric, maize + turmeric and maize + groundnuts). Recommended rates of NPK fertilizers were applied. Result showed that, leaf area index and dry matter production of all the crops were maximum under irrigation with a proper drainage system. Maize-equivalent yield was significantly highest (8.2 tha^{-1}) with maize + turmeric compared with sole crops or with maize + groundnuts in the first year.

However, in the second year, the difference between maize + turmeric and maize + groundnuts was not pronounced. Net return in the first year did not differ between maize + groundnuts and maize + turmeric but in the second year maize + groundnuts gave higher returns. They concluded that Irrigation with drainage provision resulted in maximum yield equivalent (7.5 t ha^{-1}) and net return (Rs 11 752) compared with the other water management treatments.

2. 2 Yield and yield attributes

Effect of irrigation levels and micronutrients application individually and in combination on maize yield, consumptive use (Cu), and WUE and nutrients uptake was studied by Patil *et al.* (2006). They observed that response of maize was significant due to irrigation levels as well as micronutrients application. The highest mean yield of 66.74 q ha^{-1} was obtained in treatment receiving $\text{ZnSO}_4 (25 \text{ kg ha}^{-1}) + \text{FeSO}_4 (25 \text{ kg ha}^{-1})$ followed by $\text{ZnSO}_4 (10 \text{ kg ha}^{-1}) + \text{FeSO}_4 (10 \text{ kg ha}^{-1})$ application (63.08 q ha^{-1}).

✓ Two field experiments were carried out by Khalil and Samia (2006) to evaluate the effects of four irrigation intervals (irrigation every seven days, irrigation every seven days until silking then irrigation every two weeks, irrigation every two weeks until silking and irrigation every seven days, and irrigation every two weeks during the whole season) and two maize hybrids (TWC 310 and TWC 324) on maize yield, its components and some water relations to determine the most important yield components using different statistical procedures. They opined that the irrigation intervals differed significantly with respect to ear diameter, number of grains per row, number of grains per ear and biological yield in the first season. In the second season, the irrigation intervals were found to be significant for ear length, ear diameter, and number of barren per plants, plant yield, grain yield and biological yield. Both hybrids were not significantly different, except for number

of grains per ear in the first season and biological yield in the second season. The interaction between hybrids and irrigation treatments revealed that, to obtain the highest maize yield, yield components and water use efficiency.

✓ Two field experiment were conducted by Sowalim *et al.* (2003) to simulate the effect of skipping one or two irrigation(s) at different growth stages of maize. They found that severe effect of water stress on maize yield and its attributes occurred when 2 irrigations were skipped, one during vegetative growth and the other during grain filling. However, the effect was less severe on grain yield when the 3rd and 6th irrigation were skipped, where yield was reduced by 36.71% versus 41.52% when the 3rd and 5th irrigation were skipped.

A field experiment was conducted for maize intercropped to evaluate the effects of limited supplemental irrigation on yield performance and water use efficiency (WUE) were investigated by Zhang *et al.* (2005) using winter wheat (*Triticum aestivum*) with maize overtopping in a series of field experiments. These investigated how a single drip irrigation added at different stages of wheat growth, and accurately controlled to be 35 mm in each case, affected soil water content, grain yield, number of grains, grain weight per spike and plant height. The WUE and soil water potential were also estimated. Limited single irrigation in grain filling had the best effect on yield increase of intercropped wheat.

A field experiments were undertaken by Nikus *et al.* (2005) using different maturity sets for 2 consecutive seasons at Melka Werer, Ethiopia, to identify potential maize cultivars for production. Results revealed that maize can be grown successfully in the Middle Awash valley during the cool season with a mean grain yield of more than 6.0 t/ha. Medium maturing cultivars performed best in the region. The PHB3253 cultivar produced the highest grain yield (6.1 tha^{-1}) with practically comparable biomass yield levels to the

late maturing groups that produced the highest biomass yield but less grain yield. The cultivars, in all sets, matured earlier compared to their already described maturity days under rainfed conditions and also recorded comparably short plant height.

A field experiment was conducted by El Gizawy (2005) to study the effects of 3 irrigation intervals (every 10, 15 and 20 days), 4 N rates (0, 50, 100 and 150 kgfeddan⁻¹ as ammonium nitrate) and Zn (tap water control and 0.05% Zn EDTA, 14% Zn; 70 mg Znlitre⁻¹), as well as their interactions, on the yield, uptake and agronomic efficiency of N in maize. Result revealed that, irrigation every 20 days resulted in the lowest values of plant and ear heights, ear length and diameter, number of rows per ear, number of grains per row, ear weight, grain yield per ear, shelling percentage, 100-grain weight, grain yieldfeddan⁻¹, grain protein content (GPC), N uptake, agronomic N efficiency (AEN) and apparent N recovery (ARN). The highest values of these parameters were recorded for 150 kg Nfeddan⁻¹. AEN and ARN decreased with increasing N application rate in both seasons. However, differences between 100 and 150 kg Nfeddan⁻¹ with regard to ear weight, grain yield per ear, shelling percentage, grain yieldfeddan⁻¹ and grain protein content were not significant. Zn application as foliar spray increased the yield, yield components, GPC, N uptake and ARN. Zn had no significant effect on AEN in both seasons. [1 feddan=0.42 ha].

A field study was conducted by Ghulam *et al.* (2005) to determine the effect of 4 irrigation schedules (control, -4, -8 and -12 bars), based on actual evapotranspiration (ET) and 4 N fertilizer rates (0, 100, 200 and 300 kg/ha) on maize cv. Golden. Averaged over the 2 seasons, result revealed that, the response of total dry matter (TDM) and I₃ (-8 bars) based on crop evapotranspiration was greater than the control (I₁) or I₂ (-4 bars) irrigation schedule. The seasonal water requirements of the maize crop under irrigated conditions

varied from 181 mm to 220 mm after due account of rainfall. The average response varied from 5.90 and 2.37-3.01 gmm⁻²mm⁻¹ for TDM and grain yield, respectively.

An experiment was conducted by Sepaskhah and Khajehabdollahi (2005) to determine the yield and water-use efficiency of maize under fixed and variable alternate furrow irrigation (fixed AFI, variable AFI) and every furrow irrigation (EFI) at different irrigation intervals in areas with shallow and deep groundwater. In variable AFI, water was applied to the furrow, which was dry in the previous irrigation cycle. The results indicated that even at 4-day irrigation intervals the water needs of maize on a fine textured soil in both areas (with deep and shallow water table) are not met by AFI. The decrease in grain yield due to water stress was mainly due to the decrease in the number of grains per cob and to a lesser extent to the decrease in 1000-grain weight. They also found when water was insufficient for full irrigation, the relative grain yield (yield per unit water applied) of maize under AFI was higher than those under EFI.

Field experiments were conducted by Fernandez *et al.* (2004) to determine the potential productivity of maize as a second crop in the autumn-winter season, ten irrigated maize. They studied the yield response of eight maize hybrids to five rates of each N, P, K, plant stand (S) and planting date (D) in a split plot arrangement replicated twice. Result revealed that, conditional maximum grain yields (CMGY) for the H-515 and H-516 hybrids responded to four groupings depending on the quality of water for irrigation, pest protection and control of other limiting factors. The average CMGY across ten locations and two years was 8.30 and 8.87 t ha⁻¹ for the hybrids H-515 and H-516, respectively. Associated N-P-K-S-D treatments varied significantly among locations and hybrids giving as a result a significant genotype x management x location interaction.

A field experiment was conducted by Megyes *et al.* (2005) in Latokep, Hungary, to study the correlation between irrigation and fertilizer application and to evaluate the effects of irrigation and fertilizer application on maize yields. Irrigation and fertilizer application were strongly correlated with the yield. Result revealed that, the effect of irrigation depended on the natural water and nutrient supplies of the soil and on the specific fertilizer rates. Both fertilizer application and irrigation had a significant effect on the yield. The correlation between the year and the crop production factors was also significant. The yield-increasing effect of irrigation and fertilizer application differed significantly in the experimental years.

A field experiment was undertaken by Ogola *et al.* (2005) using a split-plot design with watering regimes (rainfed and irrigation) as main plots and plant population density (66 667 and 133 333 plants ha^{-1}) as subplots. Evapotranspiration (ET) was determined by monitoring soil moisture content at 7 d intervals using a neutron probe, Esc was measured daily using microlysimeters, and T was calculated as the difference between ET and Esc. They found that, an increase in planting density increased q by 24% under irrigation but reduced q by 17% under rainfed conditions. Esc was 4% less, and T was 9% greater at the highest plant population density owing to a larger crop leaf canopy. Irrigation increased both Esc and T by 41%. Neither Esc nor T were affected by the interaction between population density and water regime. The increase in q at high planting density under irrigated conditions was due to an increase in transpiration efficiency (TE) and a decrease in Esc, while the decrease in q under rainfed conditions was as a result of the predominant decrease in TE. Therefore, the water use efficiency of maize was changed through the manipulation of plant population density.

Trials have been carried out by Gimbatov and Abdurazakov (2004) in Dagestan, in southern Russia west of the Caspian Sea, of maize hybrids Krasnodarskii 427SV, Krasnodarskii 382, ZPSK704, SK566, ROSS145MV and TOSS246 and local cultivars Kremnistaya Belaya and Kremnistaya Zheltaya. Crops were irrigated 4-6 times a year ($2400-3000 \text{ m}^3 \text{ waterha}^{-1}$). The crop density was $45\,000-50\,000 \text{ plantsha}^{-1}$. Result revealed that, stable grain yields of around 10 tha^{-1} were only obtained from ZPSK704, followed by SK566 and Krasnodarskii 427SV which produced $1-1.75 \text{ tha}^{-1}$ less.

A study was conducted by Zamfir *et al.* (2003) on clay-alluvial chernozem in Teleorman, Romania to investigate the response of maize to different levels of water supply. The treatments included: no irrigation; and irrigation at 25, 50 and 75% of the optimum water supply. Results showed that yields of $7000-10\,000 \text{ kg grain/ha}$ were possible under irrigation at 50 and 75% of the optimum. Drought and heat negatively affected pollination and grain formation, resulting in 3.0-23.4% sterility degree. Intense irrigation reduced the organic matter content and chemical elements in the chernozem, and resulted in middle to high content of hydrostable micro-aggregates, and high content of structural micro-aggregates (particularly under intense irrigation). Based on structural instability index, expressed as rapport between dispersion and macrohydrostability, it is observed that the soil showed low vulnerability to destructure.

A field experiment was conducted by Stamboliev and Petrov (2003) on maize hybrid Knezha 530 during 1990-92 in Bulgaria, to determine the effects of irrigation (0, 10, 30 and 70% EC), temperature, relative humidity and precipitation on yield. Result showed that, an increase in precipitation increased yield, regardless of irrigation treatments. A decrease in relative humidity decreased yield while the increase in temperature combined with an increase in irrigation significantly increased yield.

Dimitrov and Toncheva (2003) performed an experiment to determine the effects of irrigation, plant density and nitrogen fertilizer application on the yield of maize hybrid H 708. They conclude that, irrigation and plant density exhibited more significant effects on the crop yield than nitrogen fertilizer application.

An experiment was conducted by Galbiatti *et al.* (2004). The aim of this work was to verify the effect of the water deficit on maize (*Zea mays*) crop during vegetative growth, in its production and physiological seed quality. A completely randomized statistical design with four replications, in a 3x2 factorial array was used. The treatments consisted of three irrigation periods (during maize growth; after the emission of the 12th leaf, and 20 days after flowering time), using cross hybrids seedling BR201 and DINA-70. Results indicated that the water deficit on the vegetative growth (irrigation only after the emission of the 12th leaf) was the most harmful to maize plants and their production; the water deficit did not affect the physiological seed quality. The physiological and production parameters were better in the cross hybrid DINA-70 than in the hybrid BR201.

A study on crop management practices was carried out by Sanches and Flores (2002) with the new maize hybrid (H-311 P) for irrigated conditions to determine the optimum soil moisture, plant stand and nitrogen rate (N) for the highest yields in the hybrid. They found that, the effect of increasing soil moisture was positive on all recorded traits and the higher yields were obtained with 65 000 and 75 000 plants ha⁻¹. In 1997 no differences were observed among N rates, whereas in 1998, the rate 220 kg N ha⁻¹ produced the highest yield. The combination of 80% soil moisture, 65 000 plants ha⁻¹ and 220 kg ha⁻¹ of N resulted in a yield of 9 t ha⁻¹ with the H-311 P maize hybrid under irrigated conditions in Zacatecas.

- ✓ A field experiment was conducted by Saif *et al.* (2003) in Faisalabad, Pakistan, to study the effect of two planting patterns, i.e. 60 cm apart for single rows and 30/90 cm apart for double row strips (30 cm from row to row and 90 cm from strip to strip), and different irrigation levels, i.e. 0, 3, 4, 5, and 6 irrigations, on the growth and yield of maize. They observed that planting patterns did not influence growth and yield, but the irrigation level significantly affected the number of plants per plot at harvest, number of grains per cob, 1000-grain weight, biological yield, grain yield, and harvest index. Maximum grain yield (7.49 t ha^{-1}) was obtained under 30/90 cm spacing, double row strips (30 cm from row to row and 90 cm from row to row), and irrigation six times.

A study was conducted by Manuel *et al.* (2000) to investigate the effect of different irrigation intervals on maize (Farm 27) yield between the months of December and March, a period that falls within the dry season in Rivers State, Nigeria. It was found that maize **yield** increased with increasing irrigation interval. The maximum yield was obtained with 7 days interval. Further increase in irrigation interval to 9 days decreased the yield which indicated that the most efficient water utilization occurred with the irrigation interval of 7 days.

