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Effect of Irrigation and Nitrogen on Growth and Yield of Maize

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EFFECT OF IRRIGATION AND NITROGEN ON GROWTH AND YIELD OF MAIZE

A THESIS SUBMITTED FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN THE
DEPARTMENT OF CROP SCIENCE AND TECHNOLOGY
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RAJSHAHI

BY

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DEPARTMENT OF CROP SCIENCE AND TECHNOLOGY
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RAJSHAHI

JUNE 2015

DEDICATION

Dedicated to:

From the depth of my heart I dedicate this thesis to my beloved

- *father: MD. ABU BAKER SIDDIQUE MONDAL*
- *mother: MRS. MOLUDA BEGUM*
- *wife: REBA AKTHAR*
- *son: ABIR SHAHARIAR*

DECLARATION

I do hereby declare that the dissertation entitled **Effect of Irrigation and Nitrogen on Growth and Yield of Maize** by Md. A. Majid as a partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy, at the Department of Crop Science and Technology, University of Rajshahi, is exclusively the outcome of own research work done under the supervision of Dr. Md. Saiful Islam, Professor, Department of Crop Science and Technology, University of Rajshahi.

I further declare that this dissertation has not been submitted in part or full to any other academic Institute or Organization for the award any degree or receiving financial grant.

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CERTIFICATE

It is pleasure for me to certify that the dissertation entitled **Effect of Irrigation and Nitrogen on Growth and Yield of Maize** by Md. A. Majid is an original research work of Crop Science and Technology under my supervision for the award of the Degree of Doctor of Philosophy from the Department of Crop Science and Technology, University of Rajshahi. As far I know, no other person was associated with the completion of the study or anybody has done a research on the same topic as yet.

I have gone through the draft and final version of the dissertation and it appears to me ok for submission to the Department of Crop Science and Technology, University of Rajshahi as a partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy.

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The author

ABSTRACT

The purpose of this study was to determine the effect of irrigation amount applied with optimum irrigation on field maize *(Zea mays* L.) growth and yield in Bangladesh. Irrigation management treatments were created as rainfall irrigation, one irrigation, two irrigation" s and three irrigations replenishment of water depleted in root zone from 100% replenishment treatment in every irrigation system. In BARJ hybrid maize-7 growth stages were significantly affected all parameters and the average grain yields varied from 6.61 to 10.32t ha-^{1}· In BARI hybrid maize-9 growth stages were also affected all parameters and the average grain yields varied from 6.68 to 10.44 t ha-^{1}· In the research, irrigation significantly affected growth and yields, which increased with irrigation up to three irrigation level increased growth and yield but remarkable varied rainfall irrigation and any irrigation system. Three time irrigations reference irrigation treatment gave the highest growth and grain yield. The results revealed that the full irrigation is the best choice for higher growth and yield.

Due to the strong influence of nitrogen (N) on plant productivity a vast amount of N fertilizers is used to maximize crop growth and yield. Over-use of N fertilizers leads to severe pollution of the environment, especially the aquatic ecosystem as well as reducing farmer's income. Growing of N efficient cultivars is an important prerequisite for integrated nutrient management strategies in both low and high input agriculture. Taking maize as a sample crop, this paper reviews the response of plants to low N stress, the physiological processes which may control N use efficiency in low N and over use of N fertilizers input

conditions. Since the modem hybrid maize cultivars is quite high, further improvement of these cultivars to adapt to low N soils should aim to increase their capacity to accumulate N at low N levels. The results show that a dose of 230 kg N ha-^{1} can provide significantly higher grain yield of maize, albeit 115 kg N ha-^{1}was comparable with it. A combination of 230 kg N ha-^{1} results in significantly higher values of yield attributes. This may be worth-recommending. But it would be better, if recommendation is made based on the economic optimum doses for maize.

A field study was conducted to assess the interaction effects of irrigation and nitrogen rates on hybrid maize yield. The interaction effect of irrigations and nitrogen levels significantly influenced on BARI hybrid maize-7 of different growth and yield parameters viz. plant height, plant girth, total tillers planr1, effective tiller planr ^{1}, non-effective tiller planr ^{1}, total roots planf^{1}, straw weight planf^{1}, straw yield t ha-', cob length, cob girth, grain line cob-1, grain number line-1, total grain cob-^{1}, grain weight cob-1, 1000 grin weight cob-^{1}, grain weight cob-^{1}, 1000 grin weight cob-^{1}, grains yield t ha-^{1}, straw yield t ha-^{1} and biological yield t ha-' but no response in cob grain free length and harvest index (%)(Table 09 - 12). From the above research work it could be concluded that application of N @ 230kg ha-^{1} with three irrigations would be better for growth and yield of maize.

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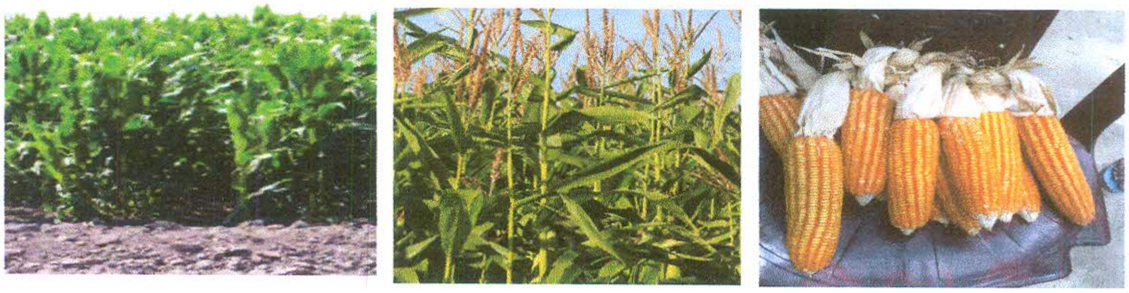


Chapter-ONE

1. Introduction

Maize (*Zea mays* L) is one of the most versatile emerging crop having wider adaptability under varied agro-climatic conditions and successful cultivation in diverse seasons and ecologies for various purposes. Globally, maize is known as "Queen" of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 150 million ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36% (782 million ton) of the global grain production. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries *etc*. In modern maize production systems, enhanced management variability often results from increased growth and yield for limiting resources such as irrigation and nitrogen. Karam *et al*. (2003) found that grain and dry matter yield, and leaf area index was reduced by severity of water stress and nutrient deficiency. Past studies have often emphasized that stand uniformity is essential for high productivity levels, and that the increased irrigation and nitrogen variability (determined and expressed using a variety of maize growth, yield and developmental parameters) reduces per-unit-area maize growth and grain yields through reduced stress tolerance. Ayars *et al*. (2013) stated that yield reduction (22.6–26.4%) caused by deficit irrigation was associated with a decrease in kernel number and weight. Therefore, at optimum management, resource availability must be adequate to help maintain uniform growth, development, and grain yield of adjacent plants in a maize canopy. Among different essential nutrients, N is highly limiting in Bangladesh soils that exerts a profound effect on plant growth and development owing to its metabolic and physiological needs. The beneficial effects of irrigation and nitrogen on crop production are well documented. However, irrigation and nitrogen mining of crops for optimum productivity widely varies on account of different agro-climates, soils, cultivars, management practices and other factors. The yield potential of maize can be realized only when it is grown with adequate irrigation and nitrogen fertilizer. The impact of irrigation and nitrogen on growth and yield of maize has been studied extensively, as it varies with genotype, agronomic management practices, and location. The importance of plant and crop geometry of irrigation and nitrogen factors in deciding growth and yield of maize is well established.

Maize (*Zea mays* L.) is a member of the family Poaceae. It was originated in Mexico where its oldest known ears could be traced back to about 7000 years ago (Mangeidorf *et al*., 2014). In world production, maize is ranked as the third major cereal crop after wheat and rice. The crop has a wider range of uses. These include the following human food, industrial processed food production of starch and used as forage to feed animals. Maize with its large number of cultivars and different maturity periods has wider range of tolerance to different environmental conditions (Purseglove, 2012). In Bangladesh, maize also can be grown to produce grains yield and forage in all seasons to solve problems of human food and livestock feed shortage during this period. Maize proved to be most suitable food grains and forage as it is characterized by its high energy content and considerable protein content, compared to other cereal food and forage crops (Ipperisil *et al*., 2009). The reason behind planting maize for green forage production is to obtain succulent vegetative part in a comparatively short time (Toosey et al.,2012).

Maize, also known as corn and Indian corn, is any of the diverse cultured forms of the annual cereal grass (family Poaceae) of the species *Zea mays* L, which grows as large grains set in rows on an ear or cob. Generally the term corn, which is the term popular in the United States, Canada, New Zealand, Australia, India and Bangladesh for this plant and seed, is a generic British English term in Europe for cereal grains in general, or the principal crop in a region, such as the term for wheat in England or oats in Scotland and Ireland. Maize is an economically important plant, particularly widely cultivated maximum countries in the world, where it is the leading grain crop, ahead of wheat, oats, rice, and others. As maize advances its own survival and reproduction, it also serves a value for humans. All parts of this generally tall plant are utilized, with the stalks for fodder for livestock feed, as well as paper and wallboard, the cobs and kernels for food and to make fuel, the husks for tamales, and the silk for medicinal tea. Corn serves as the foundation for such products as bourbon, corn flour, corn oil, cornmeal, cornstarch, corn syrup, and laundry starch, and the multicolored Indian corn serves decorative use (Herbst et al., 2011).

Water supply plays a significant role in the utilization of fertilizer active substances especially that of nitrogen. Due to the changing precipitation, the effect of fertilization strongly varies on an annual basis. The correlation of irrigation and fertilization has been investigated by many Hungarian researchers. The irrigation and fertilizer research results of Nagy 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. In irrigated treatments which means a higher yield level economic fertilizer doses are greater, due to the positive correlation of irrigation and fertilization, than in unirrigated treatments. In irrigation treatments, the effect of year is moderate and yield fluctuation decreases. The annual fertilizer reaction differs to a smaller extent than in unirrigated treatments, thus nutrient supply can be planned with greater safety. The irrigation and fertilization experiment results of Hanson et al., (2009) have proved that irrigation increases the efficiency of fertilization. The efficiency of fertilizers also depends on agro ecological conditions (Lamm et al., 2005).

1.1 Effect of irrigation

Today, the government of Bangladesh through its financial assistance program is trying to encourage farmers to grow maize. It is grown almost all over the country under varied soil and climatic conditions. Most of the maize in Bangladesh is irrigated and is grown under low rainfall and heat stress conditions. In these conditions, irrigation is the major factor determining yield. It is consequently essential to determine the water regimes leading to highest yield. Maize has been reported in the literature to have high irrigation requirements (Stone *et al*., 2006; Karam *et al*., 2003). Maize grain yield increased significantly by irrigation water amount and irrigation frequency (Yazar *et al*., 2009; Kara and Biber, 2008; Farré and Faci, 2013). However, water availability is usually the most important natural factor limiting expansion and development of agriculture in Bangladesh. Competition for water from other sectors such as industry and domestic use will force irrigation to operate under water scarcity. When water supplies are limiting, the farmer's goal should be to maximize net income per unit water used rather than per land unit. Deficit irrigation, by reducing irrigation water use, can aid in coping with situations where water supply is restricted. In field crops, a well-designed deficit irrigation regime can optimize water productivity over an area when full irrigation is not possible (Fereres and Soriano, 2007).

Maize crop water application of deficit irrigation requires thorough understanding of the yield response to water (crop sensitivity to drought stress) and of the economic impact of reductions in harvest (English, 2010). However, maize has been reported to be very sensitive to drought (Otegui *et al*., 2005). Pandey *et al*. (2010) stated that yield reduction (22.6–26.4%) caused by deficit irrigation was associated with a decrease in kernel number and weight. The effects of deficit irrigation for the same crop may vary with location. Climate and soil type of the location are perhaps the most important factors dictating the influence of deficit irrigation (Igbadun *et al*., 2007). Shortage in irrigation water supplies has motivated farmers to find ways to produce crops, especially maize, with less irrigation water, such as using more efficient irrigation systems and changing from fully–irrigated to deficit irrigated cropping systems. Furrow irrigation is the most common method used for irrigating row crops such as maize in Bangladesh. However, the drip irrigation method is becoming more popular because of numerous advantages over other methods (Hanson *et al*., 2007). Some advantages of drip irrigation over other irrigation methods include improved water and nutrient management, improved saline water management, potential for improved yields and crop quality, reducing the incidence of diseases and weeds in dry row middles, greater control on applied water resulting in less water and nutrient loss through deep percolation, and reduced total water requirements (Dogan and Kirnak, 2010). During the past decade, Bangladesh government has been financially supporting the farmers who are willing to set up drip irrigation system. Therefore, the use of drip irrigation is increasing substantially each year in the region. However, local information from the northern and char region of Bangladesh on the response of maize yield with drip irrigation is very limited, especially dealing with the effect of limited water allocations. In northern climatic region, little attempt has been made to assess the water–yield relationships and optimum water management programs of maize for recently developed hybrids.

With increasing concern about declining water resources, there is a great intension to improve water management in farming systems to improve water saving (Buttar *et al.*, 2007). Several possible approaches such as irrigation technologies and efficient irrigation scheduling (Kirda, 2010) may be adapted for more effective uses of limited water supplies. The great challenge of the agricultural sector is to produce more food from less water, which can be achieved by increasing crop water productivity. Irrigated agriculture is the largest water consuming sector and it faces competing demands from other sectors (Sander et al., 2011 and Bastianssen et al., 2014, Kijne *et al.*, 2003). The effect of different irrigation scheduling methods on root zone soil moisture, growth, yield parameters and water use efficiency of maize that under water scarcity conditions, irrigation should be scheduled at 45% of the maximum allowable depletion of available soil water of maize to obtain high yield parameters and high irrigation water use efficiency (Panda *et al.*, 2014). Little information is available on the effect of soil water and plant rooting depth monitoring with different irrigation methods on water savings in maize production compared with conventional irrigation scheduling (based on a fixed irrigation interval) and irrigation required based on Penman-Montith equation.

The water budget method balance the amount of water applied with the amount taken out through evaporation and transpiration. The plant's soil water storage is considered a bank or reservoir that can hold a limited amount of water due that is useful to the crop. Adding excessive water to the soil reservoir will mean a loss of water due to deep percolation or run off. The evaporation or the crop water use is the daily withdraw from the bank. The bank or reservoir is replenished with irrigation or rainfall. The water budget model works (Sivakumar, M.V.K. and Wallace, J.S., 2011) well with a computer spread sheet (worksheet 1) that allows the Daily

ET, precipitation, and irrigation amounts to be entered. However there had been no or minimal irrigation scheduling technologies developed for determining the optimum soil water regime for irrigated maize despite high irrigation advocacy by the government and other development partners. This has resulted farmers to over or under irrigate their maize crops that cause low yield and environmental degradation.

The main aim of this study is to examine the effect of different irrigation amounts applied with irrigation on growth performance, grain yield, water use efficiency, total production cost and net return of maize grown in a sub-humid climate of Bangladesh.

1.2 Effect of nitrogen

Maize is one of the grasses that present greater N requirements to reach high grain yields, removing from the soil between 20 and 25 kg of N per ton of grain produced (Muzilli et al., 2012). Nitrogen plays a pivotal role in several physiological processes inside the plant. It is fundamental to establish the plant's photosynthetic capacity (Halvorson et al., 2009); it prolongs the effective leaf area duration, delaying senescence and important for ear and kernel initiation, contributing to define maize sink capacity (Torbert *et al.*, 2011); and it helps to maintain functional kernels throughout grain filling, influencing the number of developed kernels and kernel final size (Huber *et al.*, 2004; John *et al.*, 2007). The effect of N availability on important maize agronomic traits has been examined by a number of workers (Evans *et al.*, 2008; McCullough *et al.*, 2014). Nitrogen limiting conditions produce several restrictions to plant development, delaying silking, decreasing pre-anthesis crop growth rate (McCullough *et al.*, 2014), dwindling leaf area index at flowering and accelerating leaf senescence rates throughout the life cycle (Wittwer *et al.*, 2008). Maize grain yield potential has increased dramatically during the last 50 years especially in temperate regions of the world (Russelle *et al*., 2011; Toosey *et al*., 2012). This yield enhancement can be largely attributed to the release of genetic superior hybrids, higher plant densities, increased use of chemical fertilizers, reduction of row spacing, improved cultural practices, better weed and pest control (Cakir *et al*., 2014; Dong *et al*., 2011; Totawat, *et al*., 2011).