A field trial was carried by Prandzhev *et al.* (2000) to compare the influence of soil irrigation with pipes versus irrigation via closed furrows on the development of maize cv. Pioneer. The watering regime was regulated by means of a system of 3 tensiometers with spring vacuum meters situated at a depth of 20 cm and one at a depth of 65 cm. The watering periods were determined according to recommended critical potentials as measured by the shallow tensiometers for the crop's different growth phases. They observed that the size of the irrigation norms was determined by the increase in

momentary potential, as monitored during watering by the deep tensiometer. An increase in yield of 20% was achieved by a 50% decrease in irrigation norms.

The effects of water and nitrogen application on maize crop components (BR 201) and productivity in the cerrado area of Roraima, Brazil, were studied by Araujo *et al.* (1999). The statistical analysis consisted of a 4x4 randomized block design, using split plots with 16 treatments and 4 replications. The four water depths used were 392.6; 337.6; 282.6 and 227.6 mm and the four nitrogen rates were 0; 50; 100 and 150 kg ha⁻¹. The water depth used influenced the height of the maize plant. Irrigation and nitrogen levels influenced the mass of 100 seeds, the number of ears per hectare and the grain productivity. The seed N levels were linearly influenced by the nitrogen fertilization.

Studies were carried out by Xavier *et al.* (2000) during 1998-99 in Galicia, NW Spain, to investigate the effects of direct sowing and tillage, with or without irrigation, on crop yield of maize (cv. Clarica). They conclude that, no major differences were found between direct sowing and tillage, but irrigation increased crop yield significantly.

A field experiment was conducted by Tyagi *et al.* (1998) with maize cv. Ageti 76 was grown at densities of 53 333, 66 666 or 88 888 plants/ha, was irrigated at ID:CPE ratios of 0.2, 0.4 or 0.6, and was given 0, 75, 150 or 225 kg N/ha. Result revealed that, yield component values generally decreased with increasing plant density, while grain yield increased. Yield increased with increasing irrigation and N rates.

Maize cultivars were evaluated under irrigation and drought stress conditions by Terrazas *et al.* (1995). They found that, drought significantly lengthened the time to male flowering and stigma exsertion and the interval between male and female flowering, resulting in greater floral asynchrony. Drought also appreciably reduced plant height, prolificacy index

and the percentage of grains per ear. The interval between male and female flowering and the prolificacy index were correlated with yield under drought, suggesting that they could be used as indicators of drought tolerance in a population.

In a trials by Zhirkov (1995) with maize hybrid Knezha 530 was given 180 or 240 kg N, 120 or 180 kg P and 120 or 180 kg K/ha and given no irrigation (4500 or 5500 plants/ha) or at 80% of soil water capacity (6000 or 7000 plants/ha) with a 20, 40 or 60% decrease in the depth of water applied. Result showed that, yield decreased from 13.55 to 10.01 t/ha with reduction in irrigation rate and this effect was enhanced in warm, dry years. The yield decrease was proportionally greater at the lowest amount of irrigation. Plant density and fertilizer rate had no consistent effect on yield

✓Silking is delayed by soil water deficiency, so that the silking period does not correspond to the tasselling and pollen maturation periods, resulting in poor pollination and significant yield reduction. The effect of irrigation on seed yield depended on the amount and distribution of rainfall in the growing season, the edaphic and climatic conditions and the hybrid type. Most irrigated hybrids achieved 5-7 t/ha, while in dry years unirrigated hybrids gave 1-1.5 t ha⁻¹. Under extreme drought, yields lower than 1 t ha⁻¹ were found (Dragovic and Cirovic 1995).

In a field trial by Raju and Iruthayaraj (1995) on maize with 75, 125 or 175 kg N ha⁻¹ and irrigated (every furrow, alternate furrows or paired skip furrows) at irrigation water:cumulative pan evaporation ratios (IW:CPE) of 0.5 or 0.75. They observed that, grain yield was highest in both seasons with irrigating in every furrow at IW:CPE ratio of 0.75 and it increased with rate of N application. N, P and K uptake increased with rate of N application and were higher with irrigation at 0.75 IW:CPE in every furrow or alternate furrow irrigation rather than paired skip furrows.

In field experiments by Eliades (1993) on maize cv. Aris was given irrigation at 60, 80, 100 or 120% of the crop evapotranspiration using drip irrigation with pores spaced 40, 80 or 120 cm apart. They found that average grain yield was obtained with 560 mm of irrigation water, the equivalent of 0.60 evaporation from a screened Class A pan (Epan). Irrigation water requirements increased linearly between the initial and mid-season development stage from 0.26 to 0.90 of Epan, and subsequently progressively decreased to 0.57 of Epan. Reduction of the irrigation water by 20 or 40% caused 8 or 21% reduction in yield, respectively. Grain quality was satisfactory with all amounts of water. Dripper spacing did not affect yield or grain quality.

A field experiment with 3 levels of water management practices (rainfed with and without drainage, and irrigation with drainage) and 5 cropping systems (maize, groundnuts, turmeric, maize + turmeric and maize + groundnuts) was conducted by Singh *et al.* (2000) at Pusa, Bihar, India. Recommended rates of NPK fertilizers were applied. They observed that leaf area index and dry matter production of all the crops were maximum under irrigation with a proper drainage system. Maize-equivalent yield was significantly highest (8.2 t ha^{-1}) with maize + turmeric compared with sole crops or with maize + groundnuts in the first year. However, in the second year, the difference between maize + turmeric and maize + groundnuts was not pronounced. Net return in the first year did not differ between maize + groundnuts and maize + turmeric but in the second year maize + groundnuts gave higher returns. Irrigation with drainage provision resulted in maximum yield equivalent (7.5 t ha^{-1}) and net return (Rs 11 752) compared with the other water management treatments.

A field study was conducted by Bharati *et al.* (2007) in Pusa, Bihar, to evaluate the effect of irrigation on yield and plant water relations of winter maize-based intercropping

systems: sole maize; maize-potato; maize-rajmash; and maize-toria. Irrigation treatments were (IW:CPE) 0.6, 0.8, 1.0 and 1.2. They observed that increase in maize equivalent yield was obtained up to 5 irrigations each of 6 cm scheduled through IW:CPE ratio of 1.2 (87.6 and 92.84 q ha⁻¹), followed by 1.0 (84.68 and 89.65 q ha⁻¹), 0.8 (78.88 and 83.67 q ha⁻¹), and 0.6 ratio (69.45 and 75.00 q ha⁻¹), in the first and second years, respectively. Maximum maize equivalent yield was observed under maize-potato system (123.48 and 140.07 q ha⁻¹), followed by maize-rajmash (83.83 and 82.64 q/ha) and maize-toria (57.73 and 61.86 q ha⁻¹). The water use efficiency was maximum (average of 2 years) with lower levels of irrigation and among, the intercrops, water use efficiency based on maize yield was recorded with potato (219.39 kg ha⁻¹-cm, and 561.89 kg ha⁻¹-cm), and lowest with toria (119.90 kg ha⁻¹-cm and 256.0 kg ha⁻¹-cm), respectively. The water requirement was maximum under 1.2 IW:CPE ratio due to the maximum number of irrigation. In both years, the water requirement was lowest in maize-rajmash.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at Research Field and Laboratory in the Department of Crop Physiology and Ecology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, during the period of November, 2010 to July, 2011. Details of the methodology of the experiment followed during the research period are presented in this chapter.

3.1 Experimental site and soil

The location of the experimental site was at 25°38' N latitude and 88°41' longitude 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). The soil was sandy loam and fertility status of the soil is presented in Appendix III.

3.2 Climate and Weather

The experimental field was under subtropical climate characterized by winter during the month of November, 2010 to July, 2011. The means of meteorological information, like precipitation, relative humidity, maximum temperature, minimum temperature and average temperature, day length and sunshine hours of the experimental site during the crop growing period are presented in Appendix IV.

3.3 Experimental design and layout

The experiment was laid out in a two factors Randomized Complete Block Design (RCBD) with three replications. The experimental plot was first divided into three blocks

each representing a replication. Each block then divided into nine-unit plot of 3m x 3m sizes. The distance between block to block was 1m and plot to plot was 0.5m.

3.4 Experimental treatments

The experiment comprised of two sets of factors such as

Factor A: Three maize variety

V_1 = NK 40

V_2 = Hybrid 981

V_3 = BHM 11

Factor B: Three irrigation level

I_0 = control

I_1 = 300 mm in total life span

I_2 = 450 mm in total life span

3.5 Land preparation

The selected land was first opened with a tractor and exposed to sunlight for a week. The land was then harrowed, ploughed and cross-ploughed six times by a power tiller followed by laddering to obtain a good tilt. Later on, large clods were broken into small pieces, all weed as well as crop residues were removed and the land was leveled to obtain a desirable tilt for sowing of seed. Finally, the experimental plot was divided into 27 plots as stated earlier.

3.6 Fertilizer application

Fifteen days ahead of sowing, whole amount of cow dung was applied. Nitrogen was applied in the form of urea as per experimental treatment TSP, MP, Gypsum, Zinc sulphate, Boric acid and half of urea was applied as the basal dose. The remaining half of urea was top dressed in two equal splits, first half at knee height stage i.e. 30 days after sowing (DAS) and the rest half at about one week before silking (50 DAS).

Table 1: Fertilizer application

Nutrients	Nutrient dosed (kg/ha)	Source
N	180	Urea
P	24	TSP
K	60	MP
S	12	Gypsum
Zn	20	Zinc Sulphate
B	1.0	Boric acid

Source: BARC, Fertilizer Recommendation Guide, 1997

3.7 Planting material

Three hybrid variety of maize i.e., NK 40, Hybrid 981 and BHM 11 were used as planting materials.

3.8 Sowing of seed

The seeds were sown in rows as per treatment on 12 November 2010. Two healthy seeds were sown in each pit. After germination a single healthy plant was maintained per pit.

3.9 Irrigation

During the growing period, the experimental land was irrigated three times first at 30 DAS, the second at 55 DAS and the third at 80 DAS. A Bucket was used for irrigation.

The plots were irrigated as per the experimental treatments as follows:

- i) I_0 = No irrigation
- ii) I_1 = 300 mm irrigation in total life span
- iii) I_2 = 450 mm irrigation in total life span

At the time of irrigation sufficient care was taken to avoid the flow of irrigation water from one plot to another. Irrigation water coming through the channel was uplifted to each

plot using a bucket. An equivalent of 300 mm water equal to 6 Bucket of water and 450 mm water equal to 9 Bucket of water was applied for irrigation.

3.10 Weeding

Weeding was done twice during the growing period. The first weeding was carried out at 25 DAS and the second one at 55 DAS.

3.11 Earthing-up

Ear thing-up was made twice during the growing period first at 30 days after sowing. The second one was preceded by top dressing of remaining half of urea.

3.12 Sampling and data collection

Records on the emergence of seeds were take every alternate day up to 10 days after sowing and finally the percentage of emergence were calculated. Variation of days required to emergence of seeds in each plots were also recorded. With the advancement of plant growth the following observation

Three plants per plot randomly selected & plant height was measured at 15 days interval starting from 30 days and continued till maturity of the crop from the base of the plants to tip of the longest leaf.

To study the ontogenetic growth characteristics a total nine harvests including final harvest were made. Data were collected on soil moisture, some phenological characteristics and yield and yield attributes. The first crop sampling was done at 30 DAS and continued with 15 days interval up to 150 DAS. From each plot three plants were randomly selected and uprooted to collect necessary parameters at every harvest. The plants were separated into leaves, stems, and spikes and the corresponding dry weight were recorded after oven drying at $80 \pm 2^{\circ}\text{C}$ for 72 hours. The leaf area of each sample was measured by digital leaf area meter (Model: CI 202, USA).

3.12.1 Phenological parameters

Following phonological parameters were observed and calculated.

- i) Emergence: Days when 50% seeds were completed emergence.
- ii) Tasseling stage: Days when tassel come out at 50% of plants.
- iii) Cob initiation stage: Days when cob initiation taken place at 50% of plants.
- iv) Silking stage: Days when silk come out at 50% of plants.
- v) Pollen shading stage: Days when pollen dusting was started at 50% of plants.
- vi) Maturity stage: The number of days from sowing to maturity was determined by cob-sheath turned brownish, grains became hard and silks get dried completely.
- vii) Leaf area per plant was measured by a digital leaf area meter (Model: CI 202, USA) at 10 days interval.

3.12.2 Morpho-physiological and growth parameters

Initially the entire sample from a plot was considered for observation. But with the advancement of growth, when balk of sample increased, a sub-sample representing at least 25% of the fresh matter was used. Comparing the sub-sample with total harvest, leaf area and dry matter per meter were calculated. Standard growth analyses were furnished such as leaf area index (LAI), crop growth rate (CGR), leaf area duration (LAD), relative growth rate (RGR) and net assimilation rate (NAR) following the standard formulate of Radford (1967) and Hunt (1978).

- I) Total dry matter (TDM): The total dry matter (gmm^{-2}) was calculated by summing of leaf dry weight, stem dry weight, tassel dry weight, cob dry

weight, seed weight (when present) and the dry weight was taken in an electric balance.

- II) Leaf area index (LAI): It is the ratio of leaf area and ground area of a plant

$$LAI = \frac{1}{P} \times LA$$

- III) Leaf area duration (LAD): It expresses the magnitude and persistence of leaf are or leafiness during the period of crop growth (Gardner *et al.* 1985).

$$LAD = \frac{(LAI_2 + LAI_1) \times (T_2 - T_1)}{2} \text{ day}$$

- IV) Crop growth rate (CGR): Rate of dry matter production per unit time per unit land are.

$$CGR = \frac{W_2 - W_1}{P(T_2 - T_1)} \text{ g / m}^2 \text{ / day}$$

- V) Relative growth rate (RGR): Rate of dry matter production per unit dry matter per unit time.

$$RGR = \frac{l_n W_2 - l_n W_1}{T_2 - T_1} \text{ g / g / day}$$

- VI) Net assimilation rate (NAR): Rate of dry matter production per unit leaf area per unit time.

$$NAR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{l_n LA_2 - l_n LA_1}{LA_2 - LA_1} \text{ g / m}^2 \text{ / day}$$

Where,

LA = Total leaf area

LA₁ = Total leaf area at time T₁

LA₂ = Total leaf area at time T₂

W₁ = Total dry weight at time T₁

W₂ = Total dry weight at time T₂

P = Ground area

l_n = Natural logation

3.12.3 Moisture Retention Capacity (MRC)

Three matured flag leaves were collected from each replication of each variety. Their fresh weights were taken separately. Then they were weighed at 30 minutes interval for 8 times. After that the time interval was 90 minutes. The leaves were dried in an oven at 85°C for 24 hours before weighing. During the experiment the average relative humidity was 65% and the minimum and the maximum temperatures were 21°C and 24°C, respectively. The MRC was calculated by following formula:

$$\text{MRC} = \frac{\text{FW} - \text{DW}}{\text{FW}} \times 100$$

Where,

FW = Fresh weight

DW = Dry weight

3.2.4 Relative leaf water Content (RLWC)

Relative leaf water content (RLWC) was determined from the flag leaves. The leaves were collected at 8 am, 12 noon and 4 pm. Three leaves were taken from each replication of each variety of each treatment. Their fresh weights were taken immediately and were sinked into water and kept in test tube for four hours. After 4 hours when the cells of the leaves became fully turgid, they were taken out from water and after drying with blotting paper their turgid weights were determined. Then the leaves were dried in an oven and weighed. The relative leaf water content was calculated from the following formula (Barrs and weatherly 1962)

$$\text{Relative leaf water content (RLWC)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3.12.5 Yield and yield components

The experimental plots were harvested separately at full maturity. The harvested crop of each plot was bundled separately, tagged properly and brought to the clean threshing floor. The bundles were dried on open sunshine, threshed and then seeds were cleansed. The seed and straw weights for each plot were recorded after proper drying in the sun. Prior to harvesting, 10 plants were selected randomly from each plot and uprooted carefully for collecting data on yield contributing characters. Data on yield and yield components were collected, such as,

3.12.5.1 Plant height

Plant height was measured in centimeters from the base of the plant up to the base of the upper most ear of each selected plant at dry silk stage.

3.12.5.2 Number of cobs per plant

Numbers of cobs were recorded at maturity stage.

3.12.5.3 Cob length

It was recoded in centimeters from the base to the tip of the cob.

3.12.5.4 Cob diameter

At the middle of the cob, breadth was measured in centimeters.

3.12.5.5 Number of rows per cob

The number of row per was counted at harvest.

3.12.5.6 Number of grains per row

The number of grain per cob row was counted at harvest.

3.12.5.7 Grains per cob

It was counted after harvest.

3.12.5.8 100- grain weight

Hundred well dried and cleaned grains were randomly selected from each treatment and the weight in grams was determined by a fine electric balance.

3.12.5.9 Grain yield (t ha⁻¹)

Grain yield was measured in t ha⁻¹ after harvest. Grain yield also adjusted to 12% moisture.

3.13 Harvest index

Harvest index (HI) was calculated by dividing economic yield by biological yield of plant in each plot and expressed in percentage.

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

3.14 Statistical analyses

All the necessary parameters recorded will be analyzed statistically. A program called Microsoft Excel 2000 was used for the spreadsheet analysis and numerical calculations. All the recorded data was statistically analyzed following the ANOVA technique and the significance of mean differences were adjusted by Duncan's New Multiple Range Test, DMRT (Gomez and Gomez 1984) with the help of computer package M-STAT.

CHAPTER 4

RESULTS AND DISCUSSION

The results of the study have been presented in several Tables and Figures. Adequate discussion and possible interpretations whenever suitable have been provided in this chapter.

4.1 Phonological parameters

4.1.1 Days to tasseling

The number of days required to tasseling is presented in Table 2. Days to tasseling was significantly influenced by variety. The maize variety NK 40 was taken the maximum days (55.11) to attain their tasseling stage followed by variety BHM 11 (54.77 days). While the maize variety Hybrid 981 needed the lowest days (54.00) to attained their tasseling stage.

Days to tasseling was also significantly influenced by different levels of irrigation. Results revealed that tasseling was earlier in control condition. The I_2 plants took the maximum days (64.11) for tasseling and the lowest days (46.44) was taken for tasseling in I_0 treatment. Similar result was also reported by Sepaskhah and Parand (2006), YaJun *et al.* (2006) and Hossain (2008) in maize. They stated that irrigated plant required maximum days to tasseling than non-irrigated plant.

The interaction effect of variety and irrigation level was also significant. The lowest days (45.33) were required for tasseling in $V_1 \times I_0$ combination. On the other hand the highest days

Table 2. Some phenological stages of maize as affected by variety and irrigation level

Treatments	Day to tasseling	Day to cob initiation	Days to silking	Days to pollen shading	Days to maturity
Variety					
V ₁	55.11 a	75.33 a	79.88 a	81.22 b	110.20 a
V ₂	54.00 c	73.66 c	60.33 c	79.55 c	108.00 c
V ₃	54.77 b	75.11 b	78.55 b	80.78 b	109.30 b
Irrigation level					
I ₀	46.44 c	66.44 c	58.22 c	72.33 c	101.30 c
I ₁	53.33 b	73.44 b	71.33 b	79.22 b	108.00 b
I ₂	64.11 a	84.22 a	85.24 a	90.00 a	118.00 a
Interaction (Variety x Irrigation level)					
V ₁ ×I ₀	45.33 h	66.33 g	71.66 f	72.66 g	101.66 g
V ₁ × I ₁	54.33 d	74.33 d	79.00 d	80.66 d	109.66 d
V ₁ × I ₂	64.66 a	84.66 a	89.66 a	90.33 a	119.33 a
V ₂ × I ₀	47.33 f	66.33 g	71.00 h	72.00 i	101.00 i
V ₂ × I ₁	51.33 e	71.33 e	76.00 e	77.00 f	106.00 f
V ₂ × I ₂	63.33 c	83.33 b	88.66 c	89.66 c	117.00 c
V ₃ × I ₀	46.66 g	66.66 f	71.33 g	72.33 h	101.33 h
V ₃ × I ₁	54.33 d	74.66 c	79.00 d	80.00 e	109.00 e
V ₃ × I ₂	64.33 b	84.66 a	89.00 b	90.00 b	117.66 b
CV (%)	4.58	5.48	3.59	3.47	2.79

In a column, figures having same letter(s) do not differ significantly at $P \leq 0.05$ by DMRT. Here, V₁ =NK 40, V₂ =Hybrid 981, V₃ =BHM 11, I₀ =No irrigation, I₁=300 mm irrigation in total life span and I₂=450 mm irrigation in total life span.

(64.66) were required for tasseling in V_1 plants combined with 450 mm irrigation in total life cycle (I_2). The second highest days (64.33) and third highest days (63.33) required for tasseling were recorded in V_3 with I_2 irrigation and V_2 with I_2 combination. Other treatments performed moderately.

4.1.2 Days to cob initiation

The number of days required to cob initiation is presented in Table 2. Days to cob initiation was significantly influenced by variety. The highest days (75.33) to cob initiation required in the maize variety NK 40 and the lowest days (73.66) was recorded in the variety hybrid 981 followed by variety BHM 11 (75.11 days).

Days to cob initiation was significantly influenced by different levels of irrigation (Table 2). Results showed that cob initiation was taken maximum days (84.22) in the plants grown with application of 450 mm irrigation in total life span and the controlled plants needed the lowest days (66.44) for cob initiation. Similar result was also reported by YaJun *et al.* (2006) in maize. They observed that all the phenological stage taken maximum days with irrigation than control.

The interaction effect of variety and irrigation levels on days required for cob initiation was of maize statistically significant (Table 2). The lowest day (66.33) required for cob initiation in variety Hybrid 981 (V_2) combined with control (I_0) irrigation followed by variety BHM 11 with no irrigation (66.66). On the other hand, the highest days (84.66) required for cob initiation in variety NK 40 with combination of I_2 (application of 450 mm water throughout the total life span). Statistically similar result was also recorded in BHM 11 with I_2 and Hybrid 981 with I_2 i.e., 84.66 days and 83.33 days, respectively required for cob initiation.

4.1.3 Days to silking

The number of days required to silking significantly affected by variety is presented in Table 2. The lowest days (60.33) was needed for silking in the maize Hybrid 981 and the highest day (79.88) was required in variety NK 40.

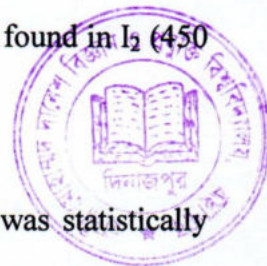
Days to silking was significantly influenced by different levels of irrigation (Table 2). Result showed that silking was earlier in the plants grown with no irrigation. The highest number of days (85.24) for silking was found in I_2 (application of 450 mm water in total life span) and the lowest (58.22) days required in I_0 (control) condition. The result of the present study is similar to the result of Sepaskhah and Parand (2006) and YaJun *et al.* (2006) where, they found that silking taken higher days in irrigated crops.

The interaction effect of variety and irrigation levels on days to silking was statistically significant (Table 2). The treatment combination of variety Hybrid 981 with control treatment needed lowest days (71.00) for silking whereas variety NK 40 with 450mm irrigation (I_2) required the highest days (89.66) for silking which was at par with the treatment combination of variety BHM 11 with 450 mm irrigation ($V_3 \times I_2$) and variety Hybrid 981 with 450mm water ($V_2 \times I_2$) that is 89.00 days and 88.66 days, respectively.

4.1.4 Days to pollen shading

The number of days required to pollen shading is presented in Table 2. Days to pollen shading was significantly influenced by different maize variety. The lowest day (79.55) was taken for pollen shading in variety Hybrid 981 and the highest days (81.22) was needed in variety NK 40 followed by BHM 11 (80.78 days).

Days to pollen shading was significantly influenced by different levels of irrigation (Table 2). Table showed that pollen shading was delayed in the plants grown with 450mm irrigation in total life span. The highest days (90.00) to pollen shading was found in I_2 (450 mm water) and the lowest days (72.33) was required in I_0 .



The interaction effect of variety and irrigation levels on pollen shading was statistically significant (Table 2). The treatment combination of V_2 (var. Hybrid 981) with I_0 (control) needed lowest days (72.00) for pollen shading followed by V_3 (BHM 11) with I_0 (72.33 days), whereas, V_1 (var. NK 40) with I_2 (450 mm irrigation in total life cycle) required the highest days (90.33) needed for pollen shading, which was statistically similar with the treatment combination of $V_1 \times I_2$ (90.00 days) and $V_2 \times I_2$ (89.66 days), respectively.

4.1.5 Days to maturity

The number of days required to maturity is presented in Table 2. Days to maturity was significantly influenced due to three different maize varieties. The lowest days (108.00) needed for maturity was recorded in the maize var. Hybrid 981 and the highest days for maturity (110.20) was recorded in var. NK 40 followed by var. BHM 11 (109.30 days).

Days to maturity was significantly influenced by different levels of irrigation (Table 2). Table showed that plants grown with I_2 (application of 450 mm water in total life cycle) needed highest days (118.00) for maturity whereas I_0 (control) required the lowest days (101.30) for maturity. Similar result was also reported by Hossain (2008) in maize and Hafiz *et al.* (2009) and Rahman (2008) in barley. They stated that irrigated plant takes maximum days to maturity than non-irrigated plant.

The interaction effect of variety and irrigation levels on days to maturity was statistically significant (Table 2). Maize variety Hybrid 981 (V_1) with I_0 (control) needed lowest days

(101.00) for maturity. This was at par with var. BHM 11 (V_3) with control (I_0) and var. NK 40 (V_1) with I_0 (control) i.e., 101.33 days and 101.66 days, respectively. Whereas, the maize var. NK 40 (V_1) with I_2 (application of 450mm irrigation in total life span) required the highest days (119.33) for maturity followed by $V_3 \times I_2$ and $V_2 \times I_2$ i.e. 117.66 days and 117.00 days, respectively.

4.2 Morpho-physiological and growth parameters

4.2.1 Plant height

Plant height of maize as influenced by variety and irrigation level at different days after sowing (Table 3). Plant height was significantly influenced by variety in association with different levels of irrigation. Results showed that plant height increased steadily from 30 to 75 DAS after that plant height increased sharply up to 120 DAS. Results revealed that maize var. NK 40 (V_1) produced tallest plant than var. BHM 11 (V_3) and var. Hybrid 981 (V_2). While maize var. Hybrid 981 produce the shortest plant from 30 to 120 DAS. The maize var. BHM 11 performed moderately in this case.

Plant height showed a significant variation due to different irrigation levels (Table 3). Result showed that, plant height increase with the increasing irrigation level. The highest plant height was recorded with the application of 450 mm irrigation in total life cycle (I_2 treatment) and the lowest plant height was recorded in the case of I_0 treatment (control). Similar result was also reported JinFeng *et al.* (2006), YaJun *et al.* (2006), Singh and Sudhanshu (2005), Sepaskhah and Parand (2006), Kusaksz and Kusaksz (2005) and Jiotode *et al.* (2002).