The continuous development of shape and activity of a plant is called plant development (Development). Analysis of crop development basis on incremental distinct events, namely phenol stage such as seedling emergence, flower initiation and emergence of flower will be easier the flowers will be easier. Amount of development and growth of plant has determined amount of growth in each of phonological stages (Phenophases) and evaluation of crop development in relation to environmental condition. Nitrogen has a major effect on growth among the major nutrients needed by plants (especially the three elements of N, P, K) and the growth of maize plant has been proven various experiments (Subramanian *et al*., 2006; Carpici *et al*., 2010) and Plants give it different responses. Maize need to nitrogen is different due to weather conditions, soil type and maize rotation (Blackmer, *et al*., 2009; Bundy, *et al*., 2014). Amount of Nitrogen stored in soil can affect plant growth and development (Muchow and Mccullovgh *et al*., 2014). Due to the high purity plant is easily accomplished within itself these materials after entering of amino acids to cell and participate them as a part of its structure in all metabolism ways. This process allows the plant to save some energy and thus it shows resistance and metabolic stability against stresses caused by environmental conditions. In addition, this process lead to growth and promotion of biosynthesis of amino acids in the plant and it leads to qualitative and quantitative increase of herbal products (Ashok *et al*., 2009).

Forge yield in maize increases and quality decreases rapidly as plant matures (Barkjer, *et al*., 2013), indicating that harvesting at early heading stage is generally the right time to produce high forage yield with high quality. When maize is grown for silage it is harvested 2–3 weeks earlier than maize harvested for grain. Pain (2005) reported that when maize is the most suitable crop to be grown for silage in temperate countries, forage maize become one of the most important feed stuff for ruminants specially cattle (Rouanet *et al*., 2007). Forage maize compared to other grasses has a relatively high content of non-structural carbohydrate. In case of silage maize, sugars within the cell and the water soluble carbohydrates are more important in the preservation of the silage material (Pain, 2005). Other carbohydrate sugars are often added to the crop for silage making. In some performance studies, the introduced variety 8742, recorded the highest relative growth rate, leaf area and dry weight as compared to Mugtama 45 and Tlatizapan 8743 (Mohammoud *et al*., 2007). Therefore, the selection of cultivars for forage production may be an important management practice, because it influences the nutritive value (Grbill *et al*., 2011). Nitrogen element is the nutrient that most frequently limits yield and plays an important role in quality of maize crops. It is almost deficient in most soils of Bangladesh and most of the tropics (Jules, 2014). Singh *et al*. (2006) found that the biological yield, content and uptake of nitrogen in grain and stover of maize were highest with nitrogen as urea applied in two split dressings. Sawi *et al*., 2013 and Omara *et al*., 2009 observed that nitrogen had significant effects on chemical composition of leaves, plant height, leaves, internodes number per plant at early stages. Shoot and root dry weight and cob number per plant. Nitrogen also significantly affected final seed yield and some yield components such as number and weight of cobs/m^{2}and weight of seeds per cob, also affected straw yield. Gasim *et al*., (2011) found that the addition of nitrogen increased forage fresh and dry yield, also increased percentage of crude protein in leaf stem.

This work was carried out to evaluate the effects of N rates on growth and grain yield, N use efficiency and other agronomic traits of hybrids cultivated in different decades in Bangladesh. The main objectives of this study were to investigate the influence of different nitrogen sources on growth, yield and quality of maize and fodder maize under irrigation.

1.3 Effect of interaction between irrigation and nitrogen

Maize occupies an important position in the existing cropping systems of Bangladesh due to source of good economic return in a short duration and diversified products such as corn oil, glucose-D, starch etc. The average grain yield of maize is not only substantially lower compared with other important maize growing countries but also less than the production potential of existing genotypes. Main constraints to increase maize productivity are malnutrition, inadequate water supply, weed infestation, pest attack etc. Thus there is a need to develop a site specific agro technology to increase productivity of maize by making improvement in some basic components of the existing maize production technology in Bangladesh. The method and extent of fertilization should be determined not on the basis of maximum yield, but solely on the basis of profitability (Ipperisil, 2009). According to Debreczeni (2010) the upper limit of fertilizer application has to be determined on the basis of optimal level of economic cultivation originating from surplus yield. Accurate precipitation forecasts can only be given with the knowledge of precipitation and ground water conditions regarding a specific plot (Balasubramanian, 2009). If precipitation and the easily accessible water supply of the soil do not satisfy the needs of the plant, then the deficiency has to be compensated with irrigation (Petrasovit *et al.*, 2008).

Maize has high yield potential and responds well to different management practices. Among various management practices, irrigation and nitrogen play a significant role in realizing the maximum potential of the crop. Irrigation scheduling is the technology for applying the proper amount of water at the right time. Reasons for using irrigation scheduling are to reduce water applications, energy consumption and deep percolation of water below the crop root zone (Ritter & Manager, 2012). Water is further required to provide constant turgor pressure that supports the plant and facilitates cell enlargement after cell division has been initiated. Hence, plant growth and survival depend on adequate water availability. Irrigation also improves the efficiency of fertilizer utilization by the crop. Increases in irrigation frequency increased N, P and K uptake by maize (Prasad & Prasad, 2008). Maximum grain yield and greater water use efficiency were achieved when irrigating to 100% of field capacity (Mbagwu & Hamblin, 2010). Highest grain yield was obtained with 120 kg ha^{-1} and irrigation at 25% depletion of available soil moisture (Patel *et al.,* 2009). Crude portion contents increased with increase in irrigation frequency (Pillai *et al.,* 2010). Management of crop nutrition includes correct manure application at right time, optimum level and appropriate method of application. Nitrogen, being an integral part of structural and functional proteins, chlorophyll and nucleic acids such as RNA and DNA as well as essential for proper carbohydrate utilization, plays a vital role in crop development (Tisdale *et al.,* 2010). Increase leaf area index, leaf area duration, photosynthetic rate and increased radiation interception and radiation use efficiency (Muchow & Davis, 2010; Silvakumar *et al.*, 2008; Connor *et al.,* 2013). Both nitrogen deficiency and excess affects assimilate partitioning between vegetative and reproductive organs (Mbagwu & Hamblin, 2010). Crude protein concentration is frequently increased by adequate nitrogen supply (Tisdale *et al.,* 2010). The present study was therefore, undertaken to determine the optimum level of irrigation schedules and nitrogen rates for enhanced growth and grain yield of maize in Bangladesh.

1.4 Objectives of research

Potentiality of maize crop for its growth and yield can be fully exploited by adopting suitable agronomic practices such as optimum irrigation levels, fertilizers dose, soil conditions, growing season and water availability. The major plant nutrients N, P and K limit the normal plant growth and yield. Increasing the productivity per unit area through agronomic management is one of the important strategies to enhance the productivity of maize. Precision irrigation level and N dose research for sustainable water resource and N fertilizers management is the greatest research need in Bangladesh with the objectives:

1). to find out optimum irrigation levels on growth and yield of hybrid maize.

2). to find out optimum nitrogen dose on the growth and yield of hybrid maize.

3). to study the interaction effect between irrigation levels and suitable nitrogen dose on the growth and yield of hybrid maize.

3). to find out suitable hybrid maize varieties.

Chapter Two

Review of Literature

Chapter-TWO

2. Review of Literature

2.1. Effect of irrigation on growth and growth performances on experimental maize varieties

Buttar *et al.* (2007) started that with increasing concern about declining water resources, there is a great intension to improve water management in farming systems to improve water saving. Several possible approaches such as irrigation technologies and efficient irrigation scheduling (Kirda, 2010) may be adapted for more effective uses of limited water supplies. The great challenge of the agricultural sector is to produce more food from less water, which can be achieved by increasing crop water productivity. Irrigated agriculture is the largest water consuming sector and it faces competing demands from other sectors (Bastionssen, 2014, Kijne *et al.*, 2013).

Corbeels *et al.* (2008) and Feddema *et al.* (2005) did not measure significant differences when N fertilizer was applied. Combined nutrient and irrigation supply levels are more commonly researched (e.g. Otegui *et al.*, 2005; Pandey *et al.*, 2010; Zwart Szalokine , 2012). Optimum values for amount nutrient and irrigation water application can be found to maximize crop water productivity.

Davis Wit (2010) was among the first to describe the photosynthesis transpiration relationship. Bierhuizen (2008) researched the influence of climatic parameters on this relationship and found a proportionally inverse relation (reviewed and confirmed by Tanner and Sinclair in 2013) between vapour pressure deficit of the air and crop water productivity.

Similar results were found by Stone (2006) for pastures grown at different latitudes. As the vapour pressure deficit generally decreases when moving away from the equator, CWP is expected to increase with increasing latitude.

Dong *et al.* (2010) found similar results and concluded that there was no significant difference between continuous flooding and alternate wetting and drying experiments; 10 year average ETact and CWP amounted 590 and 591mm and 1.49 and 1.58 kgm^{-3} for continuous flooding and intermittent irrigation experiments, respectively.

Doorenbos and Kassam (2009) noted the partitioning of evapotranspiration in evaporation and transpiration in field experiments is, however, difficult and therefore not a practical solution. Moreover, evaporation is always a component related to crop specific growth, tillage and water management practices, and this water is no longer available for other usage or reuse in the basin. Since evapotranspiration is based on root water uptake, supplies from rainfall, irrigation and capillary rise are integrated. Despite that CWP is a key element in longer-term and strategic water resources planning; the actual and practically feasible values are hardly understood.

Doorenbos and Kassam (2009) carried out application of manure led to higher production and straw mulching improved soil water and soil temperature conditions. CWP for the experiment with straw mulching was 2.67 and 2.41 kgm^{-3} for a combination of straw mulching and manure. ETact in the winter season was tempered to 268 and 236 mm, respectively, while yields were relatively high with 7150 and 5707 kg ha^{-1}. Bhat (2008) give a very similar range of 0.4–1.6 kgm^{-3} for lowland rice conditions.

Fereres and Soriano (2007) obtained when water supplies are limiting, the farmer's goal should be to maximize net income per unit water used rather than per land unit. Deficit irrigation, by reducing irrigation water use, can aid in coping with situations where water supply is restricted. In field crops, a well-designed deficit irrigation regime can optimize water productivity over an area when full irrigation is not possible.

Grism (2011) conducted a study on CWP values for irrigated cotton in Arizona and California and concluded that CWP values exceed the range given by Doorenbos and Kassam (2009) in many cases. In rice production CWP increased due to shorter growing periods and due to increase in the ratio of photosynthesis to transpiration (Peny *et al*., 2008). It is likely that CWP for other crops has changed significantly as well. Various studies have researched water use and yield relationship of specific crops, on specific locations, with specific cultural and water management practices. The current investigation summarizes the results of field experiments that have been conducted over the last 25 years and tries to find a range of plausible values for four major staple crops: wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), cotton (*Gossypium* spp.) and maize (*Zea mays* L.).

Hanson *et al*. (2007) carried out shortage in irrigation water supplies in the Marmara region has motivated farmers to find ways to produce none effective tillers of crops, especially maize, with less irrigation water, such as using more efficient irrigation systems and changing from fully–irrigated to deficit irrigated cropping systems. Furrow irrigation is the most common method used for irrigating row crops such as maize in the Marmara region of Turkey. However, the drip irrigation method is becoming more popular because of numerous advantages over other methods.

Hatfield *et al.* (2011) reviewed the effects of soil management on CWP by modification of the soil surface, such as tillage and mulching, and by improvement in soil nutrient status by adding nitrogen and/or phosphorus. A modification of the soil surface changes the processes of ET act and is often found to be positively related to CWP. Nutrients indirectly affect the physiological efficiency of the plant. In the nitrogen rate is plotted against the CWP of wheat during studies in Niger, Syria and Uruguay. CWP increases when nitrogen is applied and reaches an optimum at a rate of approximately 150 kg ha^{-1}.

Jin *et al.* (2009) conducted experiments in which maize was planted in furrows and the soil covered with plastic leaving holes for infiltration near the plants, thus reducing soil evaporation and improving soil water status of the root zone.

Kar *et al.* (2006) in a combination of alternate furrow irrigation and deficit irrigation experiments under Chinese conditions: low amounts of irrigation water were alternately applied to one of the two neighboring furrows. ET act was with 226mm very low, whereas grain yield was still 9058 kg ha^{-1}.

Kijne *et al.* (2013) studied irrigated agriculture is the largest water-consuming sector and it faces competing demands from other sectors, such as the industrial and the domestic sectors. With an increasing population and less water available for agricultural production, the food security for future generations is at stake. The agricultural sector faces the challenge to produce more food with less water by increasing Crop Water Productivity (CWP). A higher CWP results in either the same production from less water resources, or a higher production from the same water resources, so this is of direct benefit for other water users.

Kipkorir *et al*. (2012) provide several strategies for enhancement of CWP by integrating varietal improvement and better resources management at plant level, field level and agro-climatic level. Examples of options and practices that can be taken are: increasing the harvest index, improving drought tolerance and salinity tolerance (plant level), applying deficit irrigation, adjusting the planting dates and tillage to reduce evaporation and to increase infiltration (field level), water reuse and spatial analysis for maximum production and minimum ETact (agro-ecological level), to mention a few. Due to agronomical research (e.g. plant breeding) and improved land and water management practices, CWP has increased during the years.

Mishra *et al*. (2011) showed that although irrigation water is saved, there is no significant improvement in CWP, which remains between 0.80 and 0.99 kgm^{-3}. For this specific study in India, the ETact was not reduced because irrigation application was in excess of ETact.

Payero *et al*. (2008) reported the strong quadratic relationships between the amount of irrigation water applied varied from 76 to 1120 mm in 2007 and from 91 to 997 mm in 2008. Active root depth for maize assumed to be 90 cm, and therefore, deep percolation measurements were made 90–120 cm soil depth. Result indicated that percolation occurred only with T–125 treatment of about 9% calculated from 2 years average. Regression analysis indicated a linear relationship between seasonal ET and seasonal water applied.

Peny *et al*. (2008) experiments with results older than approximately 25 years are excluded to minimize the influence of older varieties with lower harvest index and longer growth period. The results of experiments were first re-organized into a crop-wise data base that includes latitude/longitude, country, location, ETact, Yact, biomass production, harvest index, experimental year and reference. Some of the references cited provide the results of each field experiments, while others give averages, e.g. each experimental year or each management strategy applied. Each value, whether it is reported as an average of more experiments or a unique value for one experiment, is considered as one value in the database.

Shi *et al*. (2013) measured in lysimeter experiments higher CWP values for intermittent irrigation experiments (2.0 kgm^{-3}) compared with continuous looding (1.6 kgm^{-3}), whereas yields were only 200 kg ha^{-1} lower). Moreover, ET act in the intermittent experiment (347 mm) was 22% lower compared to continuous flooding. For the sake of clarity, Selvaraju (2012) distinguishes "dry" and "wet" water savings: reduction in ET act is a wet saving because the evapotranspired water is lost for future use in the basin. On the other hand irrigation water savings are dry savings as the water may be recycled within the basin for future use (unless it is polluted). As is shown by the results from Mishra *et al*. (2011) and Dong *et al*. (2011) intermittent irrigation is merely an example of dry water saving as ETact is hardly affected by reduced supplies.

Yazar *et al*. (2012) found that without irrigation CWP in rained systems is low, but that CWP rapidly increases when a little irrigation water is applied. According to the database, optimum values for CWP are reached at approximately 150 and 280mm of irrigation water applied for wheat and maize, respectively (in addition to rainfall). Maximum water productivity will often not coincide with farmers' interests, whose aim is a maximum land productivity or economic profitability. It requires a shift in irrigation science, irrigation water management and basin water allocation to move away from 'maximum irrigation-maximum yield' strategies to 'less irrigation-maximum CWP' policies. Besides the total amount of irrigation water applied, the timing of irrigation is important.

Yildirim and Kodal (2008) reported that seasonal ET in maize varied between 300 and 1024 mm in Ankara, Turkey. The seasonal values of ET per treatment ranged from 311 to 1078 mm in 2007 and from 298 to 1061 mm in 2008. As expected, the highest seasonal ET occurred in the T-125 treatment and the lowest ET occurred in the non–irrigated treatment (T-0). Under furrow irrigation applications, seasonal ET of maize obtained by Gencoglan and Yazar (2009) was 1026 mm for full irrigation treatment and 410 mm for non-irrigated treatment in the Cukurova region of Turkey.