Table 3. Plant height of maize as influenced by variety and irrigation level at different days after sowing

Treatments	Days after sowing						
	30	45	60	75	90	105	120
Variety							
V ₁	24.51 a	37.54 a	50.11 a	64.798 a	113.80 a	128.70 a	163.50 a
V ₂	23.98 c	31.25 c	40.91 c	55.88 c	103.00 c	116.10 c	156.70 c
V ₃	24.12 b	34.42 b	46.46 b	59.88 b	105.10 b	123.80 b	157.00 b
Irrigation level							
I ₀	22.77 c	29.63 c	39.49 c	52.02 c	87.74 c	101.60 c	128.10 c
I ₁	24.31 b	34.46 b	44.92 b	60.15 b	109.00 b	125.30 b	163.00 b
I ₂	25.53 a	39.12 a	53.25 a	68.55 a	125.25 a	141.80 a	186.10 a
Interaction (Variety x Irrigation)							
V ₁ × I ₀	22.20 i	30.46 g	42.16 f	54.57 g	86.90 h	102.63 h	120.53 i
V ₁ × I ₁	25.13 c	37.00 c	48.27 c	63.83 c	110.67 e	125.03 e	173.27 d
V ₁ × I ₂	26.20 a	45.16 a	59.90 a	76.50 a	143.83 a	158.56 a	196.73 a
V ₂ × I ₀	22.76 h	28.60 i	37.10 a	50.00 i	90.96 g	98.66 i	138.13 g
V ₂ × I ₁	24.06 e	31.46 f	40.76 g	56.50 f	110.86 d	120.76 f	152.26 f
V ₂ × I ₂	25.53 b	33.70 e	44.86 e	61.15 d	113.53 c	128.76 d	180.53 c
V ₃ × I ₀	23.36 g	29.83 h	39.20 h	51.50 h	85.37 i	103.40 g	125.53 h
V ₃ × I ₁	23.73 f	34.93 d	45.73 d	60.13 e	105.46 f	130.03 c	163.60 e
V ₃ × I ₂	24.86 d	38.50 b	55.00 b	68.00 b	118.10 b	138.00 b	181.00 b
CV (%)	5.54	6.87	6.59	12.34	12.58	11.54	15.48

In a column Figures having same letter(s) do not differ significantly at $P \leq 0.05$ by DMRT. Here, V₁=NK 40, V₂=Hybrid 981, V₃=BHM 11, I₀=No irrigation, I₁=300 mm irrigation in total life span and I₂=450 mm irrigation in total life span.

Different maize variety in combination with irrigation level significantly influenced the plant height of maize are presented in Table 3. Results showed that, maize var. NK 40 (V_1) with the combination of I_2 (application of 450 mm irrigation in total life span) produce the tallest plant after 120 days of sowing.

4.2.2 Total dry matter

The effects of different varieties and irrigation levels on total dry matter (gm^{-2}) production of maize are presented in Figure 1. TDM production varied significantly due to different varieties and irrigation levels. Results revealed that the effect of irrigation on TDM production pattern was almost similar for all varieties. It was observed that TDM increased gradually from 30 to 60 DAS and thereafter increased sharply with the advancement of the growth period. However, results indicated that TDM production increased with increasing irrigation level till 135 DAS and thereafter reached a constant level. The highest TDM production was observed in maize var. NK 40 with the application of 450 mm irrigation in total life span (I_2) at all the growth stages, followed by var. BHM 11 with 300 mm irrigation in total life span ($V_3 \times I_1$) and var. Hybrid 981 with no irrigation ($V_3 \times I_0$). Similar result was reported by Singh *et al.* (2000), Jiotode *et al.* (2002), Iqbal *et al.* (2003), Kusaksz and Kusaksz (2005), ChunYan *et al.* (2004), YaJun *et al.* (2006) and JinFeng *et al.* (2006) in maize. They reported that TDM increased with increasing level of irrigation at all growth stages. Similar result was also reported by Sing *et al.* (2006) and Moussa and Maksoud (2004) in wheat.

4.2.3 Leaf area index (LAI)

Leaf area index measured for different maize varieties and irrigation levels at different days after sowing (Figure 2). The pattern of LAI curves was found almost similar in all varieties

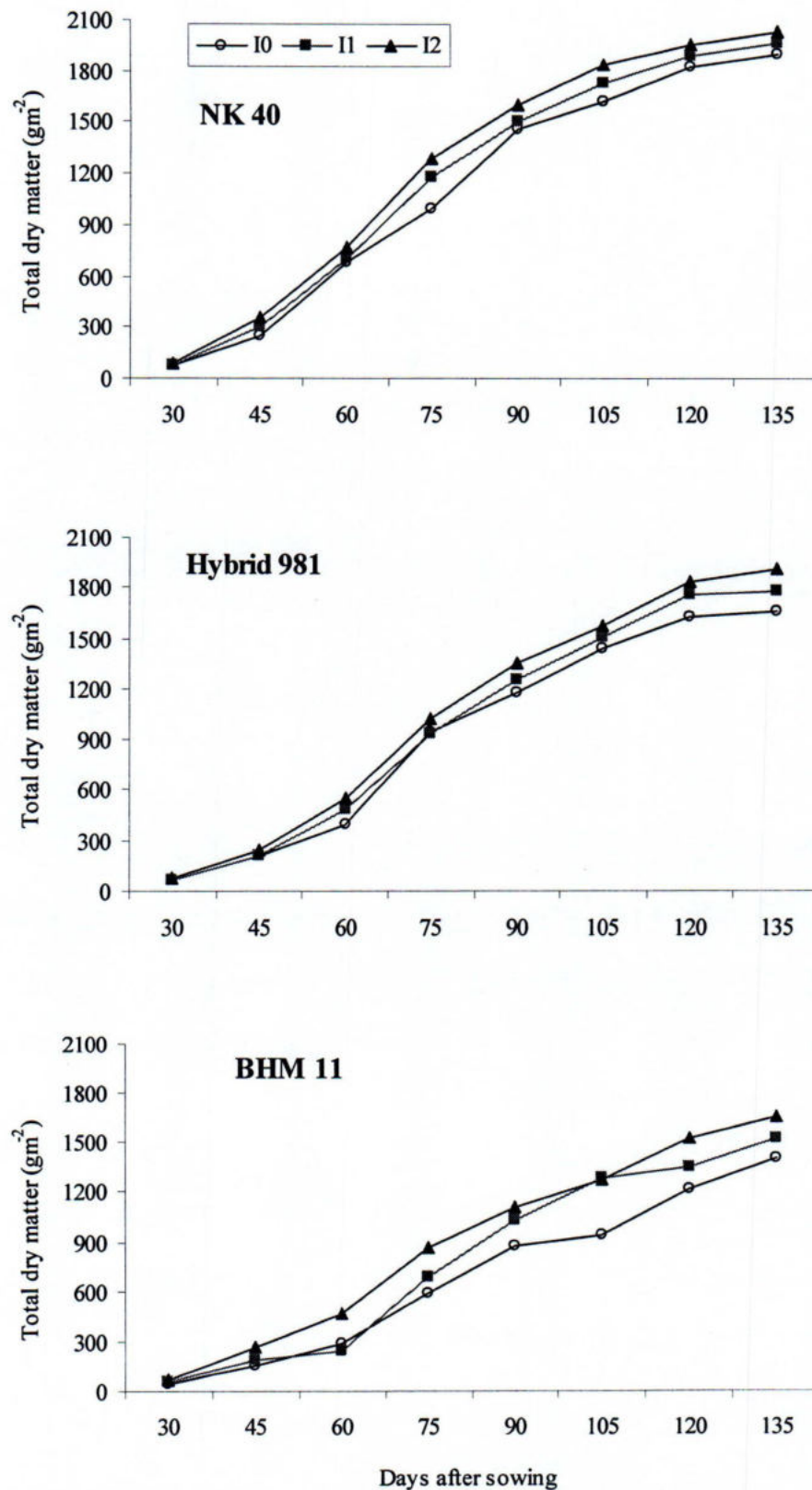


Figure 1. The pattern of total dry matter (g/m^2) accumulation with time in three maize varieties (V_1 =NK 40, V_2 =Hybrid 981, and V_3 =BHM 11) under different irrigation levels (I_0 =No irrigation, I_1 =300 mm irrigation in total life span and I_2 =450 mm irrigation in total life span)

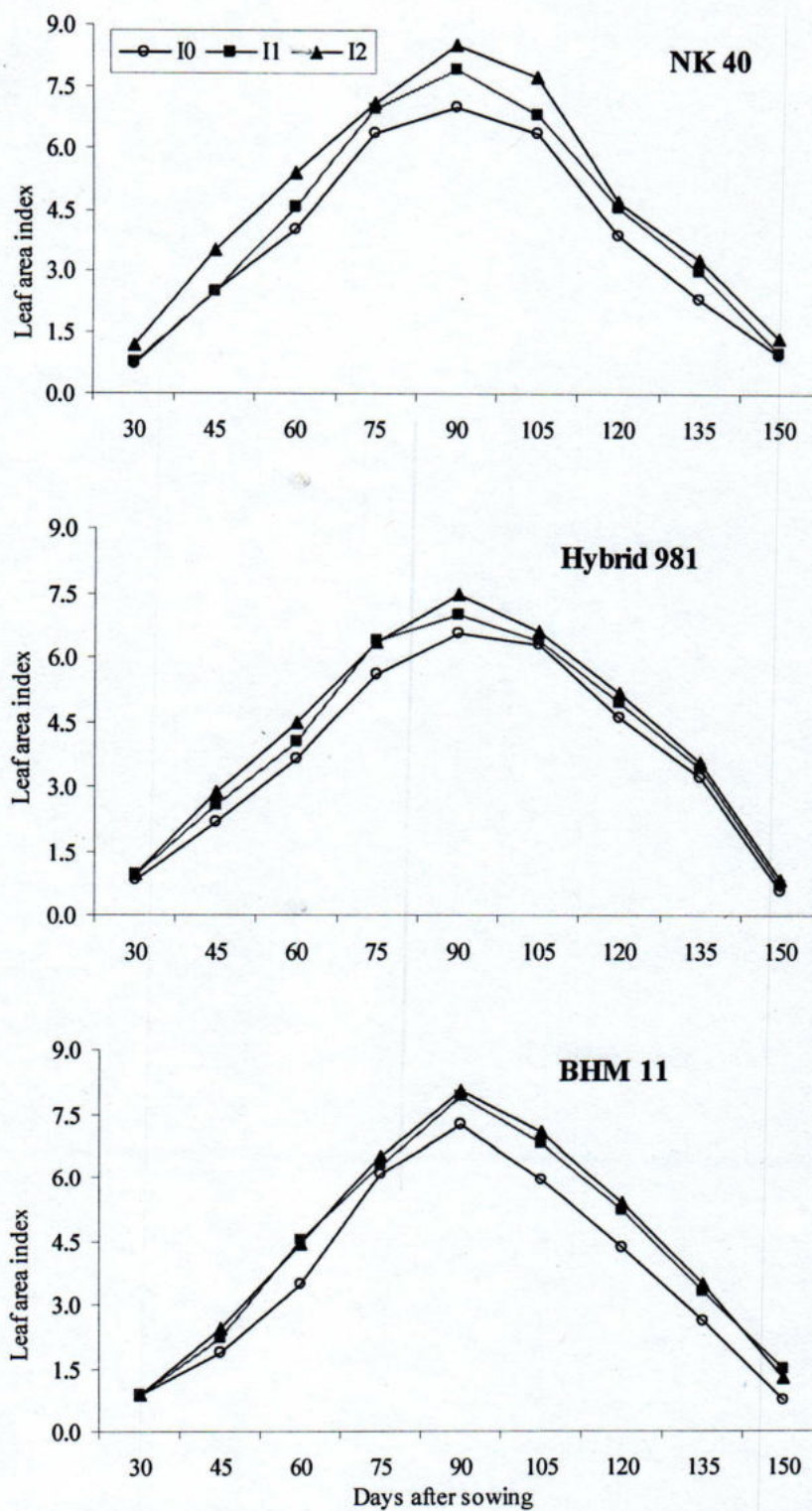


Figure 2. The pattern of leaf area index with time in three maize varieties (V_1 =NK 40, V_2 =Hybrid 981, and V_3 =BHM 11) under different irrigation levels (I_0 =No irrigation, I_1 =300 mm irrigation in total life span and I_2 =450 mm irrigation in total life span)

for different levels irrigation. LAI varied significantly due to variety and different levels of irrigation at 30 to 150 DAS. The LAI values increased progressively up to 90 DAS and afterwards declined in the same way till maturity. The declining of leaf area index after attaining a peak value was due to leaf rolling and senescence with aging. The maize var. NK 40 was found to have the ability to produce maximum LAI (8.50) at 90 DAS with 450 mm irrigation (I_2) and the lowest LAI was produced with no irrigation (I_0) in association of maize var. Hybrid 981. This result is in agreements with Kusaksz and Kusaksz (2005), ChunYan *et al.* (2004) and YaJun *et al.* (2006) in maize. They stated that irrigated plants had the highest LAI in every sampling. Higher LAI values due to increase in irrigation frequencies were also reported by Dhuka *et al.* (2006) and Pal *et al.* (1996) in wheat, and Hafiz *et al.* (2009) in barley.

4.2.4 Leaf area duration (LAD)

Leaf area duration expresses the magnitude and persistence of leaf area or leafiness during the period of crop growth (Gardner *et al.* 1985). LAD was evaluated for three different maize varieties and irrigation levels (Figure 3). Results revealed that LAD increased with the increasing irrigation level. The pattern of LAD curves was found almost similar in all maize varieties for each irrigation level. LAD varied significantly due to variety and irrigation level at 30-45, 45-60, 60-75, 75-90, 90-105, 105-120, 120-135 and 135-150 DAS for all treatments combination. The LAD values increased progressively up to 90-105 DAS and afterwards declined till maturity. Decline in LAD after attaining a peak was due to leaf rolling and senescence. I_0 (no irrigation) produced the lowest LAD for all the varieties. On.

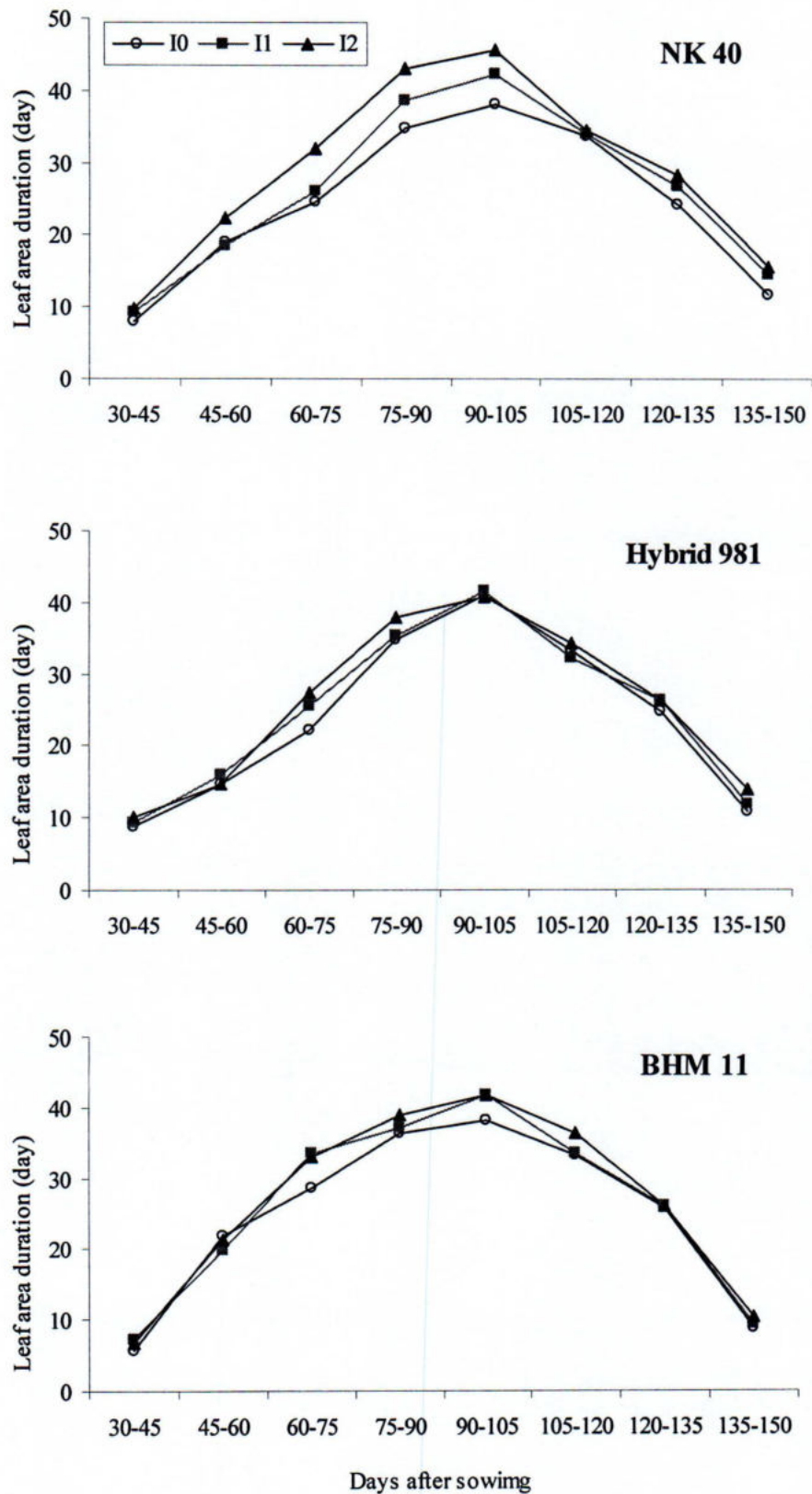


Figure 3. The pattern of leaf area duration (day) with time in three maize varieties (V_1 =NK 40, V_2 =Hybrid 981, and V_3 =BHM 11) under different irrigation levels (I_0 =No irrigation, I_1 =300 mm irrigation in total life span and I_2 =450 mm irrigation in total life span)

the other hand, the highest value of LAD was recorded with I₂ (450 mm irrigation in total life span). Among the different varieties, maize var. NK 40 (V₁) produced the highest LAD while the var. Hybrid 981 had the lowest LAD in all stages of growth. This result is in agreements with Pal *et al.* (1996) in wheat and Hafiz *et al.* (2009) and Rahman (2008) in barley. Results further revealed that LAD was greater in irrigated plots than in control plots

4.2.5 Crop growth rate (CGR)

The pattern of crop growth rate ($\text{gm}^{-2}\text{day}^{-1}$) of three maize varieties under different irrigation levels is presented in Figure 4. Crop growth rate was significantly influenced by variety and irrigation level. Results revealed that the effect of irrigation on CGR was almost similar for every variety. In all varieties and irrigation regimes CGR was started from a lower value and reached at peak (90-120 DAS) and thereafter showed a declining pattern in all cases. Generally, 450 mm irrigation (I₂) produced the highest CGR in all the cases. The highest ($37.29 \text{ gm}^{-2}\text{day}^{-1}$) CGR at 90-105 DAS was observed in the maize var. NK 40 with I₂ (450 mm irrigation in total life span) and the lowest ($30.90 \text{ gm}^{-2}\text{day}^{-1}$) in var. Hybrid 981 (V₂) with I₀ (no irrigation) treatment at 90-105 DAS. Similar result was reported by Riaz *et al.* (2002) in maize. They reported that CGR increased with the increasing irrigation level. The results of the present study also supported with the findings of Abdorrahmani *et al.* (2005), Sarker and Paul (1998), Pal *et al.* (1996) in wheat and Hafiz *et al.* (2009) in barley.

4.2.6 Relative growth rate (RGR)

The influence of variety and irrigation level on RGR was calculated from 30-45 to 135-150 DAS. Irrespective of variety and irrigation level, the RGR showed its highest values in the early stage of plant development (Figure 5). This result partially alike with the findings of

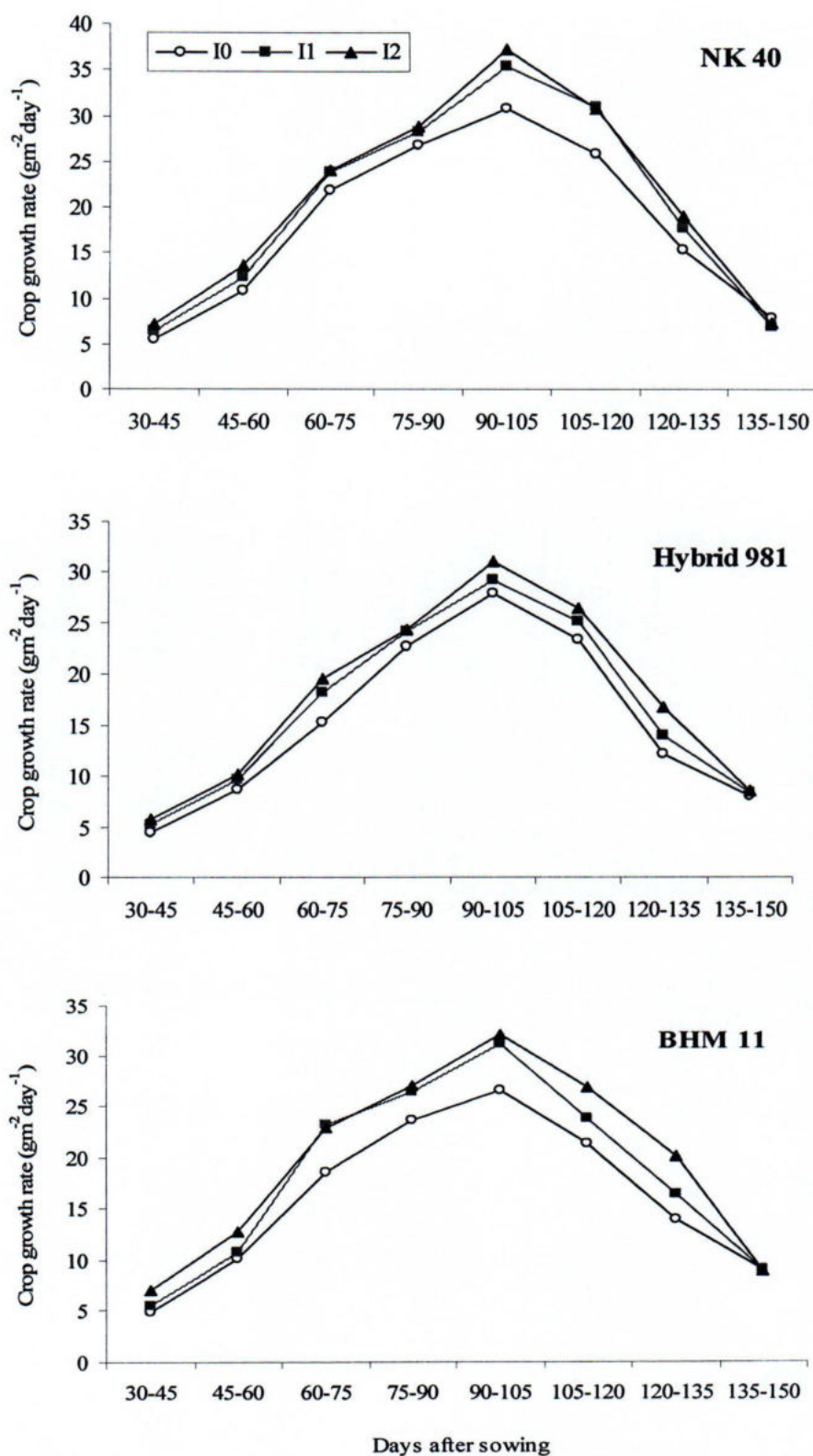


Figure 4. The pattern of crop growth rate ($\text{gm}^{-2}\text{day}^{-1}$) with time in three maize varieties (V_1 =NK 40, V_2 =Hybrid 981, and V_3 =BHM 11) under different irrigation levels (I_0 =No irrigation, I_1 =300 mm irrigation in total life span and I_2 =450 mm irrigation in total life span)

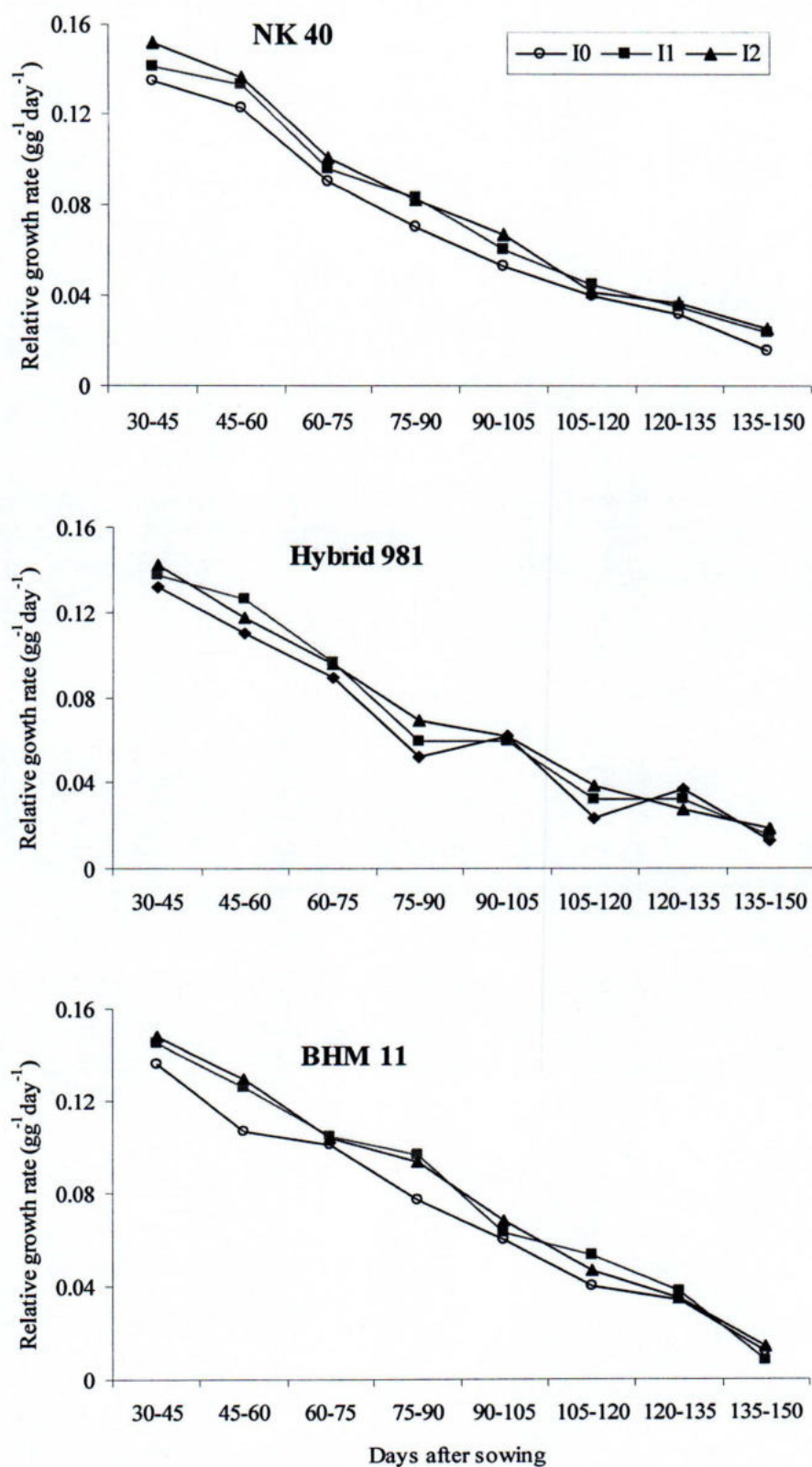


Figure 5. The pattern of relative growth rate ($\text{gg}^{-1} \text{day}^{-1}$) with time in three maize varieties (V_1 =NK 40, V_2 =Hybrid 981, and V_3 =BHM 11) under different irrigation levels (I_0 =No irrigation, I_1 =300 mm irrigation in total life span and I_2 =450 mm irrigation in total life span)

VanEijnatten (1963) who observed higher RGR at early stage of development and then a slow decline. Results revealed that irrigation had significant influence on RGR at all growth stages. There was an inverse relationship between RGR and plant age in all treatments. The RGR gave the highest values at 30-45 DAS and then followed by a declining trend till maturity. However, results revealed that I_2 i.e. application of 450 mm irrigation in total life span produced the maximum RGR with the maize var. NK 40 (V_1). The control treatment (I_0) gave the minimum RGR with the var. Hybrid 981 (V_2). The results of the present study is in agreement with the results of Hafiz *et al.* (2009) in barley where they observed greater RGR was recorded in irrigated plant over control.