Zwart and Bastiaanssen (2014) reviewed 84 literature sources that had studied water use efficiency of corn and concluded that water use efficiency can be increased significantly if irrigation water is reduced and crop water deficit is intentionally induced. Panda *et al*. (2014) evaluated the effect of different irrigation scheduling methods on root zone soil moisture, growth, yield parameters and water use efficiency of corn and concluded that under water scarcity conditions, irrigation should be scheduled at 45% of the maximum allowable depletion of available soil water of corn to obtain high yield parameters and high irrigation water use efficiency. Little information is available on the effect of soil water and plant rooting depth monitoring with different irrigation methods on water savings in corn and sugar beet production compared with conventional irrigation scheduling (based on a fixed irrigation interval) and irrigation required based on Penman-Montith equation.

2.2. Effect of irrigation on yield and yield performances on experimental maize varieties

Allen *et al*. (2008) studied from greenhouse experiments, pot experiments and water balance simulation models were excluded. Also, experiments based on the reference evapotranspiration method have not been regarded as being suitable for the current review; evapotranspiration is not measured but estimated. The soil water balance methods that monitor soil water content during the growing season by measurements of gravimetric soil moisture, or by neutron scattering equipment (neutron probes) or by time-domain-reflectometry (TDR), is also often used. Micro-meteorological in situ flux measurement techniques, such as the Bowen ratio and eddy-correlation methods are not common for agronomical studies (they are mainly used for micro-meteorological and climate studies in which yield is not reported). Yield is defined as the marketable part of the total above ground biomass production; for wheat, maize and rice total grain yield is considered, and for cotton the total lint yield and/or total seed yield. Unfortunately, very few sources give the moisture content at which the yield was measured, which inevitably means an error exists in the final results.

Ayars *et al*. (2013) Some advantages of drip irrigation over other irrigation methods include improved water and nutrient management, improved saline water management, potential for improved yields and crop quality, reducing the incidence of diseases and weeds in dry row middles, greater control on applied water resulting in less water and nutrient loss through deep percolation, and reduced total water requirements.

Bozkurt *et al*. (2011) reported that the highest grain yield was found in 120% of evaporation from a class A Pan under the Eastern Mediterranean climatic conditions in Turkey. This ranged from 5650 to 16340 kg ha^{-1} in 2007 and from 5490 to 16730 kg ha^{-1} in 2008 for the different irrigation regimes. Increased water amounts resulted in a relatively higher yield, since water deficit was the main yield–limiting factor in both years. The maximum yield was obtained at T 125 and the minimum yield at T 0 in both 2007 and 2008. However, in 2007, there was no significant difference between the treatments T 100 and T 75 i.e. irrigated with a 25 percent deficit.

Cakir (2014), Oktem (2013) and Igbadun *et al*. (2007) observed a linear relationship was found between seasonal ET and grain yield in both years. Grain yield responded linearly to crop water consumption.

Dogan and Kirnak (2010) noted during the past decade, Turkish government has been financially supporting the farmers who are willing to set up drip irrigation system. Therefore, the use of drip irrigation is increasing substantially each year in the region. However, local information from the Marmara region of Turkey on the response of maize yield with drip irrigation is very limited, especially dealing with the effect of limited water allocations. In Marmara climatic region, little attempt has been made to assess the water-yield relationships and optimum water management programs of maize for recently developed hybrids.

Dong *et al*. (2010) reported the maximum values go up to 2.20 kgm^{-3} and were measured in China on alternate wetting and drying maize plots. Maize grain yield of over 10 t /ha was amongst the highest measured, whereas ET act was on the lower side with 465mm.

Gencoglan and Yazar (2009), Kipkorir *et al.* (2012), Bozkurt *et al.* (2006), and Farré and Faci (2013) reported the relationship between applied water and grain yield was quadratic. Small irrigation amounts increased yield, more or less linearly up to a level where the relationship was curvilinear because part of the water applied is not used in ET. At a point of 1100 mm of irrigation water amount, yield reached its maximum value (16730 kg ha^{-1}). Moreover, the regression equation shows that additional amounts of irrigation did not increase it any further. However, Payero *et al.* (2006) reported that there was linear relationship between grain yield and seasonal irrigation water amount.

Hanson *et al.* (2009) evaluated improved furrow irrigation, surface drip and subsurface drip irrigation methods for reducing deep percolation, increasing yield and saving applied water. They reported that overall performance showed volumes of applied water from the drip methods ranged between 43 and 74% of that required from the furrow method. Also less variability in plant mass and yield occurred for the drip plots.

Lamm *et al.* (2005) stated that it is difficult to plan deficit irrigation for maize without causing yield reduction. Payero *et al.* (2012) reported that trying to increase crop water productivity by imposing deficit irrigation for maize might not be a beneficial strategy in a semiarid climate. Karam *et al.* (2003) found that grain and dry matter yield, and leaf area index was reduced by severity of water stress.

Mansouri–Far *et al.* (2010) reported that irrigation water can be conserved and yields maintained in maize plant (as sensitive crop to drought stress) under water limited conditions through improved fertilizer managements and selecting more tolerant hybrids. On the other hand, the feasibility of increasing either the water uses efficiency is a decision that needs to be based not only on the biophysical response of the crop but also on economic factors. Often the objective of producers is not to increase yields but to increase profits (Payero *et al*., 2008). Determining the level of irrigation needed to optimize profits can be complex and depends on both biophysical and economic.

Oktem *et al*. (2013); Yazar *et al*. (2012); Kara *et al*. (2006) and Sharma *et al*. (2009) observed the maximum value is being taken to approach the optimal growing conditions with respect to soil fertility management and irrigation water application at a certain location. It also shows that the highest CWP values occur between 30 and 40 degrees latitude where a factor 2-3 difference in CWP of wheat, rice and maize is detected when compared to areas between 10 and 20 degrees. Many examples from literature describe the influence of irrigation water management on CWP. Deficit irrigation practices have been researched to quantify the effect on yield and to find optimum crop water productivity values.

Oktem (2006) stated that WUE increased as the amount of irrigation water increased. The ranges of WUE and IWUE obtained in this study were close to those reported in the previous literature for maize. Howell *et al*. (2011) reported WUE range of 0.89–1.45 kg m^{-3}, Yazar *et al*. (2012) reported WUE ranges of 0.87–1.42 kg m^{-3}, Oktem *et al*. (2013) reported WUE range of 1.04–1.36 kg m–3 and Oktem (2006) reported IWUE range of 1.07-1.43 kg m^{-3}. However, the range of WUE and IWUE obtained in this study were higher than those reported by Igbadun *et al*. (2007) and Pandey *et al*. (2010). Generally, WUE and IWUE are influenced by crop yield potential, irrigation method, estimation and measurement of ET, crop environment, and climatic characteristics of the region.

Otegui *et al*. (2005) verified the application of deficit irrigation requires thorough understanding of the yield response to water (crop sensitivity to drought stress) and of the economic impact of reductions in harvest. However, maize has been reported to be very sensitive to drought.

Pandey *et al*. (2010) stated that yield reduction (22.6-26.4%) caused by deficit irrigation was associated with a decrease in kernel number and weight. The effects of deficit irrigation for the same crop may vary with location. Climate and soil type of the location are perhaps the most important factors dictating the influence of deficit irrigation (Igbadun *et al*., 2007).

Prasad *et al*., (2009) investigated in Argentina maximum values were measured exceeding 1.0 kgm^{-3} in experiments where water was applied during critical periods such as pre-seeding and flowering. Maize seed yields did not differ compared to other treatments, though Enact was lower. Finally, maize CWP values were measured ranging from 0.22 kgm^{-3} up to a maximum of 3.99 kgm^{-3} which exhibits a large range of variation (CV = 0.38). In 67% of the publications the maximum value of the source exceeds the value of 1.6 kgm^{-3} provided by FAO33. The CWP range of 1.1–2.7 kgm^{-3} for maize, a C_4 crop, is significantly higher than wheat, rice and cotton, which are C_3 crops. The maximum values were measured by Crop water productivity (CWP) benchmark values per unit of water depletion according to FAO33 (Doorenbos and Kassam, 2009).

Saranga *et al*. (2008) measured average lint yield values of 1300 kg ha^{-1} in a field trial with deficit irrigation, while seasonal ETact was very low with 390mm. Howell *et al*. (2011) measured similar values (0.33 kgm^{-3}) in an experiment with high frequency trickle irrigation and reduced water deficits management for narrow row maize in California (USA).

Siddique *et al*. (2010) investigated CWP of old and new wheat cultivars and found that older cultivars have lower CWP values due to lower harvest index. No significant difference in total biomass production between the old and new cultivars was found. For example in maize production CWP increased throughout the years due to developments in the new plants types with a higher ratio of photosynthesis to transpiration and due to a decrease in growth period.

Stone *et al*. (2006) and Karam *et al*. (2003) revealed in these conditions, irrigation is the major factor determining yield. It is consequently essential to determine the water regimes leading to highest yield. Maize has been reported in the literature to have high irrigation requirements. Maize grain yield increased significantly by irrigation water amount and irrigation frequency (Yazar *et al*., 2009; Kara and Biber, 2008; Farré and Faci, 2013). However, water availability is usually the most important natural factor limiting expansion and development of agriculture in Marmara region of Turkey. Competition for water from other sectors such as industry and domestic use will force irrigation to operate under water scarcity.

Yazar *et al*. (2012) reported also that the highest average maize grain yield obtained from full irrigation treatment using drip irrigation method. However, Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase grain yields at the important level. The relation between applied water and grain yield was evaluated for each experimental year.

2.3. Effect of nitrogen on growth and growth performances on experimental maize varieties

Aldrich (2014), Ozgurel (20008), Russelle *et al*. (2011) and Wells *et al*. (2014) all agree that the best practice in managing corn is the application of N fertilizer at the time (or near the time) when both the need for N and N uptake are maximum for corn plants because it promotes higher nutrient uses efficiency by reducing de-nitrification, N immobilization and leaching processes.

Ashok Kumar (2009) found that each successive increment in nitrogen level from 0 to 120 kg ha^{-1} markedly improved plant height as well as dry weight plant^{-1} in pop corn at New Delhi. Konuskan *et al.* (2010) reported positive effect of increased nitrogen application on plant height of popcorn and the highest value was obtained with 240 kg N ha^{-1}.

Ashok Kumar *et al.* (2008) observed that in maize, growth parameters were found to be the highest plant girth with the application of 120 kg nitrogen through urea and 30 kg nitrogen through poultry manure per hectare. Suryavanshi *et al*. (2008) reported that application of 150 kg nitrogen ha^{-1} was found significantly effective over 50 and 100 kg nitrogen ha^{-1} in increasing plant girth of maize from 149.20 cm to 185.61 cm in black soil during kharif season at Parbhani.

Bangarw (2008) reported that increase in N dose from 40 to 120 kg ha^{-1} significantly increased the plant effective tiller from 132.16 to 139.84 cm in silty clay loam soils at Akola. They reported significant response up to 120 kg nitrogen ha^{-1} in dry matter production of maize.

Bapatla Singh *et al*. (2008) reported that the plant height of maize in pure stand increased with application of 180 kg N ha^{-1} than with 120 kg N ha^{-1} and 60 kg N ha^{-1} on silty clay-loam soils of Tadong, Sikkim. Similarly, biomass production increased with increasing N level was also reported by Nanjundappa *et al*. (2014).

Bindhani (2007) concluded that in baby corn net returns and benefit : cost ratio were highest with 120 kg N ha^{-1}, which resulted in significant increase of 289.2, 69.8 and 39.15 per cent in net returns and 235.2, 57.7 and 34.1 per cent in benefit : cost ratio compared to that of the no nitrogen, 40 and 80 kg N ha^{-1} respectively. Suryavanshi *et al.* (2008) reported significantly higher gross returns, net monetary returns and benefit: cost ratio with 150 kg nitrogen ha^{-1} as compared to either 50 and 100 kg nitrogen ha^{-1}.

Bindhani *et al*. (2007) stated that in baby corn, application of 120 kg N ha^{-1} resulted in tallest plant with maximum dry matter yield and leaf area index, which were significantly higher than those at remaining lower levels of nitrogen.

Bindhani *et al*. (2007) reported that the nitrogen content both in baby corn and green fodder increased significantly with increasing N levels up to 120 kg ha^{-1}. (Ashok Kumar, 2009) concluded that nitrogen application also enhanced nitrogen uptake and harvest index up to 120 kg ha^{-1}.

Binder *et al*. (2010) recorded fast development of corn plants during middle vegetative stage results in maximum N uptake, meaning that even N-deficient corn should be able to respond to delayed N application.

Chamshama *et al*. (2008) evaluated from an experiment conducted on clay soils of Akola reported increase in plant height of maize hybrid (Pro Agro 4640) with higher plant density (111111 plants ha^{-1}) than with lower planting density (83333 plants ha^{-1}). Similar findings were also reported by Angureira *et al*. (2009) from Argentina on Argiudols.

Gasim (2011) observed that nitrogen fertilization accelerated the time to reach 50% tasseling, promoted the fresh and dry forage weight. Sawi (2013) found that nitrogen application increased the number of ears per plant, ear height, number of days to mid-silking and protein content, and decreased the number of barren stalks. Grain protein content was increased by nitrogen (Warrson *et al*., 2007. Rao (2014) carried out increased protein content in maize straw was obtained with increased dose of nitrogen.

Gaur (2011) indicated that the increase in plant height with nitrogen fertilizer is due to the fact that nitrogen promotes plant growth, increases the number of internodes and length of the internodes which results in progressive increase in plant height. Chauhan, 2013, Turkstat (2010) reported similar results. Nitrogen fertilizer increased number of leaves per plant and leaf area (Gasim, 2011).

Gokmen *et al.* (2011) reported that in pop corn the maximum plant height was observed with the highest dose of nitrogen *i.e.,* 250 kg ha^{-1} while lowest values were recorded at control level 0 or 50 kg N ha^{-1}. Applications of 90 kg N ha^{-1} in pop corn significantly improved dry matter per plant at harvest over 60 kg N ha^{-1}. Further increase in fertilizer dose failed to get a significant improvement. (Chauhan, 2013).

Goolsby *et al*. (2010) reported one of the most harmful ecological problems, known to be caused by accelerated agriculture, is run-off from croplands. It results in deterioration of water quality and declining sea-life. The mean annual input of N as a result of fertilizer run-off (61% of which is due to nitrate N) to the Gulf of Mexico has tripled in the last 30 years. This illustrates the damaging effects of improper fertilizer management.

Jat *et al.* (2009) found that in sweet corn plant height was significantly increased with increase in level of fertilizer from 50 per cent (60:30:30 kg NPK ha^{-1}) to 100 per cent RDF (120:60:60 kg NPK ha^{-1}). They also reported that application of 100 per cent RDF significantly produced more dry matter (137.95 g plant^{-1}) than 75 and 50 per cent RDF.

John and Warrson (2007) noted that the addition of nitrogen increased stem diameter. Kuruvilla (2006) recorded that nitrogen application resulted in greater values of plant height, leaf area, number of leaves and stem diameter of fodder maize, fresh and dry forage yield were also increased due to addition of nitrogen. Leaf to stem ratio was found also to be increased by nitrogen. The uptake of nitrogen by maize is low during early development and increased at tasseling. Although only relatively small amounts of fertilizers are required during the very early stages of plant growth, high concentration of nutrients in the roots zone at that time are beneficial in promoting early growth (Raja *et al.*, 2011).

Joji Arihara *et al.* (2008) observed highly intense crop production worldwide results in large amounts of N being removed with the harvested grain and therefore cause natural nutrient supply of soils to deplete year after year. Maintaining the balance between N lost from the soil and naturally occurring N fixation is not possible, as it previously was, during the pre-chemical era.

Kar *et al.* (2006) revealed that uptake of N in grain and stover increased significantly with successive increase in nitrogen. It ranged between 20.41 kg in control to 91.11 kg ha^{-1} at 80 kg N application. Sahoo and Mahapatra (2007) started application of 120-26.2-50 kg nitrogen, phosphorus and potassium ha^{-1} to sweet corn resulted in significant increase in nitrogen, phosphorus and potassium uptake compared to other levels tried.

Kumar and Bangarwa (2007) reported that increase in LAI (2.6 to 4.9) of maize with increase in nitrogen level from 0 to 240 kg ha^{-1} at Hisar during winter season in sandy loam soil. Similar response to increased level of nitrogen on LAI was reported by Shivay *et al.* (2009) from Pantnagar, Muniswamy *et al.* (2007) from Bangalore and Suryavanshi *et al.* (2008) from Parbhani.