4.2.7 Net assimilation rate (NAR)

The NAR, the assimilatory power of the leaf, is a complex growth parameter and is regulated by environmental variables. The significant variation of NAR due to variation in variety and irrigation level at different stages of growth is presented in Figure 6. NAR was calculated by harvest interval method for all the varieties and irrigation treatments. Results revealed that there was an inverse relationship between NAR and plant age. The highest NAR was recorded at 30-45 DAS and then followed by a continued decrease until attaining the lowest value at 135-150 DAS with heavy fluctuations for all varieties and irrigation treatments. However, results showed that I_2 in early stages had better influence on NAR of maize at most of the growth stages followed by I_1 (300 mm irrigation in total life span) and I_0 (no irrigation) respectively. Control (I_0) had the minimum NAR with the var. Hybrid 981 at all growth stages. The results of the present study as in agreement with the results Riaz *et al.* (2002) where they observed higher NAR in irrigated plant compared to control. Similar results were also reported by Sarker and Paul (1998), Mandal *et al.* (1991), Pal *et al.*

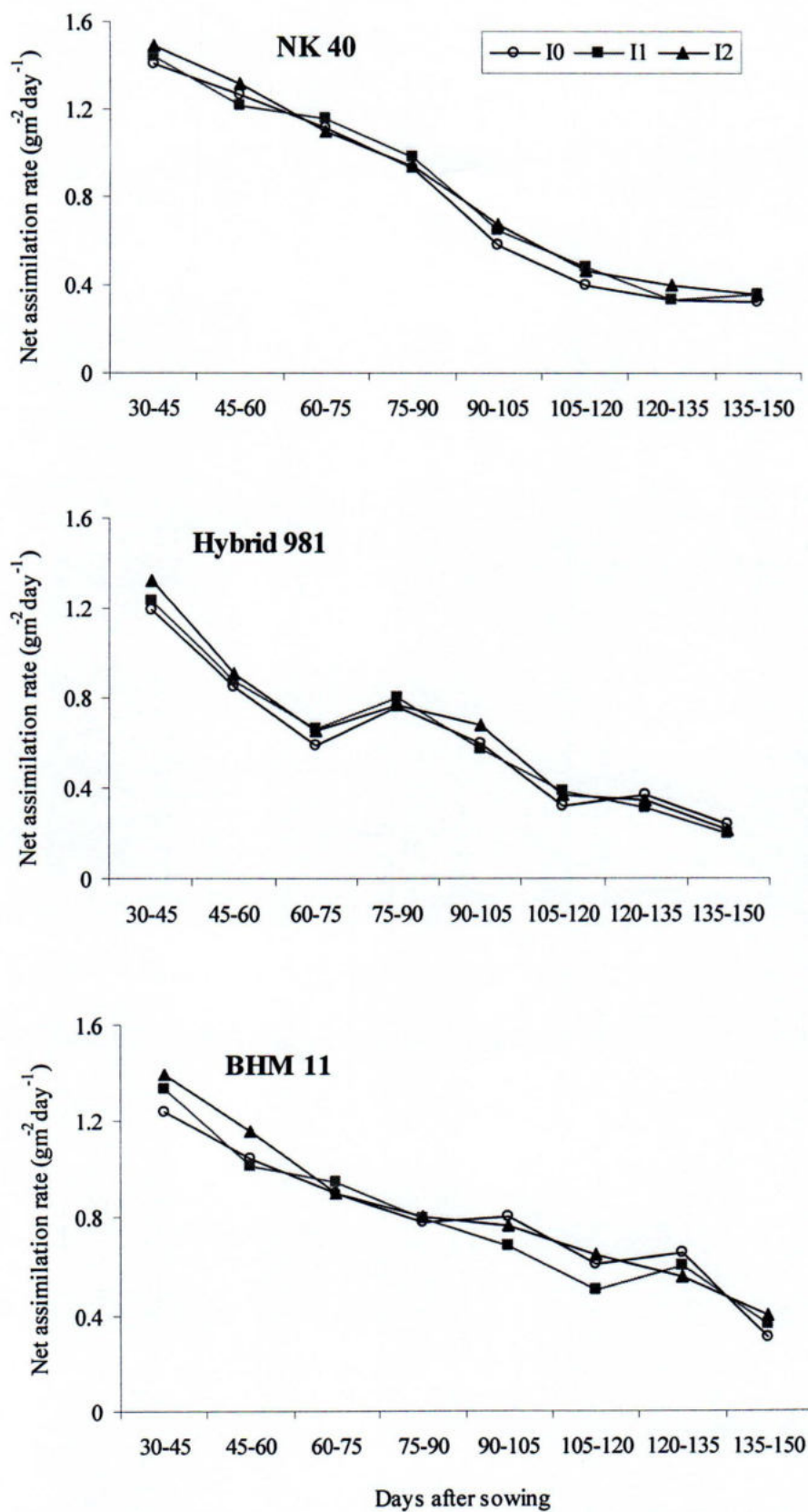


Figure 6. The pattern of net assimilation rate ($\text{g/m}^2/\text{day}$) with time in three maize varieties (V_1 =NK 40, V_2 =Hybrid 981, and V_3 =BHM 11) under different irrigation levels (I_0 =No irrigation, I_1 =300 mm irrigation in total life span and I_2 =450 mm irrigation in total life span)

(1996), in wheat and Hafiz *et al.* (2009) and Rahman (2008) in barley where, they observed higher NAR in irrigated plants than in control and Rahman (1997) in millet.

4.3 Relative leaf water content (RLWC)

Relative leaf water content was calculated at three different times of the day and it was significantly varied with different maize varieties (Table 4). The highest relative leaf water content was found at 8.00 am. and it was decreased at 12.00 noon and it again increased at 4.30 pm. The cultivar V₁ (maize var. NK 40) showed the highest RLWC at 8.00 a.m., 12.00 noon and 4.30 pm (91.50, 72.55 and 90.24%, respectively) while the lowest RLWC were recorded with the variety V₂ (maize var. Hybrid 981) (87.89, 70.15, and 84.98% at 8.00 am, 12.00 noon and 4.30 pm, respectively). Irrigation levels also significantly affected the RLWC of maize (Table 4). RLWC showed an increasing trend with increasing irrigation level. Application of 450 mm irrigation in total life gave the highest RLWC in all cases i.e., 93.60, 79.58 and 90.35% (8.00 am, 12.00 noon and 4.30 pm, respectively). This result is similar with the results of Hossain (2008) in maize, Sing and Patel (1996) in wheat. They reported that RLWC was low in water stressed leaf and Hafiz *et al.* (2009) and Rahman (2008) in barley. They reported that RLWC was the highest with three irrigations at crown root initiation, booting and anthesis stage and the lowest RLWC was recorded without irrigation.

Significant interaction also found between variety and irrigation levels on RLWC of maize (Table 2). Among the treatment combinations the variety V₁ (NK 40) with I₂ (450 mm irrigation in total life span) irrigation gave the highest RLWC in all cases i.e., 95.98, 82.15 and 92.74% (8.00 am, 12.00 noon and 4.30 pm, respectively). Followed by V₃ (BHM 11) with I₂ (450 mm irrigation in total life span) in all cases i.e., 8.00 am, 12.00 noon and 4.30

Table 4. Relative leaf water content of three maize varieties as influenced by irrigation level

Treatments	Relative leaf water content (%)		
	8:00 am	12.00 noon	4.30 pm
Variety			
V ₁	91.50 a	72.55 a	90.24 a
V ₂	87.89 b	70.15 b	84.98 b
V ₃	89.52 ab	71.87 a	87.59 ab
Irrigation level			
I ₀	81.59 c	63.25 c	80.26 c
I ₁	91.56 b	74.55 b	89.56 b
I ₂	93.60 a	79.58 a	90.35 a
Interaction			
V ₁ ×I ₀	85.55 f	67.55 e	84.15 e
V ₁ ×I ₁	94.72 ab	76.38 bc	91.58 ab
V ₁ ×I ₂	95.98 a	82.15 a	92.74 a
V ₂ ×I ₀	81.25 h	62.45 g	77.69 g
V ₂ ×I ₁	89.85 d	73.25 cd	87.58 d
V ₂ ×I ₂	93.87 c	77.05 b	90.26 bc
V ₃ ×I ₀	82.35 gh	65.14 f	78.98 f
V ₃ ×I ₁	93.54 cd	74.18 c	89.85 c
V ₃ ×I ₂	94.15 ab	80.35 ab	90.36 bc
CV (%)	5.89	6.55	8.58

In a column Figures having same letter(s) do not differ significantly at $P \leq 0.05$ by DMRT. Here, V₁=NK 40, V₂=Hybrid 981, V₃=BHM 11, I₀=No irrigation, I₁=300 mm irrigation in total life span and I₂=450 mm irrigation in total life span.

pm (94.15, 80.35 and 90.36%, respectively). The lowest RLWC was recorded in variety Hybrid 981 (V_2) with no irrigation at 8.00 am, 12.00 noon and 4.30 pm (81.25, 62.45 and 77.69%, respectively). At early morning RLWC was maximum it might be due to lower transpiration during morning in all plant and it was decreased with the advancement of time of the day up to noon due to higher transpiration rate for all cases and in afternoon it was again increased due to lower transpiration rate.

4.4 Moisture retention capacity (MRC)

Moisture retention capacity values of the flag leaves for three maize varieties under different irrigation levels was shown in Figure 7. The moisture retention capacity of the maize plants with higher irrigation level I_2 (450 mm irrigation in total life span) was higher than the I_0 (control) plants. Starting from a higher value, moisture retention capacity decreased gradually with the advancement of time for all the varieties and irrigation level. Among the three maize varieties, the higher moisture retention capacity was observed in maize var. NK 40 and in maize var. BHM 11 with the I_2 (450 mm water through out the life span). At the control condition again the highest moisture retention capacity was observed in maize var. NK 40 and in maize var. BHM 11. On the other hand the lower moisture retention capacity was observed in maize var. Hybrid 981 with I_0 (no water through out the life span). From the result it was found that moisture retention capacity was higher in 450mm irrigated condition. Similar result was observed in maize (Hossain 2008) and in wheat (Sarker, 1997, Sarker, 1996 and Rahman, 1997) and in barley (Rahman 2008). This might be due to folding of the leaves owing to increased dryness and also because of evapotranspiration.

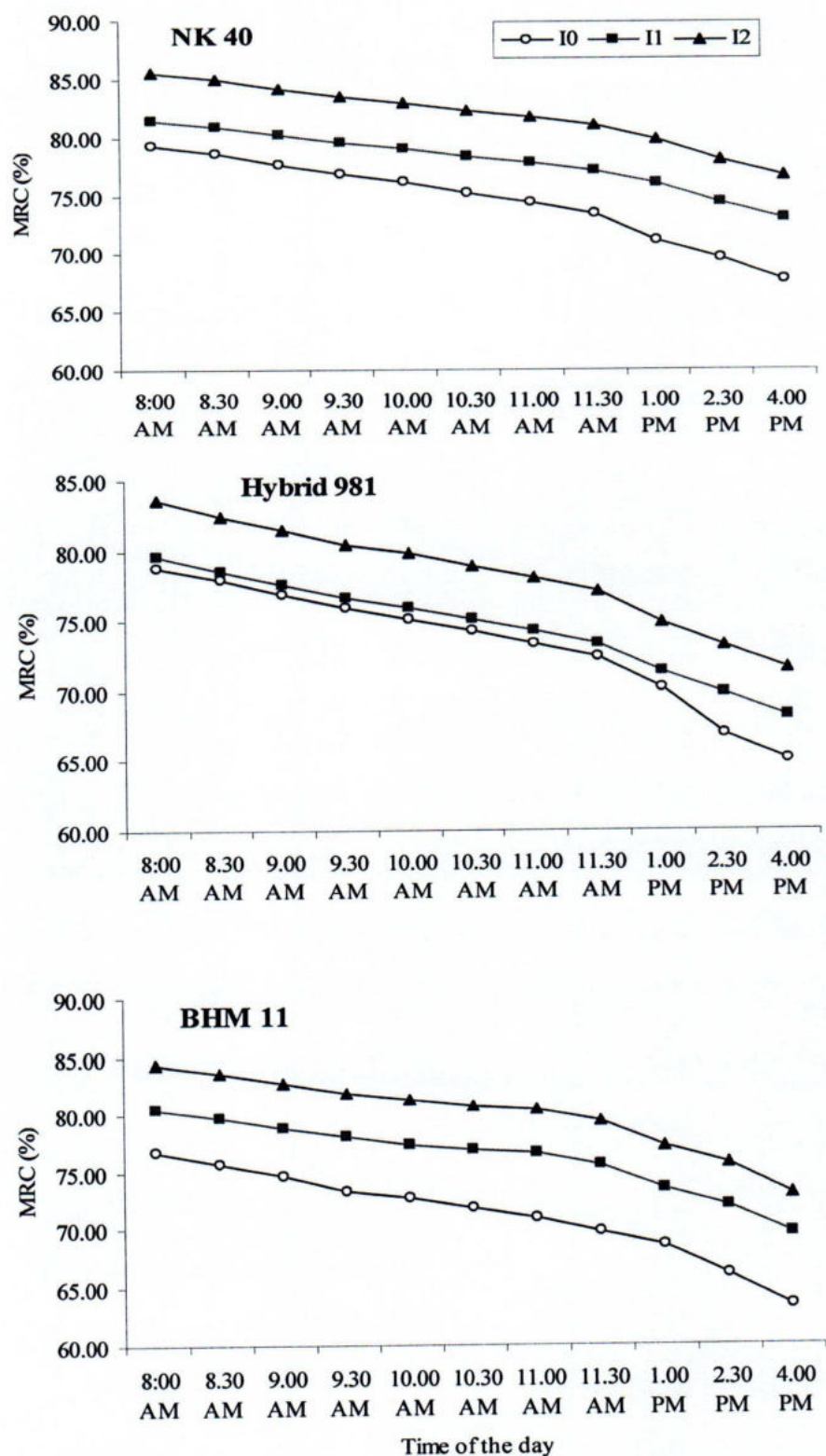


Figure 7. The pattern of moisture retention capacity (%) with time in three maize varieties (V_1 =NK 40, V_2 =Hybrid 981, and V_3 =BHM 11) under different irrigation levels (I_0 =No irrigation, I_1 =300 mm irrigation in total life span and I_2 =450 mm irrigation in total life span).

4.5 Yield and yield components

4.5.1 Cob length

Cob length of maize for different varieties and irrigation levels are presented in Table 5. Significant variation in cob length was found in different varieties. The maximum cob length (18.21 cm) was found in maize var. NK 40 and the minimum cob length (17.26 cm) was found in maize var. Hybrid 981. Cob length was significantly influenced by different level of irrigation (Table 5). Cob length increased with the increasing irrigation level. The maximum cob length (18.54 cm) was recorded in I_2 (450 mm water in total life span) growing condition and the minimum cob length (17.01 cm) was found in I_0 (no irrigation) growing condition. Similar effect of irrigation on cob length had also been reported Sikder *et al.* (2009) in maize. They reported that under well watered condition maize plant produced the longest cob compared to non-irrigated condition. was observed in var. Hybrid 981.

The interaction effect of variety and irrigation levels on cob length of maize was statistically significant (Table 2). Among the different treatment combinations the maximum cob length (19.10 cm) was obtained in maize variety NK 40 (V_1) combination with I_2 (450 mm water

in total life span) followed by V_3 (var. BHM 11) with I_2 (18.19 cm). The third highest cob length was recorded in V_3 with 300 mm irrigation in total life span (I_1 treatment) (18.60 cm) fourth highest cob length was recorded in var. NK 40 in combination with I_1 (18.35 cm). Whereas the shortest cob length (16.80 cm) was recorded in var. Hybrid 981 (V_2) with control (I_0). The second lowest cob length (17.12cm) was found in var. BHM 11 (V_3) in combination with I_0 .

Table 5. Yield and yield attributes of maize as influenced by variety and irrigation level

Treatments	Cob length (cm)	Cob diameter (cm)	No. of cobs per plant	No. of grain Rows per cob	No. of grains per Row	No. of grains per cob	100 grain weight (gm)	Yield (t/ha)	Harvest index (%)
Variety									
V ₁	18.21 a	4.50 a	1.34 a	14.03 a	32.03 a	413.40 a	34.83 a	5.48 a	32.89 a
V ₂	17.26 b	4.10 c	1.18 b	13.85 b	28.42 c	395.50 c	33.97 c	4.84 c	31.28 c
V ₃	18.14 a	4.26 b	1.30 a	13.85 b	30.03 b	407.50 b	34.53 b	5.25 b	32.23 b
Irrigation level									
I ₀	17.01 b	3.87 c	1.77 c	13.17 c	22.18 c	294.00 c	32.87 c	4.20 c	29.30 c
I ₁	18.06 a	4.32 b	1.30 a	13.99 b	31.08 b	407.20 b	34.62 b	5.42 b	32.56 b
I ₂	18.54 a	4.68 a	1.33 a	14.50 a	37.22 a	515.20 a	35.84 a	5.95 a	34.54 a
Interaction (Variety x Irrigation level)									
V ₁ ×I ₀	17.10 c	3.95 de	1.13 de	13.25 e	22.25 g	298.90 g	33.19 f	4.35 e	29.85 f
V ₁ ×I ₁	18.35 ab	4.70 a	1.32 bc	14.15 c	34.35 d	415.70 d	34.75 d	5.50 c	32.95 d
V ₁ ×I ₂	19.10 a	4.86 a	1.56 a	14.70 a	39.50 a	525.56 a	36.56 a	6.60 a	35.88 a
V ₂ ×I ₀	16.80 c	3.75 f	1.07 e	13.06 f	22.10 g	290.36 i	32.35 g	4.10 f	28.95 g
V ₂ ×I ₁	17.35 bc	4.10 cd	1.16 ce	13.91 d	28.55 f	395.42 f	34.45 e	5.26 d	31.75 e
V ₂ ×I ₂	17.65 bc	4.45 b	1.30 bd	14.35 b	34.60 c	500.67 c	35.10 c	5.15 d	33.15 c
V ₃ ×I ₀	17.12 c	3.91 ef	1.11 e	13.19 ef	22.20 g	292.75 h	33.08 f	4.15 f	29.10 g
V ₃ ×I ₁	18.60 a	4.15 c	1.37 b	13.90 d	30.35 e	410.50 e	34.65 d	5.50 c	32.98 c
V ₃ ×I ₂	18.91 a	4.73 a	1.42 ab	14.45 b	37.55 b	519.26 b	35.85 b	6.10 b	34.60 b
CV (%)	6.56	5.14	3.89	9.78	15.47	12.56	8.57	6.45	8.57

In a column Figures having same letter(s) do not differ significantly at $P \leq 0.05$ by DMRT. Here, V₁=NK 40, V₂=Hybrid 981, V₃=BHM 11, I₀=No irrigation, I₁=300 mm irrigation in total life span and I₂=450 mm irrigation in total life span.

4.5.2 Cob diameter

Data on cob diameter as influenced by variety and irrigation level are presented in Table 5. The maximum cob diameter (4.50 cm) was recorded in var. NK 40 (V_1) and the minimum cob diameter (4.10 cm) was found in var. Hybrid 981 (V_2).

Cob diameter was significantly influenced by different levels of irrigation (Table 5). Cob diameter increased with increasing irrigation level. The maximum cob diameter (4.68 cm) was recorded in I_2 (450 mm irrigation in total life span) and the minimum cob diameter (3.87 cm) was found in control I_0 . The maize var. BHM 11 performed moderately in this case. Similar effect of irrigation on cob diameter was reported by Sikder *et al.* (2009) and Hossain (2008).

Statistically significant variation was found within the combine effect of variety and irrigation levels on cob diameter of maize plant (Table 2). The maximum cob diameter (4.86 cm) was obtained in interaction of maize var. NK 40 (V_1) with the application of 450mm irrigation in total life span (I_2) followed V_3 (maize var. BHM 11) with I_2 (4.73 cm). The third highest cob diameter was recorded from the treatment combination of maize var. BHM 11 (V_2) with I_2 (4.45 cm). On the other hand the minimum cob diameter (3.75 cm) was found in maize var. Hybrid 981 (V_2) with I_0 (no irrigation) followed by the $V_3 \times I_0$ and $V_1 \times I_0$ as 3.91 cm and 3.95 cm, respectively.

4.5.3 Number of cobs per plant

Number of cobplant⁻¹ was significantly influenced by variety (Table 5). The maximum number of cobplant⁻¹ (1.34) was observed in maize var. NK 40 (V_1) which was statistically similar to V_3 (var. BHM 11) and the minimum number of cobplant⁻¹ (1.18) was observed in maize var. Hybrid 981 (V_2).

Number of cobplant⁻¹ was significantly influenced by different levels of irrigation (Table 5). Number of cobplant⁻¹ increased with increasing irrigation level over control. Number of cobplant⁻¹ increased with increasing irrigation up to 450 mm irrigation in total life span. The maximum number of cobplant⁻¹ (1.33) was observed in I₂ (450 mm irrigation) and the minimum number of cobplant⁻¹ (1.77) was found in control (I₀). Similar effect of irrigation on cob diameter was reported by Sikder *et al.* (2009) and Hossain (2008).

Statistically significant interaction found between the variety and irrigation level on number of cobplant⁻¹ (Table 5). Among the treatment combinations the maximum number of cobplant⁻¹ (1.56) was obtained in var. NK 40 (V₁) with I₂ (450 mm irrigation) treatment combination. The second highest (1.42) number of cob was recorded in cv. BHM 11 with I₂ followed by V₃ (BHM 11) with I₁ (1.37). Next to this the highest cob number was recorded with the combination of V₁ × I₁ (1.32). However, the lowest number of cobplant⁻¹ (1.07) was observed in var. Hybrid 981 with control (I₀).

4.5.4 Number of grain rows per cob

Number of grain rowscob⁻¹ was significantly influenced by variety (Table 5). The maximum number of grain rowscob⁻¹ (14.03) was observed in maize var. NK 40 (V₁) and the minimum number of grain rowscob⁻¹ (13.85) was observed in var. Hybrid 981 (V₂) which was at par in V₃ (13.85).

Number of grain rowscob⁻¹ was significantly influenced by different levels of irrigation (Table 5). Number of grain rowscob⁻¹ increased with increasing irrigation level over control. Number of grain rowscob⁻¹ increased with the increasing irrigation level up to 450 mm irrigation in total life span. The maximum number of grain rowscob⁻¹ (14.50) was observed in I₂ (450 mm irrigation) and the minimum number of grain rowscob⁻¹ (13.17)

was found in I_0 . Similar result was reported by Sikder *et al.* (2009). They reported that under irrigated condition number of row per cob was higher than non-irrigated condition.

The interaction effect of variety and irrigation level on number of grain rowscob⁻¹ of maize was statistically significant (Table 5). The maximum number of grain rowscob⁻¹ (14.70) was obtained in var. NK 40 (V_1) with I_2 (450 mm irrigation in total life span) followed by V_3 (BHM 11) with I_2 (14.45). The subsequent results was found at var. Hybrid 981 (V_2) with I_2 (14.35) and the minimum number of grain rowscob⁻¹ (13.06) was found in maize var. Hybrid 981 (V_2) with I_0 . Statistically similar results also found in $V_2 \times I_0$ and $V_3 \times I_0$ i.e., 13.25 and 13.19 respectively. Others treatment combinations performed moderately in this case.

4.5.5 Number of grains per row

Number of grainsrow⁻¹ was significantly influenced by variety (Table 5). The maximum number of grainsrow⁻¹ (32.03) was observed in maize var. NK 40 and the minimum number of grainsrow⁻¹ (28.42) was observed in var. maize Hybrid 981 (V_2).

Number of grainsrow⁻¹ was significantly influenced by different level of irrigation (Table 5). Number of grainrow⁻¹ increased with increasing irrigation level over control. Number of grainsrow⁻¹ increased with the increasing irrigation level. The maximum number of grainsrow⁻¹ (37.22) was observed in I_2 growing condition and the minimum number of grainsrow⁻¹ (22.18) was found in I_0 (control). Similar effect of irrigation on cob diameter was reported by Sikder *et al.* (2009) and Hossain (2008).

Variety and level of irrigation significantly affected the number of grainsrow⁻¹ of maize (Table 5). Among the treatment combinations, the highest number of grainsrow⁻¹ (39.50) was obtained in maize var. NK 40 with I_2 followed by V_3 with I_2 (37.55). The third highest

number of grainrow⁻¹ was recorded at V₂ with I₂ (34.60) which were statistically similar with V₁ x I₁. Whereas, the minimum number (22.10) of grainsrow⁻¹ was in maize var. Hybrid 981 (V₂) with I₀ (control) treatment combination.

4.5.6 Number of grains per cob

Number of grainscob⁻¹ was significantly influenced by variety (Table 5). Among the three maize varieties the maximum number of grainscob⁻¹ (413.40) was observed in var. NK 40 (V₁) and the minimum number of grainscob⁻¹ (395.50) was observed in var. Hybrid 981 (V₂).

Number of grainscob⁻¹ was significantly influenced by different levels of irrigation (Table 5). Number of grainscob⁻¹ increased with increasing irrigation level over control. The maximum number of grainscob⁻¹ (515.20) was recorded with the application of 450 mm irrigation in total life span (I₂) and the minimum number of grainscob⁻¹ (294.00) was found in control (I₀). Similar effect of irrigation on number of grainscob⁻¹ was reported by Sikder *et al.* (2009). They observed that under irrigated condition number of row per cob was higher than non-irrigated condition.

A significant interaction effect was found between the combination of variety and irrigation level on number of grainscob⁻¹ of maize (Table 5). The results indicated that the maximum number of grainscob⁻¹ (525.56) was obtained in maize var. NK 40 (V₁) with I₂ (450 mm irrigation) treatment combination. Statistically similar results was also found in var. BHM 11 with the combination of I₂ (519.26), followed by V₂ (Hybrid 981) with I₂ (500.67). The next highest (415.70) number of grain per cob was recorded in V₁ with I₁ (300mm irrigation). While the minimum number of grainscob⁻¹ (290.36) was obtained in var. Hybrid 981 (V₂) with I₀ treatment combination.