Lamm (2005) and Venugopal Rao (2013) also reported the similar kind of response up to 240 kg N ha^{-1} from Bapatla under maize fallow zero tillage conditions on sandy clay loam soils. Regardless of soils and regions, a few researchers reported increased growth parameters and decrease in the days to reach 50 per cent tasseling and silking with increasing rate of N application.

Lamm (2005) observed higher dry matter, crop growth rate, leaf area and leaf area index in maize under alley cropping with *Albizia* than in sole cropping. Similarly, in a study conducted at Jhansi on the tree-crop interaction in *Albizia procera* and black gram and mustard agrisilvi system it was noticed that there was significant reduction in the crop yield due to the limited availability of light to the crop (Nath *et al.,* 2009).

Ma *et al*. (2009) recorded the highest loss of N during the growing season at the location with the highest rate of N fertilizer applied; net gain of mineral N had occurred throughout the growing season at the check location where there was no N fertilizer applied. This showed that significant amounts of mineralized plant-available N can be contributed to the soil from the atmosphere via precipitation and dry deposition. Therefore, it is necessary to evaluate the amount of residual N present in soil by conducting a preplant soil test.

Mcullough *et al*. (2014) conducted an experiment and found that nitrogen uptake was more with lower planting density of 66666 plants ha^{-1} than that with higher plant densities (88888 plants ha^{-1} and 133333 plants ha^{-1}) on clay loam soils at Bapatla. Similar findings were also reported earlier by Shapiro and Wortmann (2007) from Nebraska on silty clay loam soils. In contrast, nutrient uptake was significantly superior with higher level of planting density (100000 plants ha^{-1}) than lower plant population (67000 and 80000 plants ha^{-1}) on sandy clay loam soils of Bapatla.

Mhamoud (2012) recorded maximum none effective leaf of maize crop with 150 kg N ha^{-1}. The result of the experiment conducted by Muniswamy *et al.* (2007) at Bangalore during kharif season indicated that plant height of maize increased (151.3 to 175.2 cm) significantly with each increment of nitrogen from 80 to 160 kg ha^{-1}.

Misra *et al*. (2014) found that N uptake increased with increase in plant population from 55000 plants ha^{-1} to 98000 plants ha^{-1} on sandy loam soils during winter at Bahraich (U P). Singh *et al*. (2014) indicated that the uptake of N P and K was significantly higher when the crop grown at 83333 plants ha^{-1} compared to the rest of the treatments (55555 plants/ ha, 66666 plants ha^{-1} and 111111 plants ha^{-1}) on silty loam soils of Faizabad (U P) during winter season.

Mishra *et al.* (2011) reported that in eastern Uttar Pradesh, among the three levels of nitrogen tried viz., 0, 75, and 150kg N ha^{-1}, 150 kg N ha^{-1} produced maximum leaf area index in winter maize. Vadivel *et al.* (2011) observed that with index and dry matter of maize increased significantly.

Mitra *et al.* (2014) evaluated the efficiency of in-season N application and concluded that both NUE and grain yields can be increased by delaying N fertilization for corn. Mixed and site-specific results of split N fertilization of corn indicate that more extensive data is needed to confirm or contradict the effectiveness of this method of corn fertilization.

Moga *et al.* (2006) found that the highest grain yield for winter maize was achieved by application of N fertilizer to the established crop. Fertilization delayed until Feke's 5 enabled the crop to overcome N stress present earlier in the growing season and achieve maximum or near maximum yields.

Nandal (2005 and Agarwal (2012) reported significant maize growth response up to 200 kg N ha^{-1} from Hissar, Kumar *et al.* (2005) up to 175 kg N ha^{-1} from Ludhiana, Singh *et al.* (2011) up to 150 kg N ha^{-1} from up to 135 kg N ha^{-1}. Nitrogen utilization from the mineral fertilizer also depended on the interaction between the N fertilization level and the magnesium dose and method of its application. These dependences have been described by first- degree equations. The application of 15 kg Mg·ha^{-1} applied broadcast or in rows caused an increase in N utilization from the applied mineral fertilizer (plotted at a higher level) in relation to the objects where Mg was not applied.

Nath *et al.* (2009) observed that in sweet corn the dry matter accumulation increased significantly by enhancing the fertility level up to 90 kg N + 45 kg P_2O_5 ha^{-1}.

Panthnagar (2011) and Shivay *et al.* (2009) reported increase in plant height and dry matter accumulation in maize with the application of 120 kg N ha^{-1} compared to that at lower rates of application on silty clay loam soils.

Pandey *et al.* (2010) conducted a field experiment conducted during rainy season at Almora envisaged that among three levels of N tried 120 kg N ha^{-1} resulted in maximum plant height of baby corn. Sunder Singh (2011) revealed that in baby corn during summer season there was a significant increase in plant height and girth with every increment dose of N up to 150 kg ha^{-1} where as during kharif season the significant difference in plant height was observed only up to 120 kg/ha.

Petasovit (2008) obtained a return of nitrogen in his fertilization variant NPK + Mg 91%, while normally after NPK application, the nitrogen return was 74%. The nitrogen harvest index is an indicator of the up taken component transformed into the biomass of the usable plant organs. This index always has a higher value than the yield harvest index, caused by a higher percentage of N content in the grain than in the stover of maize the dependence decreased. In case of the hybrid 'stay-green' type, the increase in N dose by 1 kg N·ha^{-1} caused an increment in the nitrogen harvest index by 0.0001, while in the traditional cultivar this index value decreased by 0.0003.

Petasovit (2008) reported the presence of magnesium in multi-component fertilizers significantly increased the utilization of nitrogen from ammonium saltpeter and contributed to the increased playability of fertilization and, at the same time, meeting the requirements of good agricultural practice.

Reddy *et al*. (2007) from Warangal on sandy clay loam soil observed that application of 240 kg N ha^{-1} resulted in significantly higher nitrogen uptake (kernel or stover or total) compared to lower doses of 120 and 180 kg ha^{-1} under zero tillage conditions in maize fallows. Connor *et al.* (2013) reported a tight association between plant density and N rate on uptake of N P K was documented at India.

Sander *et al*., (2011) stated from an experiment conducted during *kharif* at Kanpur observed that growth attributes of maize *viz*., plant height, stem girth and number of functional leaves were significantly higher with wider row spacing (60 cm) than with narrow row spacing (45 cm). Singh *et al. (*2014) reported that dry matter production at 90 and 120 days after sowing (DAS) increased significantly with increase in population levels from 55556 plants ha^{-1} to 111111 plants ha^{-1} on silty loam soils of Faizabad (U P) during winter season.

Sahoo and Mahapatra (2014) observed significant higher net profit (Rs 20,700 ha^{-1}) due to 180 kg N ha-1 over 60 kg N ha^{-1} (Rs 15,300 ha^{-1}). Kar *et al.* (2006) reported that application of nitrogen from 0 to 80 kg ha^{-1} gave significantly higher net returns (Rs 32,086 to Rs 61,532 ha-1) and benefit: cost ratio (1.73 to 3.76) of sweet corn during kharif season in sandy loam soils of Bhubaneshwar.

Shanti *et al.* (2007) reported advancement of silking by 7.9 and 8.4 days, respectively due to 120 and 160 kg N ha^{-1} in comparison with the crop in no nitrogen treatment (control). Earlier appearance of silks (60.6 to 56.2 days) was also observed with increase in nitrogen level from 80 to 160 kg ha^{-1} by Muniswamy *et al.* (2007).

Shanti *et al.* (2007) envisaged that in maize, among five levels of nitrogen tried, 160 kg N ha^{-1} resulted in maximum leaf area index and dry matter accumulation per plant.

Sharma *et al.* (2010) reported that application of 120 kg nitrogen ha^{-1} resulted in higher net returns than with lower levels. Pandey *et al.* (2010) found that application of 120 kg N ha^{-1} gave significantly higher net returns of 27.3 and 8.6 per cent over 60 and 90 kg N ha^{-1}, respectively and the benefit : cost ratio was also found to be the highest with 120 kg N ha^{-1}. Significant increase in net monetary returns (Rs 10,685) was recorded by Ameta and Dhakar (2010) with 150 kg N ha^{-1} over 60 kg N/ha (Rs 8,572) in maize.

Singh *et al.* (2012) stated from their field study at Varanasi on clay loam soils revealed that the plant height and dry matter production per plant were significantly increased up to 150 kg N ha^{-1}. Peny *et al.* (2008) observed that the growth parameters like plant height, number of leaves plant^{-1}, stem girth, leaf area index and dry matter accumulation plant^{-1} were significantly influenced by N levels, and all these parameters tended to increase with increasing levels of N from 75 to175 kg ha^{-1} on Alfisols of Anand.

Singh *et al.* (2010) found significant increase in nitrogen uptake with successive increment of nitrogen up to 100 kg ha^{-1}, beyond which the increase was only marginal up to 200 kg ha^{-1}. Ashok Kumar (2008) also reported the similar findings in popcorn.

Singh *et al.* (2007) reported that nitrogen uptake by winter maize significantly increased with successive increment of N levels from 50 kg ha^{-1} to 150 kg ha^{-1} on sandy loam soils of Dholi, Bihar. Bhaskaran *et al.* (2012) also reported a positive trend in NPK uptake with increase in N application at all growth stages of maize. Gaur *et al.* (2014) and Shivay *et al.* (2012) also reported similar findings.

Singh and Tajbaksh (2012) conducted a field trial during *kharif* season on loamy sand soils of Ludhiana (Punjab) and found that dry matter accumulation was significantly the highest under plant population of 100000 plants ha^{-1} (60 cm x 16.6 cm) than that of with 50000 plants ha^{-1} (60 cm x 33.3 cm) or 75000 plants ha^{-1} (60 cm x 22.2 cm).

Sofi *et al.* (2004) observed that the highest uptake of nutrients in maize with the application of 160 kg nitrogen and 80 kg potassium ha^{-1}. Sutaliya and Singh (2005) recorded that uptake of nitrogen, phosphorus and potassium was distinctly higher with application of 180-90-60 kg nitrogen, phosphorus and potassium ha^{-1} than with 120-60-40 or 60-30-20 kg nitrogen, phosphorus and potassium ha^{-1}.

Solie *et al.* (2006) and Stone *et al.* (2006) showed that on-the-go optical sensing and variable rate application are practical and reliable tools for determining optimum N rate, placement methods and timing of mid-season fertilization. They showed that it is possible to successfully address the issue of spatial variability present in the field by using sensors which measure light reflected of plant canopy and determine normalized difference vegetative index (NDVI). Precision sensing at high resolutions (one square meter) enables accurate prediction of yield potential and estimation of N fertilizer needed, increasing N uptake and decreasing the risk of N loss, and, therefore, increasing NUE.

Singh Sunder (2011) reported that in baby corn, increasing nitrogen levels recorded significant increase in roots production in maize up to 150 kg ha^{-1} but it was comparable with 180 kg ha^{-1} both in *kharif* and summer seasons.

Suryavanshi *et al.* (2008) revealed that application of 150 kg N ha^{-1} was found significantly effective over 100 kg N ha^{-1} and 50 kg N ha^{-1} in increasing mean plant height, leaf area, and total dry matter plant^{-1} of maize on Vertisols of Parbhani. The experiment conducted by Bharathi (2010) and reported from Guntur (A P), that significantly the maximum plant height and dry matter production were observed in maize with the application of 225 kg N ha^{-1} on clay soils.

Tabu *et al.* (2006) documented from their experiment in small holder farmers fields revealed that N fertilizer @ 60 kg ha^{-1} significantly increased the plant height and number of leaves plant-1 over the rest of N levels (0, 20 and 40 kg ha^{-1}).

Thakur and Sharma (2009) concluded that the application of nitrogen @ 150 and 200 kg ha^{-1} gave 29.2 and 37.6 percent higher net returns, respectively over 100 kg N ha^{-1} and the net returns per rupee invested increased with increased levels of nitrogen application. However, this increase was maximum growth and yield with increased nitrogen application from 100 to 200 kg ha^{-1}.

Thakur *et al.* (2007) studied the response of baby corn to different levels of nitrogen and found that growth parameters viz., plant height, leaf area and dry matter accumulation were increased with increasing levels of nitrogen application upto 150 kg N ha^{-1}. Nitrogen fertilizer had noticeable influence on crop growth, girth and yield of baby corn. Significant increase in plant height was observed up to 120 kg N ha $^{-1}$ (Sahoo and Panda, 2009). Thakur and Sharma (2009) reported that plant height of baby corn was found significantly increased up to 200 kg N/ha.

Teal *et al.* (2006) showed that corn grain yield potential can be accurately estimated mid-season using NDVI at the V8 growth stage. There is a need to investigate whether side dress N fertilization in corn can be delayed until mid-season without leading to irreversible grain yield loss.

Tripathi *et al.* (2007) found that application of nitrogen gave a significant additional increase in crude protein contents of forage oats. He applied of 15 kg Mg·ha^{-1} (in rows or broadcast) significantly increased N utilization in relation to the objects without magnesium. Between the two methods of magnesium application, no significant difference in this value was found. The experiment showed the joint action of the N dose with the fodder maize cultivar type as exerted on the size of nitrogen utilization from the applied nitrogen fertilization. These mutual dependences have been described by a first-degree equation, where for the hybrid LG 2244 'stay-green' type the resulting curve plotted at a higher level than for the traditional cultivar. For each applied 1 kg N·ha^{-1}, the N utilization in the cultivar LG 2244 'stay-green' type decreased by 0.45%, while in Anjou 258 it decreased by 0.42%.

Vetsch and Randall (2014) found a significant difference in N recovery: 87% for spring N application compared with only 45% when N was applied in fall. Relative leaf chlorophyll measurements taken at different growth stages were not significantly different for fall and spring applied N. However, starting from growth stage V6, N deficiency was recorded for the plants fertilized in the fall. A wide range of factors affects the decision about when is the best time to apply N fertilizer so that the crop will benefit the most. Among them are fertilizer rate, fertilizer type, method of application, climatic conditions, amount of residual nitrogen present in soil prior to fertilization, and the level of nitrogen deficiency imposed on the crop.

Wells and Blitzer (2014) and Wells *et al*. (2012) stated the most efficient time for N application is at growth stage V6, when corn plants active development significantly increases N plant needs. Russelle *et al*. (2011) also concluded that nitrogen uptake rate is known to be affected by many factors such as weather, planting date, and time of fertilizer application but is usually highest between V8 and V12.

Wittwer (2008) referred to crop production as "the world's most important renewable resource to be able to sustain global food security, while using natural resources wisely and minimizing the negative impact of intense agriculture on the environment, represents, perhaps, the most difficult challenge which researchers and crop producers are facing today. As stated by Basra (2008), crops stand between people and starvation" because cereal grains such as rice, wheat and corn supply the majority of calories (approximately 60%) and protein (50%) for human consumption.

Yadav *et al*. (2013) observed significant increase in plant height and dry matter production of maize up to 180 kg N ha^{-1}. Further, they reported that sulking period was also significantly advanced by 10 days under the highest level of nitrogen over no nitrogen application on sandy loam soils of Chindwara. Sharma (2010) from his field experiment conducted at IARI, New Delhi, on sandy loam soil, reported a significant increase in the plant height and number of leaves $plant^{-1}$, with each successive increase in the level of fertilizers used. Similarly, Krishnaveni and Rasheed (2012) from Coimbatore and Prasad *et al*. (2008) from Pusa also reported that increase in maize growth with increasing levels of N application from 0 to 120 kg ha^{-1} and 0 to 150 kg ha^{-1}, respectively. A few other researchers also reported significant response of maize to N application up to 120 kg ha^{-1} on light soils.

2.4. Effect of nitrogen on yield and yield performances of experimental maize varieties

Ashok Kumar (2009) observed that in pop corn maximum values of yield attributes viz., cob girth, cob length, grains ear^{-1} and shelling percentage were recorded with the application of 120 kg N ha^{-1}. Cob weight increased with increase in nitrogen application and the heaviest cobs were obtained at 240 kg N ha^{-1}.

Ashok Kumar (2009) studied the net returns $rupee^{-1}$ invested was also enhanced with higher nitrogen levels, but significant improvement was found up to 80 kg N ha^{-1}. There was marked improvement in net returns with each successive increase in nitrogen level from 0 to 120 kg ha^{-1}. The maximum net returns of Rs. 49.57 thousands ha^{-1} were noticed with 120 kg N ha^{-1}, which was 560.9, 64.5 and 10.0 % higher over 0, 40 and 80 kg N ha^{-1}.

Ashok Kumar *et al.* (2008) found that successive increase in levels of nitrogen from 0 to 120 kg ha^{-1} recorded markedly higher green cob yield amounting 119.6, 200.0 and 222.4 % with application of 40, 80 and 120 ha^{-1} respectively over control.

Ashok Kumar *et al.* (2008) also revealed that in maize, highest values for all the yield parameters like number of cobs per plant, length of cob, no of grains per cob and test weight were obtained with the application of 30 kg N through poultry manure in addition to 120 kg N through urea.

Bharathi *et al.* (2011) reported that on clay soils of Guntur, Andhra Pradesh increase in yield attributes, kernel and stover yield of *rabi* maize under no-till condition was up to 240 kg N ha^{-1} application. Similarly, Lakshmi and Venkata Rao (2013) also reported same findings up to 240 kg N ha^{-1} from Bapatla under maize fallow zero tillage conditions on sandy clay loam soils.

Bhat *et al.* (2008) reported that maximum values for cobs per plant (1.46), grain rows per cob (16.13), grains per row (44.60), grain per cob (718.01), test weight (205 g) were obtained with nitrogen at 150 kg ha^{-1} supplied through urea and azotobacter followed by treatments with nitrogen at the same rate but through urea and poultry manure.

Bindhani *et al.* (2007) observed that in baby corn a significant increase in baby corns/plant, their fresh weight, length and girth were also recorded up to 120 kg N ha^{-1}. Singh *et al.* (2010) reported that significant increase in baby corn weight, cobs per plant, baby corn girth was observed with the application of 180 + 38.7 + 74.7 kg N+P+K ha^{-1} compared to 60 + 12.9 + 24.9 kg N + P + K ha^{-1}.

Binder *et al.* (2010) stated tower grain yield was achieved by late fertilization of slightly N deficient corn; slight increase in yield was observed for severely deficient corn fertilized late in season, but the maximum yield was not achieved. Severely N-deficient corn showed high N response compared with less N-deficient corn, but did not result in higher grain yield.

Bindhani *et al.* (2007) reported baby corn yield recorded with 120 kg N ha^{-1} was found to be significantly higher than that with 60 and 90 kg N ha^{-1}. Application of 120 kg N ha^{-1} in baby corn resulted in the highest baby corn yield, which was 28.6, 52.2 and 178.7% higher than that of 80, 40 kg N ha^{-1} and the no nitrogen respectively. Significant increased in baby cob and corn yield were observed with the application of 180 kg N ha^{-1} compared to 60 kg N ha^{-1}.

Blackmer *et al.* (2009) found that delaying N fertilization until mid-season allows for more accurate determination of crop need for N, and they suggested carrying out in-season soil test to avoid over application and minimize N loss. One of the problems associated with the application of N later in the growing season is the suppression of corn grain yield due to N deficiency. Understanding the effects imposed to corn by delayed N application is extremely important for improvement of fertilizer recommendations because the effectiveness of delayed N application to corn is strongly dependent on the degree of N deficiency at that time.

Bundy *et al.* (2014) evaluated long term N experiments on silt loam soil at Madison, WI and the data combined over 50 years, the kernel yields increased linearly by about 150 kg ha^{-1} $year^{-1}$ in the medium (140 kg N ha^{-1}) and high (240 kg N ha^{-1}) long term N treatments while yields in the control long term treatment have remained relatively constant over time. Similar lines of findings were also reported by Halvorson (2009) from Colorado and Mengu *et al.* (2008) from Udaipur on clay loam soil. Reddy *et al.* (2007) from Warangal observed that application of 180 kg N ha^{-1} was found to be optimum for getting higher yields of maize under zero tillage conditions in rice fallows on sandy clay loam soil.

Chamshama *et al.* (2014) reported that in an intercropping of maize with *Faidherbia albida,* the grain yield was 90 percent of sole maize in the first year of normal rain and corresponding year being a dry year, intercropped maize yield was 64 per cent higher than sole maize yield.

Chauhan *et al.* (2013) observed increased baby corn yield with increased levels of nitrogen from 80 to 160 kg ha^{-1} and the increase was more during winter than in wet season. Significantly higher stover yield was obtained with increase in fertilizer dose from 60 + 30 kg N and P_2O_5 ha^{-1} to 90 +45 kg N and P_2O_5 ha^{-1} and further increase did not result any significant response in pop corn.

Chauhan *et al.* (2013) reported that application of 90 + 45 kg N and P2O5 ha^{-1} in pop corn significantly improved grain yield over 60 + 30 kg N and P2O5 ha^{-1}. Further increase in fertilizer dose failed to get a significant improvement.

Gaur (2011) obtained higher stover yield at 60 kg N ha^{-1}. However, Venugopal (2011) found that application of 160 kg N ha^{-1} gave significantly higher stover yield (7326 kg ha^{-1}) as compared to no nitrogen (1817 kg ha^{-1}) in maize.

Gaur *et al.* (2012) observed application of 202.5 kg N ha^{-1} recorded highest N-uptake by shoot and grain. N-uptake by grain (64 to 89 kg ha^{-1}) and stover (46 to 61 kg ha^{-1}) increased significantly with increase in N-levels from 80 to 120 kg ha^{-1}.

Increasing the nitrogen dose up to 90 kg ha^{-1} increased the nitrogen and phosphorus uptake by grain and fodder maize (Singh *et al.*, 2012).

Gaur *et al.* (2012) reported significantly higher stover yield due to 120 kg N ha^{-1}at Udaipur during rabi season in vertisols. Another study made by Selvaraju and Iruthayaraj (2014) revealed that 175 kg N ha^{-1} increased the stover yield significantly over 75 kg N ha^{-1}.

Gokmen *et al*. (2011) observed that in popcorn, the kernel number per ear increased by about 6% as nitrogen increased from zero to 250 kg N ha^{-1} and also stated that maximum cob length was obtained from 250 kg N ha^{-1}.

Hissar *et al.* (2010) conducted a field study conducted during winter seasons on sandy loam soils of reported a linear response of maize to nitrogen application up to 200 kg N ha^{-1}. The highest grain yield obtained with the application of 200 kg N ha^{-1} was significantly higher than that of the rest of N levels 0 to 150 kg ha^{-1}.

Karam *et al.* (2003) noticed that 100 kg N ha^{-1} was optimum for maximum cob yield of sweet corn and the increase in green cob yield beyond 120 kg N ha^{-1} was not appreciable. Raja (2011) revealed that application of increasing doses of nitrogen significantly increased the number of primes from 50,376 at control to 65,639 at 120 kg ha^{-1}.

Kar *et al.* (2006) recorded that increased nitrogen application from 20 kg N ha^{-1} to 80 Kg N ha^{-1} significantly increased the cob length from 14.6 cm to 17.5 cm and cob girth from 13.8 cm to 16.7 cm.

Kumaresan (2011) revealed that the application of 100 per cent recommended dose of nitrogen and phosphorus in maize resulted in significant increase of cob grain free. Parmar and Sharma (2011) reported that the nitrogen uptake in maize increased to a considerable extent with nitrogen application up to 120 kg ha^{-1}.

Kumpavat and Rathore (2005) reported maximum stover yield due to application of 120 kg ha^{-1}. There was linear increase in stover yield due to increase in N level from 62.5 to 250 kg ha^{-1}. Bangarwa and Gaur (2008) reported higher stover yield (48.72 q) at 120 kg N ha^{-1}. Similar response to higher "N" levels was reported by Ameta and Dhakar (2000), Kar *et al.* (2006) and Suryavanshi *et al*. (2008).

Misra *et al*. (2014) stated that protein content in grain and N uptake were higher under 200 kg N ha^{-1} compared to that under with lower levels of N due to higher yield attributes recorded with 200 kg N ha^{-1} on sandy loam soils of Bahraich, Uttar Pradesh. Selvaraju and Iruthayaraju (2012) observed from their field experiment on clay loam soils of Coimbatore noticed an increase in N, P and K uptake with increased level of N application from 75 to 175 kg ha^{-1}, irrespective of the season. Field experiments conducted on a clay loam soil at Bapatla, indicated the increment of added N had a distinct and significant effect on the uptake of N by grain and stover over the lower levels. The highest level of N (150 kg ha^{-1}) resulted in significantly the maximum uptake of N by the maize crop. Nitrogen application at this rate also increased P and K uptake by both the grain and stover.

Mullins *et al.* (2009) opined that application of 112 kg N ha^{-1} was sufficient for sweet corn, where as Akthar and Silva (2009) obtained maximum weight of green cobs with 150 kg N ha^{-1} which was on par with 120 kg N ha^{-1}.

Nath *et al.* (2009) reported that in sweet corn an increase of 11.6% and 16.9% in cob length and cob girth were recorded when the fertility level was raised from 50 to 70 kg N ha^{-1} and an application of 110 kg N ha^{-1} accounted for significant increase (10.1%) over 70 kg N ha^{-1} in cob girth.

Nanjundappa *et al.* (2014) found that increased nitrogen uptake by grain was increased up to 150 kg nitrogen ha^{-1}, which was found at 225 kg nitrogen ha^{-1}. Selvaraju and Iruthayaraj (2014) studied application of 175 kg N ha^{-1} significantly increased the N-uptake as compared to lower levels.

Nandal *et al.* (2005) reported that supplying N to the maize plant during the time of peak seed demand prevents premature senescence, and increases seed yield. Barker and Sawyer (2005) found that even though N fertilizer applied during reproductive stages increased plant N concentration, it did not result in increased grain N concentration, grain yield or grain quality.

Oktem and Oktem (2005) revealed that cob length increased from 16.42 cm at 150 kg N ha^{-1} to 20. 88 cm at 350 kg N ha^{-1}. They also concluded that cob girth was increased with application of N up to 250 kg ha^{-1}, beyond the level of 250 kg ha^{-1} there was no significant increase.

Pandey *et al.* (2010) reported that the number of baby corn cobs per plant and cob weight were highest with 120 kg N ha^{-1} than at 60 and 90 kg Nha^{-1} but did not observe any significant difference in the length of baby corn with increased levels of nitrogen from 60 to 120 kg N ha^{-1}.

Patel *et al.* (2009) carried out from their field study and stated that application of 175 kg N ha^{-1} being at par with 150 kg N ha^{-1} produced significantly higher grain yield (5077 kg ha^{-1}) than the rest of N levels. The lowest grain yield (3796 kg ha^{-1}) was registered by 75 kg N ha^{-1} on Alfisols during rabi.

Prasad *et al.* (2008) from their experiment observed higher nutrient uptake with increase in levels of N application from 0 to 150 kg ha^{-1} on calcareous sandy loam soil at Pusa. A field study conducted on maize and the data revealed that uptake of N at harvest was significantly increased with increasing N levels up to 120 kg N ha^{-1} only resulting in the highest N uptake than 0, 60 and 180 kg N ha^{-1} on black clay loam soils at Hyderabad and clay soils of Junagadh. Nitrogen uptake by grain and stover of 'Ganga 5' maize significantly increased with increasing level of N from 0 to 100 kg ha^{-1} on clay loam soils of Pune.

Randall *et al.* (2013) demonstrated that the lowest grain yield was achieved by fall N application versus the highest grain yield with split N fertilization. Evaluation of the economic return for fall and split N application clearly showed advantages for split N application ($166.70 ha^{-1} $year^{-1}$ for fall applied N; $239.40 ha^{-1} $year^{-1}$ for split applied N).

Raja (2011) reported that increase in nitrogen levels from 0 to 120 kg N ha^{-1} significantly increased the cob length as well as cob girth of sweet corn. Sahoo and Mahapatra (2014) concluded that in an experiment conducted in sweet corn at Jashipur, increase in levels of nitrogen from 60 to 120 kg ha^{-1} increased the number of cobs per hectare, length and weight of cob.

Rao and Padmaja (2014) reported that yield of sweet corn, pop corn and hybrid maize increased significantly up to 150 kg N ha^{-1}.Kumar and Singh (2012) revealed that grain yield in Maize increased significantly with increasing levels of nitrogen (0-150kg ha^{-1}) and highest was obtained at 150kg ha^{-1}.

Roy and Thripathi (2007) the nitrogen concentration (%) in grain and stover of maize at harvest was increased with increase in levels of nitrogen from 50 to 100 kg ha^{-1}. Baskaran *et al.* (2012) revealed that the N-uptake by maize exhibited a positive trend with increased levels of nitrogen application at all stages of crop growth.

Shanti *et al.* (2007) observed that application of 160 kg N ha^{-1} recorded the highest number of cobs per plant in maize which was however, statistically on par with that of 120 kg N ha^{-1} and significantly superior to other N levels (0, 40 and 80 kg N ha^{-1}). Application of 160 kg N ha^{-1} in maize significantly increased the number of cobs per plant (1.62 to 2.12) as compared to 80 kg N ha^{-1} (Muniswamy *et al.*, 2007).

Sahoo and Mahapatra (2007) reported that a plant population of 83,300 per hectare & fertility level of 120 kg N per ha with P_2O_5 and K_2O at 26.2 kg ha^{-1} and 50 kg ha^{-1} respectively should be adopted to obtain the maximum green cob yield and net profit from sweet corn. In a field experiment conducted during Kharif season at Pune, it was reported that application of 100 per cent RDF (120:60:60 kg NPK ha^{-1}) recorded maximum cob yield (8.84 t ha^{-1}).

Sahoo and Mahapatra (2004) observed that increase in levels of nitrogen, increased green cob yield from 8.88 t ha^{-1} (60 kg ha^{-1}) to 10.53 t ha^{-1} (180 kg ha^{-1}). Kar *et al.* (2006) noticed that green cob yield of sweet corn was significantly increased with increase in nitrogen from 0 to 80 kg ha^{-1}.

Sahoo and Panda (2007) recorded the maximum baby corn yield with 120kg N ha^{-1} both winter and wet seasons. Sahoo and Panda (2009) observed increased baby corn yield with increased levels of nitrogen from 80 to 160 kg ha^{-1} and the increase was more during winter than in wet season.

Schmidt *et al.* (2012) achieved a maximum grain yield by applying at least 130 kg ha^{-1} of N fertilizer. Greater organic matter (OM) content did not decrease corn need in fertilizer N, since the fields with higher OM did not require less N to maximize grain yields. While corn grain yields varied depending on the rate of N applied, higher fertilizer rates did not necessarily increase availability of N to the plant and, consequently, increase grain yield. They recommended side dress application of N fertilizer during the growing season as a means to improve NUE.

Singh *et al.* (2007) showed primarily attributed to rooting pattern of agricultural crops affecting the nutrient and moisture relations. Likewise, Balasubramanian (2009) reported higher grain yields of pearl millet and maize in *Leucaena leucocephala* alley cropping.

Singh *et al*. (2010) from Amrutsar and Tank *et al*. (2008) reported that maize recorded more cob length, grains cob^{-1}, test weight, grain and stover yield with the application of 140 kg N ha^{-1} and 180 kg N ha^{-1}, respectively on sandy loam soils. Similar kind of improvement of maize yield attributes and yield also reported by some other researchers elsewhere (2013) even up to 240 kg N ha^{-1}.

Singh *et al*. (2007) from Dholi (Bihar) and Singh *et al*. (2011) from Hissar noticed similar response of increase in maize yield attributes and grain yield up to 150 kg N ha^{-1} application on similar type of soils. Results of an experiment conducted by Raju *et al.* (2011) during kharif season on sandy loam soils at Karimnagar revealed that the yield attributes, grain and stover yields of maize increased significantly up to 90 kg N ha^{-1} and 135 kg N ha^{-1} under rainfed situation with low and high rainfall coupled with its even distribution during first and second season, respectively.

Singh *et al*. (2009) recorded significantly higher cob length and test weight of maize at lower plant population of 50000 plants ha^{-1} (60 cm x 33.3 cm) over 75000 plants ha^{-1} (60 cm x 22.2 cm) and 100000 plants ha^{-1}(60 cm x 16.6 cm) on loamy sand soils at Ludhiana.