4.5.7 100-grain weight

100-grain weight was significantly influenced by variety (Table 5). The maximum 100-grain weight (34.83 g) was observed in maize var. NK 40 (V_1) and the minimum 100-grain weight (33.97 g) was observed in var. Hybrid 981 (V_2) which was at par with var. BHM 11 (V_3) (34.53 g).

100-grains weight was significantly influenced by different levels irrigation (Table 5). 100-grain weight increased with increasing irrigation level over control. The maximum 100-grain weight (35.84 g) was recorded in I_2 (450 mm irrigation total life span) and the minimum 100-grain weight (32.87 g) was found in I_0 . Similar effect of irrigation on 100-grain weight was reported by Sikder *et al.* (2009), Patil *et al.* (2006), Sowalim *et al.* (2003), El Gizawy (2005), Ghulam *et al.* (2005) and Saif *et al.* (2003).

Table 5 represents the interaction effect of variety and irrigation level on 100-grain weight of maize. Among all the treatment combinations the highest 100-grain weight (36.56 g) was obtained in maize var. NK 40 (V_1) with I_2 (450 mm irrigation in total life span) followed by var. with BHM 11 (V_3) with I_2 (35.85 g). The third highest 100 grain weight (34.75) was recorded in V_1 with I_1 (300 mm irrigation in total life span) and next to it, which was at par with the combination of V_3 with I_1 and V_2 with I_1 (34.65 and 34.45 g, respectively). However, the lowest 100-grain weight (32.35 g) was observed in var. maize Hybrid 981 (V_2) with I_0 (control) treatment combination. The highest 100-grain weight was in var. NK 40 with 450 mm irrigation was due to tallest plant height, maximum Cob length, maximum cob diameter, highest number of cob per plant, maximum number of grain rowscob⁻¹, maximum Number of grainsrow⁻¹, maximum number of grainscob⁻¹ that gave the highest 100-grain weight.

4.5.8 Grain yield

Different varieties are significantly influenced the grain yield of maize (Table 5). The highest grain yield (5.45 t ha^{-1}) was observed in maize var. NK 40 (V_1) followed by var. BHM 11 (V_3) (5.25 t ha^{-1}) and the minimum grain yield (4.84 t ha^{-1}) was observed in maize var. Hybrid 981 (V_2). Yield is the cumulative effect of variety with its inherent characteristics, environmental condition in which it is grown, and management practices. Variety is one of the most important factors for increasing yield. In general, it is understood that there are differences in morpho-physiological aspects among the three hybrid maize varieties such as cob length, cob diameter, number of cobplant⁻¹, number of grain rowscob⁻¹, number of grainsrow⁻¹, number of grainscob⁻¹ and 100-grain weight. All the yield contributing characteristics of the maize var. NK 40 having the higher value might be lead to maximum yield in the present study. Yield of maize also depends on different growth processes such as days to tasseling, cob initiation, silking, pollen shading and maturity which occur in the ontogeny of maize plant.

Grain yield was significantly influenced by different levels of irrigation (Table 5). Grain yield increased with increasing level of irrigation over control. The maximum grain yield (5.95 t ha^{-1}) was recorded in I_2 and the minimum grain yield (4.20 t ha^{-1}) was found in I_0 condition. Similar effect of irrigation on cob diameter was reported by Sikder *et al.* (2009) and Hossain (2008), Patil *et al.* (2006), Sowalim *et al.* (2003), El Gizawy (2005), Ghulam *et al.* (2005) and Saif *et al.* (2003) in maize. The result of the present study agreement with the result of Similar findings have also been reported by Sarwar *et al.* (2010), LiHua *et al.* (2007), Dhaka *et al.* (2006), Aydin *et al.* (2000), Moussa and Maksoud (2004), Singh *et al.* (2006), Nowak *et al.* (2005), Baheri *et al.* (2005), Hafiz *et al.* (2009) where they reported that irrigation increase the grin yield. Yield reduction in no irrigation due to water shortage

was attributed to reduce plant height, cob length, cob diameter, number of cobplant⁻¹, number of grain rowscob⁻¹, number of grainsrow⁻¹, number of grainscob⁻¹ and 100-grain weight. Moreover, the reduction in yield could be attributed to reduced photosynthetic activity by partial closure of stomata and decrease in supply of CO₂ under water stress condition (Kramer 1972). On the other hand, grain yield increased with irrigation probably due to positive effect of irrigation for higher plant height, cob length, cob diameter, number of cobplant⁻¹, number of grain rowscob⁻¹, number of grainsrow⁻¹, number of grainscob⁻¹ and 100-grain weight as observed in the present study and also because of optimum moisture helped in proper utilization of nutrients.

The interaction effect of variety and irrigation level on grain yield of maize was statistically significant (Table 5). The maximum grain yield (6.60 t ha⁻¹) was obtained in maize var. NK 40 (V₁) with I₂ (450mm irrigation in total life span) followed by V₃ (BHM 11) with I₂ (6.10 t ha⁻¹), the third most yield was recorded in V₁ with I₁ (5.50 t ha⁻¹) which was at par V₂ with I₁ (5.26 t ha⁻¹). While the minimum grain yield (4.10 t ha⁻¹) was produced in maize var. Hybrid 981 (V₂) with I₀ treatment combination. From the overall growth period and biochemical test it was observed that in V₁ and higher irrigated condition days to tasseling, days to cob initiation, days to silking, days to pollen shading and days to took highest days i.e., maximum growth period and LAI, LAD, CGR, RGR, NAR and TDM production also maximum that help to increase yield of crop.

4.5.9 Harvest index (HI)

Significant variation in harvest index was found among the varieties (Table 5). Among the different varieties, maize var. NK 40 (V₁) showed the highest HI (32.89%) and var. Hybrid 981 (V₂) had the lowest HI (31.28%)

Significant variation in harvest index was found due to different irrigation level (Table 5). I_2 (450 mm irrigation) provided the highest harvest index (34.54%). The lowest harvest index (29.30%) was found in I_0 (control) treatment.

The interaction effect of variety and irrigation level had significant variation on HI (Table 5). The highest harvest index (35.88%) was observed in maize var. NK 40 with I_2 (450 mm irrigation in total life span) and the lowest value (28.95%) was obtained in var. Hybrid 981 (V_2) with no irrigation treatment (I_0).

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted to investigate the growth, development and yield of maize as affected by irrigation level at the Research Field and Laboratory of Crop Physiology and Ecology Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur, during the period of November 2010 to June 2011. The experimental area belongs to Old Himalayan Piedmont Plain (AEZ-1) having sandy loamy soil with pH 6.1. The experimental treatments were three maize varieties (V_1 = NK 40, V_2 =Hybrid 981 and V_3 =BHM 11) and three levels of irrigation (I_0 = no irrigation, I_1 =300 mm irrigation in total life span and I_2 = 450 mm irrigation in total life span at different days after sowing). The experiment was laid out in a two factors Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 3.0 m x 3.0 m. The distance between block to block was 1.0 meter and plot to plot was 0.5 m.

Observations were made on some phenological parameters such as days to tasseling, cob initiation, silking, pollen shading and maturity. Growth parameters like TDM, LAI, LAD, CGR, RGR, NAR and some biochemical parameters like RLWC and MRC also calculated. Yield and yield attributes like plant height, cob length, cob diameter, number of cobplant⁻¹, number of grain rowscob⁻¹, number of grainsrow⁻¹, number of graincob⁻¹, 100-grain weight, grain yield and harvest index.

Variety significantly influenced all the phenological parameters. The maize var. NK 40 (V_1) required longer time for attaining every phenological stages and maize var. Hybrid 981 needed shortest time to attain different phenological stages. Effect of irrigation on tasseling, cob initiation, pollen shading, silking and maturity were significant. Plant with I_2

treatment required the highest days to tasseling, cob initiation, pollen shading, silking and maturity while I_0 require the lowest days in all cases. Interaction effect of variety and irrigation levels showed significant variation for all the phenological parameters.

Growth parameters like TDM, LAI, LAD, CGR, RGR and NAR were significantly influenced by variety. Irrigation level also influenced those parameters significantly. Irrespective of varieties higher irrigation levels resulted in higher growth parameters. Variety and irrigation level also interacted significantly for all those growth parameters. The maize var. NK 40 (V_1) showed better performance for all the growth parameters with I_2 condition.

Relative leaf water content (RLWC) significantly influenced by variety and irrigation. The highest values of RLWC at 8.00 am (91.50%), 12.00 noon (72.55%) and 4.30 pm (90.24%) were observed in maize var. NK 40 while var. Hybrid 981 showed the lowest values of RLWC at the same time of the day. The plants receiving 450 mm irrigation throughout the life span gave higher values of RLWC at 8.00 am (93.60%), 12.00 noon (79.58%) and 4.30 pm (90.35%) than control condition. Interaction between maize var. NK 40 with I_2 irrigation produced the highest values of RLWC at the same time of the day. While, Hybrid 981 with no irrigation gave the lowest values of RLWC in all cases at same time of the day. The moisture retention capacity (MRC) was lower in I_0 growing condition higher value, The higher MRC was observed in maize var. NK 40 and lower in Hybrid 981 in all irrigation condition.

The maximum cob length (18.21 cm) was found in V_1 and the minimum cob length (17.26 cm) was observed in V_2 . The maximum cob diameter (4.50 cm) was recorded in V_1 and the minimum cob diameter (4.10 cm) was found in V_2 . The maximum number of cobplant⁻¹ (1.34) was observed in V_1 and the minimum number of cobplant⁻¹ (1.18) was observed in

V₂. The maximum number of grain rowcob⁻¹ (14.03) was observed in V₁ and the minimum number of grain rowcob⁻¹ (13.85) was observed in V₂ plants. The maximum number of grainsrow⁻¹ (32.03) was observed in V₁ and the minimum number of grainsrow⁻¹ (28.42) was observed in V₂. The maximum number of grainscob⁻¹ (413.40) was observed in V₁ condition and the minimum number of grainscob⁻¹ (395.50) was observed in V₂ plants. The maximum 100-grain weight (34.83 g) was observed in V₁ and the minimum 100-grain weight (33.97 g) was observed in V₂. The highest grain yield (5.48 t ha⁻¹) was observed in V₁ and the minimum grain yield (4.84 t ha⁻¹) was observed in V₂. The highest value of harvest index (32.89%) was observed in V₁. The lowest harvest index (31.28%) was observed in V₂.

The maximum cob length, cob diameter, cobplant⁻¹, grain rowcob⁻¹, grainscob⁻¹, 100-grain weight and yield was recorded in I₂. The minimum cob length, cob diameter, cobplant⁻¹, grain rowcob⁻¹, grainscob⁻¹, 100-grain weight, yield and HI was found in I₀. The maximum cob length, cob diameter, cobplant⁻¹, grain rowcob⁻¹, grains/cob, 100-grain weight, yield and HI was obtained from V₁ with I₂. The minimum cob length, cob diameter, cobplant⁻¹, grain rowcob⁻¹, grainscob⁻¹, 100-grain weight, yield and HI was obtained in V₂ with I₀ combination. From the above discussion it could be concluded that the higher yield attributes and grain yield per plant of maize could be obtained from maize var. NK 40 with 450 mm irrigation in total life span (I₂).

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APPENDICES

Appendix I. Statistical data in cultivated area and production of maize in Bangladesh (2005-06 to 2009-10)

Year	Area (acres)	Production (metric ton)
2005-06	243165	521525
2006-07	372720	902150
2007-08	552955	1346477
2008-09	317253	729629
2009-10	375628	887391

Source: BBS, 2010

Appendix II. Comparative nutritive value of maize, wheat and rice in every 100 g of available food

Ingredients in (gm)	Maize	Wheat	Rice
Protein	10	11.1	8.9
Fates	4.3	1.7	2
Carbohydrates	73.4	75.5	77.2
Thiamin (PPM)	4.4	3.2-7.7	3-50
Riboflavin(PPM)	1.3-1.5	1-1.2	0.8-1.0
Vitamin A	7-75	0-2	0.5-1.00
Magnesium(in every gm)	0.160	0.170	0.119
Phosphorus(in every gm)	0.430	0.400	0.290

Source: Khadya O Pusti (Bengali) by Sayeda Halima Rahman. 1992.

Appendix III. Results of physical and chemical analysis of the soil samples taken from the experimental plot before planting

Characteristics	Analytical data
Textural Class	Sandy Loam
Organic matter (%)	1.1
Soil pH	6.1
total N%	0.06
P	5.91 µg/g soil
S	21.44 „
B	0.39 „
Mn	9.4 „
Zn	3.0 „
Na	0.12 me/100 g soil
Ca	1.8 „
Mg	0.30 „
K	0.15 „



Source: The physical and chemical analysis of soil samples were done by SRDI, Dinajpur.

Appendix IV. Temperature (⁰C), relative humidity (%), total rainfall (mm), sunshine hour during the growing period from November, 2010 to July, 2011

Months	Temperature (⁰ C)		Relative humidity (%)			Rainfall (mm)	Sunshine hours
	Maximum	Minimum	Maximum	Minimum	Mean		
November, 2010	28.29	18.84	96.06	50.60	81.16	0.023	7.85
December, 2010	25.39	11.92	98.87	43.61	73.32	0.206	5.34
January, 2011	20.85	9.15	97.16	53.83	81.96	0.000	3.61
February, 2011	27.06	13.33	94.17	40.25	72.07	1	6.91
March, 2011	30.69	17.86	89.16	40.83	68.25	0.87	7.39
April, 2011	31.73	21.39	93.13	50.53	74.4	2.03	7.48

Source: Meteorological substation, Rajbati, Dinajpur.