Singh and Totawat (2012) reported from Udaipur, that more number of kernels cob^{-1}, kernel and stover yield with 100 per cent recommended dose (90 kg N ha^{-1}) of N over 50 per cent and 75 per cent of recommend dose of N on clay loam soils. From a field study conducted during rabi at Varanasi, Singh *et al*. (2012) observed that application of N at 50 per cent higher (180 kg N ha^{-1}) over recommended level (120 kg N ha^{-1}) significantly enhanced the length of cob, girth of cob, number of grains cob^{-1}, grain weight cob^{-1}, test weight, grain and stover yields of maize than lower doses which was at par with that of 75 per cent higher (210 kg N ha^{-1}) over recommended dose (120 kg N ha^{-1}) on clay loam soils. Results of the field experiments conducted at Dharwad during kharif and rabi seasons revealed that application of 200 per cent RDN (300 kg N ha^{-1}) recorded significantly higher grain yield of hybrid maize (DMH-2) and was on a par with that of 150 per cent RDN (225 kg N ha^{-1}) due to 'law of diminishing returns.

Thakur *et al*. (2009) found significant increase in baby corn yield with increase in applied nitrogen dose from 100 to 200 kg ha^{-1} in a field experiment carried out during rainy season at Bajaura.

Thakur and Sharma (2009) registered higher number of baby corn cobs per plant and length of baby corn with 200 kg Nha^{-1} as compared to 100 kg N ha^{-1}. Contrary to this, significant differences were not observed in the weight of cob when nitrogen was applied at 100, 150 and 200 kg ha^{-1} to baby corn.

Thakur and Sharma (2009) reported significant increase in green forage yield of baby corn with increase in nitrogen dose from 100 to 200 kg ha^{-1}. Sahoo and Mahapatra (2007) reported that in sweet corn, application of 120 kg nitrogen ha^{-1} resulted in higher stover yield than with other nitrogen levels.

Thakur *et al*. (2007) noticed increased number of baby corn cobs per plant with 200 kg N ha^{-1} compared to no nitrogen on alfisols of Bajura, Kullu valley, Himachal Pradesh. Application of 120 kg N ha^{-1} resulted in the maximum grain number per line of baby corn without husk compared to other levels of N tried viz., 0, 20, 40, 60, 80 and 100 kg N ha^{-1}.

Thakur *et al*. (2007) demonstrated that baby corn weight with and without husk was found increased significantly with successive increase in N levels up to 100 kg N ha^{-1}. Length of baby corn, weight of ear and number of ears per plant were found to be the highest with 120 kg N ha^{-1}.

Torbert *et al*. (2011) evaluated aiming to determine how fertilizer N application timing effects corn grain yield, found split and spring fertilization to increase yields compared to fall application. Significantly lower N uptake recorded for fall application (40-60 kg ha^{-1}) compared with spring and split fertilization (90-105 kg ha^{-1}) could be explained because of leaching, erosion, and denitrification that are active during the fall-winter periods.

Turkstat *et al*. (2010) reported an increase in grain yield of maize from 61 to 137 per cent with increased level of N application from 75 to 250 kg ha^{-1} over that of no nitrogen on sandy loam soil at Hisar. Padmaja *et al*. (2011) reported that the grain and stover yields were increased significantly with increase in the level of N from 0 to 150 kg ha^{-1} on clay soils of Bapatla during rabi season.

Vadivel (2011) and Davis *et al*. (2010) from Ludhiana reported increase in yield attributing characters and grain yield with increase rate of N application up to 120 kg ha^{-1} on sandy loam soils. Similar trend of increase in grain yield of maize up to 200 kg N ha^{-1} was also noticed earlier by Guar and Mathur (2005) at IARI, New Delhi. Padmaja *al*. (2014) from Coimbatore, Purseglov *et al*. (2012) and Nimje and Seth (2011) from IARI, New Delhi, Bangarwa *et al*. (2008) from Sharma *et al*. (2013) and Hyderabd reported similar results.

2.5. Interaction effect of between irrigation and nitrogen on the growth and growth performance of experimental varieties

Angueira *et al*. (2009) from their study at Coimbatore on sandy loam soils during kharif season reported that uptake of N and P increased with increase in N level from 150 to 200 kg ha^{-1} and phosphorus from 75 to 100 kg P_2O_5 ha^{-1}. A few researchers reported earlier an increase in nutrient uptake by maize with increasing level of N application. Bhat *et al*. (2008) reported that increase of nitrogen at each incremental level had significant influence on nutrient uptake was recorded with higher level of N 240 kg ha^{-1}.

Bangarwa (2008), Muchow (2014), Ahmad (2008), and Rasheed (2012) reported interaction between irrigation schedules and nitrogen levels affecting total dry matter showed that treatments N_3I_2 combination gave the maximum biomass yield at 17.97 t ha^{-1} which was at par with N_2I_2 or N_2I_3 combinations. The positive effect on biomass yield by irrigation schedules (I_2 or I_3 treatments) and increasing N rates (200 or 300 kg ha^{-1}) may be attributed to increased vegetative growth, resulting in more leaf area index (LAI) and thus ensuring better light interception. This favorable environment resulted in greater LAI with higher CGR. Total biomass yield (11-15 tha^{-1}) achieved in this study is similar to other work.

Bruns and Abbas (2005) stated that application of full amounts of N fertilizer prior to planting may result in better roots development than carrying out split N applications. They concluded that the economic loss due to decreased grain yield may be insignificant when compared to additional production costs associated with split fertilization, such as several trips to the field.

Bundy (2014) observed the effectiveness of split N applications is largely dependent on site-specific conditions such as soil properties and climate. Even though fall application of N can be acceptable for some soil types (medium-to-fine-textured soils) combined with specific climate conditions (low winter temperatures decrease nitrification), this early fertilizer can cause decreased fertilizer-N effectiveness (10-15% less effe right time, optimum level and appropriate method of application.

Krishnamurthy *et al.* (2011) observed more barrenness, less grain weight per cob, test weight and shelling percentage with increase in plant population of maize from 55000 plants ha^{-1} (60 cm x 30 cm) to 83000 plants ha^{-1}(60 cm x 20 cm) on red sandy loam soils of Bangalore.

Maddonni *et al.* (2008) reported that an increase in plant population from 3 plants m^{-2} to 9 plants m^{-2}, increased kernel number per cob and grain yield but reduced kernel weight on silt clay loam soils at Argentina. The results of the experiment conducted at Tirupati, by Reddy (2007) revealed that grain yield of maize increased significantly with increase in plant population from 55555 plants ha^{-1} to 66666 plants ha^{-1} , beyond which the increase in yield was not statistically significant.

Mbagwn (2010) described that maximum grain yield and greater water use efficiency were achieved when irrigating to 100% of field capacity. Highest grain yield was obtained with 120 kg K_2O ha^{-1} and irrigation at 25% depletion of available soil moisture (Patel *et al.*, 2009). Crude protein contents increased with increase in irrigation frequency (Pillai *et al.*, 2010). Management of crop nutrition includes correct manuring at

Prasad & Prasad (2008) evaluated water is required to provide constant turgor pressure that supports the plant and facilitates cell enlargement after cell division has been initiated. Hence, plant growth and survival depend on adequate water availability. Irrigation also improves the efficiency of fertilizer utilization by the crop. Increases in irrigation frequency increased N, P and K uptake by maize.

Randall *et al.* (2013) studied the conventional practices historically used by most crop producers do not address the issue of successfully managing resources. Traditional approaches to fertilizing corn after harvest in the fall is still considered to be more advantageous by many crop producers because it enables them to better distribute their time and labor and benefit from better soil conditions and lower fertilizer N prices at this time (Bundy, 2006; Randall and Schmitt, 2008). However, it is necessary to evaluate the risks imposed by fall post-harvest application versus spring application and split N fertilization (40% at planting followed by 60% mid-season).

Schmidt *et al.* (2012) found, that N fertilization even as late as stage V11 did not result in irreversible yield loss, even for corn showing very significant N stress. Delaying N application until growth stages V12 and V16 caused a loss of just 3% in grain yield. They further concluded that the benefits of the delayed N fertilization in corn outweigh the risk of grain yield loss.

Tisdale *et al.* (2010) reiterated that nitrogen being an integral part of structural and functional proteins, chlorophyll and nucleic acids such as RNA and DNA as well as essential for proper carbohydrate utilization, plays a vital role in crop development. Increased application of nitrogen gives faster rate of leaf expansion (Wright *et al.,* 2012), increased leaf area index, leaf area duration, photosynthetic rate and increased radiation interception and radiation use efficiency (Muchow, 2014 & Davis, 2010; Connor *et al.,* 2013). Both nitrogen deficiency and excess affects assimilate partitioning between vegetative and reproductive organs. Crude protein concentration is frequently increased by adequate nitrogen supply (Tisdale *et al.,* 2010).

Wuest and Cassman (2012) observed higher N recovery (55% to 80%) when fertilizer was applied mid-season compared to N recovery of 30% - 55% in the case of preplant N application. Andraski *et al.* (2010) described supplying only the necessary amount of N to satisfy the crop need at the specific fertilizer application time would result in lesser amounts of residual NO_3^- in soil and, therefore, decrease the risk of N being lost from soil.

2.6. Interaction effect of between irrigation and nitrogen on the yield and yield performances of experimental varieties

Ahmad (2008) and Rasheed (2012) were reported and also noted higher number of cobs m^{-2} with higher rates of N application, under similar agro-ecological conditions. Increasing rates of nitrogen application also significantly enhanced number of cobs $plant^{-1}$ over control or lower rate (N_1, 100 kg ha^{-1}) of N application, and this response was quadratic in nature. The N_3 (300 kg ha^{-1}) treatment gave the maximum number of cobs $plant^{-1}$ than all other rates of nitrogen application. The N_2 (200 kg/ ha treatment was, however, statistically at par in the number of cobs $plant^{-1}$ with N_3 treatment during 2007. Overall, mean number of cobs $plant^{-1}$ was 0.94 and 0.91 in 2007 and 2008, respectively.

Ahmad *et, al.* (2008) also reported grain yield of > 7.0 t ha^{-1} under agro-ecological conditions of Faisalabad with better irrigation and nitrogen management. The response to increasing nitrogen rates to grain yield was highly significant. Both N_2 (200 kg ha^{-1}) and N_3 (300 kg ha^{-1}) treatments markedly enhanced grain yield than lower rate of nitrogen application (N_1) or control (nil) treatment in both years, and this response was cubic in nature. The average grain yield was ranged from 3.89 t ha^{-1} to 6.40t ha^{-1} among various nitrogen rates. Overall, mean grain yield was at 5.39t ha^{-1} in 2007 and 5.24 t ha^{-1} in 2008, respectively. The interaction between irrigation schedules and nitrogen levels on grain yield was significant in both years. Treatment N_2 I_2 combination gave the maximum grain yield at 7.26 t ha^{-1} which was at par with N_3I_3 (7.09 t ha^{-1}) combination. Lowest grain yield was produced in N_0 treatment, irrespective of irrigation schedules.

Ameta *et, al.* (2010) revealed that with each successive increase in plant population from 65000 plants ha-1 to 95000 plants ha^{-1} there was significant increase in the grain yield of maize during winter season. Emam (2011) reported that grain yield of maize responded to higher planting densities up to 83000 plants ha^{-1} and this was owing increase the rate of grain filling with no significant change in duration in grain filling period at Koushkak, Iran.

Bangarwa *et al.* (2008) and Rasheed (2012) showed lower harvest index values in lower nitrogen rates. The higher HI in N_2 (200 kg ha^{-1}) compared to other treatments was associated with their maximum TDM accumulation due to higher leaf area duration (LAD), which in turn increased interception of radiation and its utilization efficiency. Ahmad (2008) also reported similar effects of nitrogen applications on maize.

Blumenthal *et al.* (2014) reported from their field study at Nebraska, reported that kernel yields were maximized by 202 kg N ha^{-1} with 27200 plants ha^{-1} and population increased above 27200 plants ha^{-1} resulted in inconsistent kernel yields. Planting of maize at 83333 plants ha^{-1} resulted in significantly higher yield attributes *viz*., ear diameter, grain weight $plant^{-1}$, test weight and grains ear^{-1} than at 111111 plants ha^{-1} on clay loam soils of Akola.

Muchow (2014) observed that higher grain yield in maize was associated with higher HI. Since higher HI depends on the proportion of pre-and post-anthesis growth and its partitioning to grains, the differences in HI may simply be a consequence of their respective growth stage duration.

Muchow (2014) who also reported grain yield of maize at 7.9 t ha^{-1} under semi arid tropical environment in maize like other cereals is the product of number of cobs per unit area, number of grains cob^{-1} and 1000-grain weight. The increased value of three parameters under I_2 and I_3 irrigation schedules or increasing rates of N applications were improved. Therefore, grain production significantly improved under these treatments as compared to lower rates of N application or increasing water stress such as I_4 (-12 bars) treatments.

Pearson (2014); Ahmad (2008) and Rasheed (2012) concluded that higher number of cobs with N application and number of cobs per unit area was significantly influenced by different irrigation schedules. The I_2 (-4 bars) treatment gave maximum number of cobs at 7.80 m^{-2} in 1997 and 7.68 m-2 in 2008 as compared to control or I_4 (-12 bars) treatments. Both I_2 (-4bars) and I_3 (-8 bars) were, however, statistically at par in the number of cobs m^{-2} in both the seasons. Increasing rate of nitrogen application significantly ($P<0.01$) enhanced the number of cobs per unit area. This response to nitrogen was highly significant and linear in nature. The average number of cobs m^{-2} was 6.86 in N_0, 7.56 in N_1, 7.80 in N_2 and 8.17 in N_3, respectively. Overall, mean number of cobs was 7.67 m^{-2} in 2007 and 7.48 m^{-2} in 2008, respectively.

Ritter and Manager (2012) found that maize has high yield potential and responds well to different management practices. Among various management practices, irrigation and nitrogen nutrition play a significant role in realizing the maximum potential of the crop. Irrigation scheduling is the technology for applying the proper amount of water at the right time. Reasons for using irrigation scheduling are to reduce water applications, energy consumption and deep percolation of water below the crop root zone.

Shi (2013) and Rasheed (2012) carried out effect of irrigation schedules and nitrogen levels on the number of grains cob^{-1} were highly significant in both the seasons. The treatments I_2 (-4 bars) and I_3 (-8 bars) gave more number of kernels ear^{-1} than (control) or I_4 (-12 bars). The average number of kernels ear^{-1} was 327.54, 378.55, 378.10 and 344.66 in I_1, I_2, I_3 and I_4 treatments, respectively. Increasing rates of nitrogen application also significantly enhanced the number of grains cob^{-1}; $N_3 > N_2 > N_1 > N_0$. This response was, however, cubic in nature. Greater number of grains cob^{-1} by adequate application of N is in accordance with the findings of others who also reported similar effects of N application on the number of grains cob^{-1}.

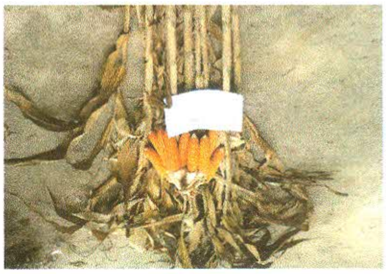
Shivay and Sing (2009) from their field study on silty clay loam of Pantnagar reported significant increase in N uptake with each successive increase in level of N application from 0 to 120 kg ha^{-1}. Similar results were also reported earlier by Vadivel *et al.* (2011) from Coimbatore on sandy clay loam soils; Singh and Totawat (2012) from Rajastan on clay soils and Kumar and Singh (2014) from Nagaland.

Toosey *et al*. (2012) observed higher grain weight by nitrogen fertilizer in maize crop. Increased nitrogen application recorded the higher mean grain weight. The higher grain weight in these treatments over control or lower rate of N application was because of adequate supply of nitrogen to the plants. Both, Ahmad (2008) and Rasheed (2012) also noted higher mean grain weight with adequate application of nitrogen in maize working under similar agro-ecological conditions. In conclusion, results demonstrate that under Faisalabad conditions, application of 200 kg N ha^{-1} is appropriate for obtaining higher grain yield (> 7 t ha^{-1}) of hybrid maize, provided proper irrigation scheduling is followed.

Warrson and Teal (2006) found higher yields for corn grown in narrow rows versus wide conventional rows irrespective of hybrids and plant populations tested in Indiana and Michigan of USA. Similar results also reported by Angueira (2009) from Argentina on Argiudols.

Chapter Three

Materials and Methods



Chapter-THREE

3. Materials and Methods

There were three phases of the research 1. Effects of irrigation on growth and yield of maize. 2. Effects of nitrogen on growth and yield of maize. 3. Interaction effects of irrigation and nitrogen on growth and yield of maize. The experiments were conducted at Natore sugar mills area in the Natore district, during the period from 2012- 2014 to study different irrigation levels nitrogen dose and interaction between irrigation and nitrogen on the growth development and yield of maize cultivar, "BARI hybrid maize-7 and BARI hybrid maize-9". A brief description of the materials used and methods followed in the experiments are given below

3.1. Effect of irrigation on growth and yield of hybrid maize

A field experiment was conducted at Natore sugar mills area at sadar upazilla of Natore District in Bangladesh. The average rainfall 200 mm and the annual evaporation is 2585 mm of this area. Soil texture was clay loamy and the soil was classified as calcareous. The plots (5m×4m= 20 squires meters every plot) were irrigated as per the experimental treatments as follows:

I_0 = rainfall (control)/no irrigation.
I_1= one irrigation
I_2= two irrigations
I_3= three irrigations

First irrigation in root initiation stages (20 DAS)
Second irrigation in panicle initiation stages (50 DAS)
Third irrigation in grain filling initiation stages (90 DAS)

The irrigation scheduling in conventional method was simulated as farmers do in the field but the length of furrows were same as the length of the former three irrigation methods. For this system irrigation interval was adjusted for soil (similar to the intervals applied by farmers). For all irrigation scheduling was based on the soil moisture deficit in root zone at each irrigation event (difference between root zone soil water at field capacity and at irrigation time) with optimum time. To determine the soil moisture deficit, within the root zone, the depths of roots were measured weekly and soil water was measured by gravimetric method at each irrigation event. In order to measure the root depth development, a number of trenches with depth and width of 1 m and 20 cm away from the plant rows were dug. At each measurement, three plants from each trench were selected and the depths of roots were measured manually by ruler. The volume of applied water was measured with flow meters installed in the delivering pipes at the beginning of plots. Also the irrigation requirement in all four irrigation methods was estimated using Penman-Montith equation on the base of the long term mean meteorological data from the nearest climate station. The analysis of variance in respect of all the selected parameters under the study together with sources of variation and corresponding degrees of freedom were been presented in table 01-04. The data were analyzed statistically using the analysis of variance (ANOVA) technique with the help of MSTAT-C and Microsoft excel program and mean differences were adjusted by Duncan's Multiple Range Test (DMRT).

3.2. Effect of nitrogen on growth and yield of maize

The experiment was conducted for one consecutive season in 2013-2014 at the demonstration farmer field of the Tabaria area in Natore District of Bangladesh. The soil is generally sandy clay loam, non-saline and non-sodic with pH (7.8). Treatments involved in the experiment consisted of different nitrogen sources. Nitrogen dose used for each treatment was in no nitrogen uses (control), 115 kg N/ha, 230 kg N/ha and 345 kg N/ha. The nitrogen sources was urea 46%N contain fertilizer (urea).

Factors of treatments:

a) No nitrogen coded as N_0
b) 115 kg N/ha, coded as N_1
c) 230 kg N/ha coded as N_2 and
d) 345 kg N/ha coded as N_3

The treatments were arranged in completely randomized block design with three replications. The seeds were sown in the first week of November 2013 for one season maize cultivar BARI hybrid maize-7 and BARI hybrid maize-9. The plot area was 20 m^2, each plot included 5 m in length and 4 m apart. Nitrogen fertilizers were applied once at sowing before the first irrigation. The crop was irrigated three times in each season at intervals of 20-30 days. To observations data on different growth parameters such as plant height, plant girth, total tillers plant^{-1}, effective tiller plant^{-1}, non-effective tiller plant^{-1}, total roots plant^{-1}, straw weight plant^{-1}, straw yield t ha^{-1}. Data on different yield parameters such as cob length, cob grain free length, cob girth, grain line cob^{-1}, grain number line^{-1}, total grain cob^{-1}, grain weight cob^{-1}, 1000 grain weight/ cob, grains yield t ha^{-1}, straw yield t ha^{-1}, biological yield t ha^{-1} and harvest index (%).

Nitrogen doses were side-dressed to the soil using urea when plants had fully six expanded leaves (according to Ritchie & Hanway, 2013). The ear leaves of five plants randomly chosen inside each RCBD plot were collected data at anthesis to estimate the plant's N status. Shoot N content was determined based upon N percentage of the ear leaf following method described by Tedesco *et al.* (2005). Plants used to estimate shoot N content were also harvested, dried and weighed. Nitrogen uptake for hybrid maize was determined multiplying ear, leaf N content and plant dry mass. The two central rows of RCBD plot were harvested, representing an area of 9.6 m^2. Ears were de-husked, dried, shelled and weighed.

An analysis of variance was performed. F values for main treatment effects and their interaction were considered significant at the $P<0.05$ level. Whenever the N rate, hybrid or the interaction between them significantly influenced a variable, a regression analysis was performed and the linear and quadratic effects calculated. The equations that reached significance at the $P<0.05$ level, provided the higher determination coefficients and better explained the biological behavior of each hybrid were chosen to summarize the information gathered for each variable. Hybrid's efficiency to convert the applied N into grain production was estimated considering the slopes calculated for genotypes with a linear response of grain yield to the range of N rates used in the trial. A t test at the $P<0.05$ level was used to compare the slopes for variables that express a significant linear response. Nitrogen efficiency values were expressed in kg of grains per kg of side-dressed nitrogen. The analysis of variance in respect of all the selected parameters under the study together with sources of variation and corresponding degrees of freedom were been presented in table 04--08. The data were analyzed statistically using the analysis of variance (ANOVA) technique with the help of MSTAT-C and Microsoft excel program, and mean differences were adjusted by Duncan's Multiple RangeTest (DMRT).

3.3. Interaction effect of irrigation and nitrogen on growth and yield of maize.

A field experiment was conducted at the farmer field Tabaria area Sadar Upazilla Natore District in Bangladesh, during December 2013 to April 2014 to find out the interaction effect of irrigation and nitrogen on growth and yield of maize. The experiment consists of (i) two irrigation treatments viz. no irrigation and three irrigation and (ii) two nitrogen levels viz. no nitrogen use and 230 kg N ha^{-1}, no nitrogen, wherein, irrigation were relegated in the main plots and nitrogen levels were assigned to the sub plots. The experiment was laid out in a split plot design with three replications having 12 unit plots of 20 m^2 size. Composite soil samples were taken to a depth of 15 cm from the experimental site with the help of Auger before sowing of crop. Soil analysis of the samples showed that experimental site had pH 8.4 and N, P_2O_5 and K_2O amount were found 0.03%, 15.3ppm and 0.28Cmol/kg, respectively and it was suitable for maize production. The soil was sandy loam in texture with organic matter 0.57%. The recommended cultural practices, except irrigation and nitrogen levels, were adopted to raise the crop. Irrespective of doses, one third quantity of nitrogen was given as recommended basal dose, at the time of final land preparation and remaining urea applied as topdressing in two equal splits at 40 DAS and 80 DAS. The crop was also fertilized with 200 kg ha^{-1} TSP, 140 kg ha^{-1}

MP, 13 kg ha^{-1} Zinc sulphate, 7 kg ha^{-1} Boric acid, 160 kg ha^{-1} Gypsum at the time of final land preparation. The crop was harvested at full maturity. To observations data on different growth parameters such as plant height, plant girth, total tillers plant^{-1}, effective tiller plant-^{1}, non-effective tiller plant-^{1}, total roots plant^{-1}, straw weight plant^{-1}, straw yield t ha-^{1}. Data on different yield parameters such as cob length, cob grain free length, cob girth, grain line cob^{-1}, grain number line^{-1}, total grain cob^{-1}, grain weight cob-^{1}, 1000 grain weight cob^{-1}, grains yield t ha^{-1}, straw yield t ha^{-1}, biological yield t ha^{-1} and harvest index (%). The analysis of variance in respect of all the selected parameters under the study together with sources of variation and corresponding degrees of freedom were been presented in table 09-12. The data were analyzed statistically using the analysis of variance (ANOVA) technique with the help of MSTAT-C and Microsoft excel program, and mean differences were adjusted by Duncan's Multiple Range Test.

3.4. Description of the experimental site

3.4.1. Location

The experimental site belongs to non-calcarious dark grey and black flood plain soil (Chalan Bill lower land) under the Chalan Bill flood plain, Agro-ecological Zone, 05(UNDP and FAO,1998).

3.4.2. Soil

The experimental field was a medium high land with silty loam soil texture having pH value of 7.6. The soil was tested in the Department of soil science, Regional soil Research Centre laboratory, Rajshahi. The soil characteristics of the experimental field have been present in appendix.

3.4.3. Climate

The experimental area was under sub-tropical climate characterized by rain fall during the Robi season (November to April) and low temperature with scanty rain fall during the season. The maximum, minimum and mean air temperature (°C), rain fall (mm), relative humidity (%), and sunshine (hours/day) during the experimental period have been given in appendix 2.

3.4.4. Seed variety selection

Maize variety BARI hybrid maize-7 and BARI hybrid maize-9 (BARI, GAM, WI) was used as planting material. It is a high yielding suit better variety. It was developed by BARI (Bangladesh Agriculture Research Institute) and was released in WI. This variety is characterized with the following aspects (BARI, WI).

3.5. Experimental treatment:

The irrigation treatments included in the experiment were as follows:

Factors, Irrigations level:-

i. No irrigation (control), coded as I_0
ii. One irrigation, coded as I_1
iii. Two irrigations, coded as I_2
iv. Three irrigations, coded as I_3

First irrigation given at crown root initiation stages, second irrigation given at cob initiation stages and third irrigation grain filling stages.

Factors: nitrogen treatments:-

a) No nitrogen coded as N_0
b) 115 kg N/ha, coded as N_1
c) 230 kg N/ha coded as N_2 and
d) 345 kg N/ha coded as N_3

3.6. Experimental design and layout.

The experiment was laid out in first two experiments RCBD and third one split-plot design in (a) four irrigations and three replications, (b) four nitrogen doses and three replication and (c) two irrigation and two nitrogen dose with three replication. Irrigation and nitrogen was first divided into four main plots and each the main plot was further divided in to three unit plot. The irrigation treatments were assigned in the main plot with every subplot. The total number of unit plot were 36 (Phases-3 x Treatment/irrigation-4 x Replication-3). The area of each unit plot was 20 squires meters (5m long and 4m wide). So the area of the research field in the phase 36x20 = 720 squires meters =18 decimal land.

3.7. Collection of seeds

Maize variety BARI hybrid maize-7 and BARI hybrid maize-9 (BARI, GAM, WI) were used as planting material. Those variety were collected from (BARI, WI) Bangladesh Agricultural Research Institute, Joydevpur, Gajipur.

3.8. Land preparation

The land of the experimental field was first opened with power tiller. Later on the land was ploughed and cross-ploughed four terms followed by laddering. The land was cleaned by collecting and removing the weeds and stubbles. Prior to sowing seeds, the whole experiment area was divided in unit plots maintains the desired spacing. The unit plot was spaded one day before planting for loosing the soil and incorporating the basal dose of fertilizers. The bounds around individual plots were made from enough to control water movement between plots.

3.9. Collection of soil samples and analysis

Soil samples were collected at 0-15cm soil depth during the time of land preparation from three locations of the experiment. This samples were composted to make a bulk sample was sieved to remove unwanted materials. This sample was air dried and preserved in polythene bags for laboratory analysis. The soil samples were analyzed by following the procedures described below-

3.9.1. Soil texture

Mechanical analysis and determination of soil textural class were done respectively by using hydrometer method (Black, 1995) and Marshall's triangular co-ordinates following the USDA system.

3.9.2. Soil pH

The pH of the soil sample was determined by glass-electrode pH meter. The ratio of soil and water in the solution was maintained at 1:2.5 (Jackson, 1962).

3.9.3. Organic matter

Wet oxidant method was followed for determination organic Carbon in the soil samples. Percentages of organic carbon determined by this method was multiplied by the Bemmelen factors, 1.724 (Page *et al.*1982) to obtain organic matter content of the soil.

3.9.4. Total nitrogen

Total nitrogen in the soil sample was estimated by following Micro Kjeldal method (Page *et al.* 1982). First, the sample was digested with 30% H_2O_2, concentrated H_2SO_4 and a catalyst mixture (K2SO4: $CuSO_4.5H_2O$: See in the ratio of 10:1:0.1). The digested samples were distilled with 40% NaOH followed by titration with 0.01N H_2SO_4.

3.9.5. Available Phosphorous

In order to determine available Phosphorous first the available Phosphorous present in soil samples was extracted by shaking with 0.5m $NaHCO_3$ solution having pH 8.5 (Olsen *et al.* 1954). Phosphorous in the extract was estimated calorimetrically by developing blue color of $SnCl_2$ reduction of Phosphomolybdate complex and measuring the color at 660 nm wavelength (Black, 1965).

3.9.6. Exchangeable potassium

Exchangeable potassium in the soil sample was determined by using flame photometer on the normal ammonium acetate at pH 7 (Black, 1965).

3.9.7. Available sulphur

The Ca $(H_2PO_4).H_2O$ solution (500ppm) was use to extract available sulphur from the soil samples. Acid seed solution (20 ppm K_2SO4 in 2M HCl) and $BaCl_2$ were added to the extract to develop turbidity. Available sulphur was then determined by measuring the turbidity calorimetrically at 535 nm wave length.

3.10. Application of fertilizers

The field was fertilized with urea, triple super phosphate, muriate of potash, zypsum, and boric acid at the recommended doses. Two third of urea and the whole amount of other fertilizers were applied at the time of final land preparation. The rest of two-thirds of urea were top dressed in two equal splits, one of the crown root initiation stages (50DAS) and the other at pencil initiation stages (80 DAS

3.11. Sowing of seeds

The seeds wee line, seeds were sown manually in 75 cm apart furrows in 25 cm distance see plant to plant at the rate of 12 kg/ha.

3.12. Irrigation

The plots (5m×4m= 20 squires meters every plot) were irrigated as per the experimental treatments as follows:

I_0 = Rainfall (control)/No irrigation.
I_1= One irrigation
I_2= Two irrigations
I_3= Three irrigations

First irrigation, in the root initiation stages (20 DAS)

Second irrigation, in the cob initiation stages (50 DAS)

Third irrigation, in the grain filling initiation stages (80 DAS)

3.13. Weeding and earth up

Different species of weeds infested the experimental plots. Among these Mutha (*Cyperus rotundus*) and Bathua (*Chenpodium album*) were prominent. Tow weeding before first and second irrigation. Two time earth up from furrows in the plant roots zone.

3.14. Plant protection

During the experimental period there was no remarkable infestation of insect-pest and diseases in the plots, so no pest control measure was taken.

3.15. Harvesting and processing

The crop will harvest at full maturity. Harvesting will done on complete full life cycle. The experimental crops will harvest plot-wise. Out of all rows of the each plot randomly 5 rows will harvest for collecting data on grain and straw yield. The harvest crop of the plot will bundle separately, tagged properly and bring to the clean threshing floor. The bundles will dry in sunshine, thresh and grains will clean. The seeds and straw weight for each plot for shill record after sun drying to constraint weight.

3.16. Collection of experimental data

A. Growth characters

To observations data on different growth parameters such as (a) plant height (b) plant girth (c) total tillers plant^{-1} (d) effective tiller plant^{-1} (e) non-effective tiller plant^{-1} (f) total roots plant^{-1} (g) straw weight plant^{-1} (h) straw yield t ha^{-1}.

B. Yield characters:

Data on different yield parameters such as (a) cob length (b)cob grain free length, (c) cob girth (d) grain line cob^{-1} (e) grain number line^{-1} (f) total grain cob^{-1} (g) grain weight cob^{-1} (h) 1000 grain weight cob^{-1} (i) grains yield t ha^{-1} (j) straw yield t ha^{-1} (k) biological yield t ha^{-1} and (l) harvest index (%).

The following growth phases, stages of development and yield were recorded.

A brief outline of the data recording procedure is given below

a) Plant height

Plant height will measured with the help of a meter scale from the bass of the plant to tip of upper most spike lets of the panicle.

b) Total tillers plant^{-1}

Number of total tillers of each sample will counted and the mean value will record.

c) Effective tillers plant^{-1}

The number of effective tillers will count and their mean values were calculated.

d) Non effective tillers plant^{-1}

The number of non-effective tiller calculated and average plant^{-1}.

e) Plant girth

Plant girth measured from the randomly selected sample of each plant and their average calculated.

f) Total roots plant^{-1}

Total roots per plant were recorded and mean were calculated later on.

g) Straw weight plant^{-1}

Straw weight plant^{-1} was recorded and mean were calculated later on.

h) Cob length

Cob length will record and mean will calculate later on.

i) Weight of 1000 grains

Weight of 1000 grains of plot will measure from the grain of sample plot.

j) Grain yield

Grain obtained from each unit of plot will sundry and weight carefully. The dry weight of grain of sample plants will add to the respective unit plot to record the final yield plot^{-1}. The grain yield will finally convert into t ha^{-1}.

k) Straw yield

Straw obtained from each unit plot including the straw of sample plant of respective unit plot will sundry and weight to record the final straw yield plot^{-1} and finally converted into t ha^{-1}.

l) Biological yield

Grain yield and straw yield all together were recorded biological yield. The biological yield was calculated with the following formula.

Biological yield= Grain yield+ Straw yield.

m) Harvest index

Harvest index is the ratio of grain yield and biological yield. The harvest index was calculated the following formula:-

Harvest index (%) = Grain yield/ Biological yield×100.

3.17. Methods of data collection

Growth parameters of plant from each plot were collected in full maturity from the growth phases to harvest. The plants were observed for their external morphology and their growing points, the shoot apices and the development of cob i. e. internal growth was studied under very carefully.

A. Growth parameters

For growth analysis, samples were calculated at full maturity. At each harvest 0.25 squires meters area of plant were cut just at the soil surface and tops were separated into leaves, stem and cob. The sample packed separately labeled with brown paper bags and oven dried for 24 hours at 85°c. Dry weight was taken separately with an electrical balance.

B. Yield parameters:

Plant sample from each plot was selected at random. Height of the plant was measured from ground level to the tip of the upper most spike let of the spike cob excluding awn. The 1000 grain weight, grain and straw yield, were recorded after proper sun drying and clearing. Harvest index was calculated with the following formula:

Harvest index (%) = Seed yield / Biological yield ×100

3.18. Statistical analysis

All the collected and calculated data were analyzed following the ANOVA-technique. The mean differences among the treatments were adjusted by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using a computer operated program named MSTAT-C.

Chapter Four

Results and Discussion

Chapter-FOUR

4. Results and Discussion

(Effect of irrigation)

The results of irrigation, nitrogen and interaction on BARI hybrid maize-7 and BARI hybrid maize-9 obtained from this experiment have been presented and discussed in this chapter. The results on the effect of irrigation were been presented in Table 01-04 and graphical presentation of different parameters have been presented in Figs 01-10. Data on different growth parameters such as plant height, plant girth, total tiller plant^{-1}, effective tiller plant^{-1}, non-effective tiller plant^{-1}, total roots plant^{-1}, straw weight plant^{-1}, straw yield t ha^{-1} and data on different yield parameters such as cob length, cob grain free length, cob girth, grain line cob^{-1}, grain number line^{-1}, total grain cob^{-1}, grain weight cob^{-1}, 1000 grin weight cob^{-1}, grain yield t ha^{-1}, straw yield t ha^{-1}, biological yield t ha^{-1} and harvest index (%). The analysis of variance in respect of all the selected parameters under the study together with sources of variation and corresponding degrees of freedom were been presented here.

4. 1. Effect of irrigation on growth and yield of BARI hybrid maize-7 and BARI hybrid maize-9

A. Growth parameters of experimental maize varieties with performance of irrigation

4.1.1.1 Plant height

Irrigation treatments showed significant effect on plant height in BARI hybrid maize-7 (Table 01). The highest plant height 273.17 cm was obtained with three irrigations which were far with one and two irrigations. The lowest plant height 216.33 cm was obtained with no irrigation. The plant height graph with different irrigation treatments in growth level i.e. plant height values increased with the increasing of irrigation levels. Afterwards the graph started to decline which is showing in Fig.1. Yazar *et al.* (2012) reported that the highest average maize plant height obtained from full irrigation treatment using drip irrigation method. However, Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase plant height at the important level.

4.1.1.2. Plant height

Irrigation levels showed positive effect on plant height in BARI hybrid maize-9 (Table 02). The highest plant height 283.00 cm obtained three irrigations which were differs from the others treatments and the lowest plant height 219.67 cm was no irrigation. Irrigation plays a vital role in vegetative growth of plant causing increased plant height. Plant height graphs of irrigation treatment resulted in a usual graphs different irrigation treatments in growth level i.e. plant height values increased gradually with the increasing of irrigation levels (Fig.1). However, maize has been reported to be very sensitive to drought (Otegui *et al.*, 2005). The application of deficit irrigation requires thorough understanding of the plant height response to water (crop sensitivity to drought stress) and of the economic impact of reductions in harvest (English, 2010).

4.1.2.1. Plant girth

Irrigation levels showed significant positive effect on plant girth in BARI hybrid maize-7 (Table 01). The highest plant girth 8.17 cm was obtained with two and three irrigations and lowest plant girth was with no irrigation which statistically differs from one irrigation levels. The plant girth values increased with the increasing of irrigation levels. But increasing of irrigation not differ in girth between two and three irrigations. Ayars *et al*., (2009); Dogan and Kirnak., (2010) found the use of drip irrigation is increasing substantially each year in the region. However, local information from the Marmara region of Turkey on the response of maize yield with drip irrigation is very limited, especially dealing with the effect of limited water allocations. In Marmara climatic region, little attempt has been made to assess the water yield relationships and optimum water management programs of maize for recently developed hybrids.

Table- 1: Effect of irrigation on the growth and growth performance of BARI hybrid maize-7

Treatments	Plant height (cm)	plant girth (cm)	Total tiller plant^{-1} (no.)	Effective tiller plant^{-1} (no.)	Non-effective tiller plant^{-1} (no.)	Total roots plant^{-1} (no.)	Straw weight plant^{-1} (g)	Straw yield (t ha^{-1})
No irrigation (I_0)	216.33	14.33	8.67	5.67	7.17	43.33	912.67	48.68
One irrigation (I_1)	246.33	14.67	12.33	2.33	7.83	47.00	1070.67	57.10
Two irrigation (I_2)	260.33	15.67	12.33	3.33	8.17	54.33	1161.67	61.95
Three irrigation (I_3)	273.67	16.00	12.00	4.00	8.17	50.33	1276.67	66.49
Sd	24.57	0.79	1.78	1.40	0.47	4.69	153.68	7.62
Cv(%)	9.86	5.23	15.75	36.55	6.02	9.63	13.90	13.01
Level of significance	**	*	**	**	*	**	**	**

In a column figures having common letters(s) do not differ significant as per DMRT

**Indicates 1 % and * indicates 5% level of probability

NS indicates not significant

4.1.2.2. Plant girth

Irrigation levels in BARI hybrid maize-9 with plant girth showed significant effect influenced (Table 02). The largest plant girth 8.17 cm obtained from three irrigation which was statistically similar in two irrigation and the lowest plant girth found within no irrigation which also similar with one irrigation. Plant girth resulted probably due to availability of water supply produced largest of plant girth. Plant growth level values increased gradually with increasing irrigation levels. Maize has been reported in the literature to have high irrigation requirements (Stone *et al.*, 2006; Karam *et al.*, 2013). Maize plant girth increased significantly by irrigation water amount and irrigation frequency (Yazar *et al.*, 2009; Kara and Biber, 2008; Farre and Faci, 2009).

4.1. 3.1. Total tillers plant^{-1}

Total tillers plant^{-1} showed positive effects among the treatments of irrigation in BARI hybrid maize-7 (Table 01). The highest total tiller plant-^{1}16 were produced with three irrigations which was not statistically differs between two and three irrigations. The lowest total tillers 14.33 showed with rainfall or no irrigation which also not statistically differs from one irrigation level. The tillers plant^{-1} graph irrespective of irrigation treatment resulted in a usual curves different irrigation treatments in growth level i. e. total tillers values increased with gradually increasing irrigation levels and the curves started to decline which is shown in (Fig.2). Ayars *et al.*, (2009); Dogan and Kirnak., (2010) showed advantages of drip irrigation over other irrigation methods include improved water and nutrient management, improved saline water management, potential for improved total tiller per plant and crop

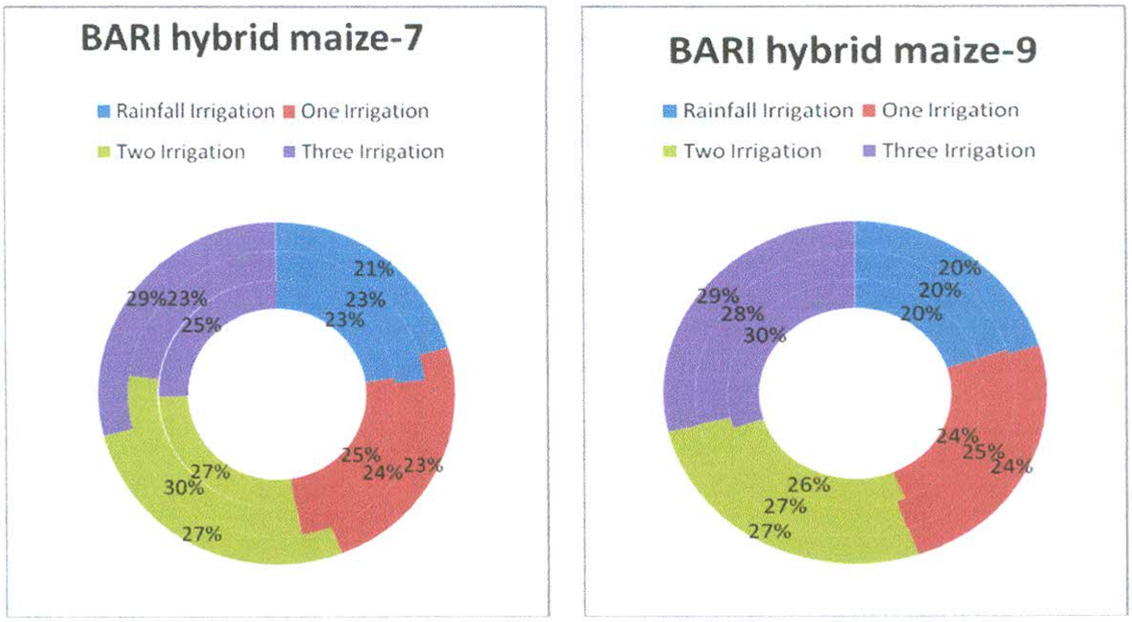


Fig. 01. Effect of irrigation on plant height of experimental varieties

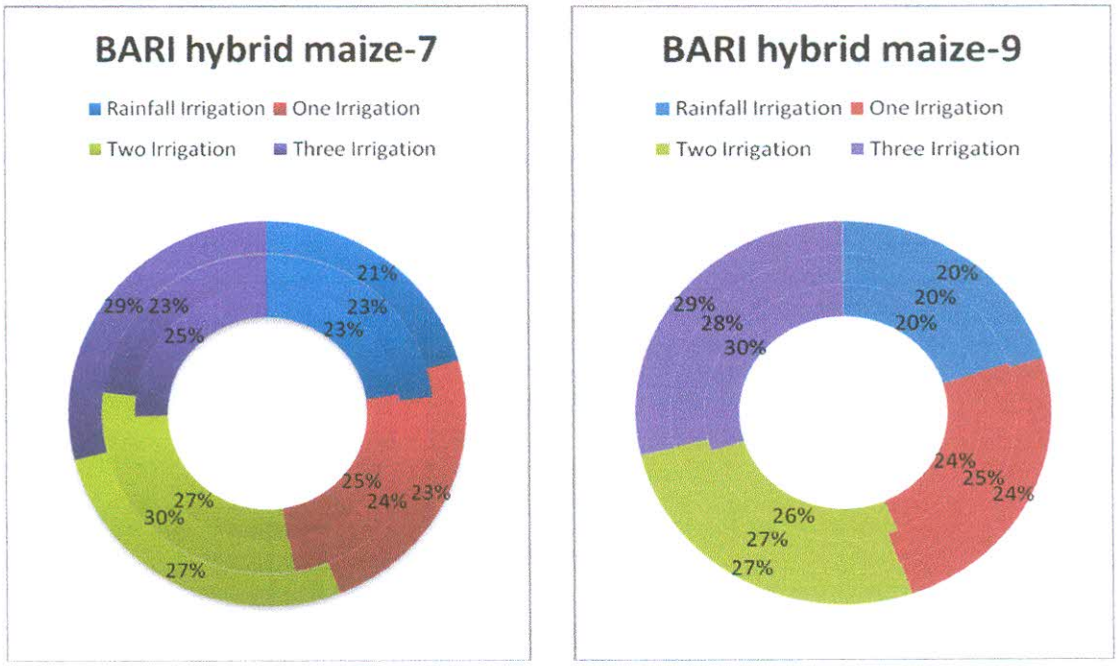


Fig. 02. Effect of irrigation on total tillers per plant of experimental varieties

production, reducing the incidence of diseases and weeds in dry row middles, greater control on applied water resulting in less water and nutrient loss through deep percolation, and reduced total water requirements.

4.1.3.2. Total tillers plant^{-1}

Total tillers plant^{-1} showed significant positive effects among the treatment in BARI hybrid maize-9 (Table 02). The highest total tillers were produced with three irrigation which was not statistically differs from highest total tillers 14.33 obtained with rainfall no irrigation also not statistically differs from one irrigate the total tiller plant-^{1} curves irrespective of irrigation treatment resulted in an usual graphs different irrigation treatments in growth level i.e. total tiller values increased with increasing irrigation level gradually and the graphs started to decline which is shown in (Fig.2). Lamm *et al.* (2005) stated that it is difficult to plan deficit irrigation for maize without causing total tillers reduction. Payero *et al.* (2006) reported that trying to increase crop water productivity by imposing deficit irrigation for maize might not be a beneficial strategy in a semi-arid climate. Karam *et al.* (2013) found that grain and dry matter yield and leaf area index was reduced by severity of water stress.

4.1. 4.1. Effective tillers plant^{-1}

Effective tillers plant^{-1} t ha^{-1} obtained with irrigation treatments in BARI hybrid maize-7. The highest effective tillers 12.33 produced with one and two irrigation which was not statistically differ with three irrigations. The lowest effective tillers 8.67 were produced with the no irrigation

Table- 2 : Effect of irrigation on the growth and growth performance of BARI hybrid maize-9

Treatments	Plant height (cm)	plant girth (cm)	Total tiller plant^{-1} (no.)	Effective tiller plant^{-1} (no.)	Non-effective tiller plant^{-1} (no.)	Total roots plant^{-1} (no.)	Straw weight plant^{-1} (g)	Straw yield (t ha^{-1})
No irrigation (I_0)	219.67	12.67	9.67	3.00	7.17	37.33	928.33	49.39
One irrigation (I_1)	246.67	14.67	11.33	3.33	7.33	41.67	1104.33	58.90
Two irrigation (I2)	271.00	15.67	12.33	3.33	8.00	41.33	1218.33	64.98
Three irrigation (I_3)	283.00	T	12.67	4.00	8.17	51.67	1322.67	70.54
Sd	28.03	1.71	1.35	0.42	0.49	6.10	168.85	9.06
Cv (%)	10.99	11.44	11.71	12.27	6.39	14.19	14.76	14.86
Level of significance	**	*	**	**	*	**	**	**

In a column figures having common letters(s) do not differ significant as per DMRT

**Indicates 1 % and * indicates 5% level of probability

NS indicates not significant

treatment (Table 01). The irrigation treatments of replication in growth level of effective tillers values increased of irrigation levels gradually increased of effective tillers values. The result might be probably availability soil moisture more effective tillers produced. Bozkurt *et al.* (2011) reported that the highest effective tillers were found in 120% of evaporation from a Class A Pan under the Eastern Mediterranean climatic conditions in Turkey.

4.1.4. 2. Effective tillers plant^{-1}

Effective tillers showed positive effect among the irrigation treatments in BARI hybrid maize-9 (Table 02).The maximum effective tillers found in three irrigations and it was not statistically differ from one and two irrigation. The lowest effective tiller 8.67 was produced with the no irrigation treatments. The effective tillers plant^{-1} resulted effective tillers values in gradually increased with the increasing irrigation level. Effective tillers might probably due to irrigation treatment more effective tillers production. Yildirim and Kodal (2008) reported that seasonal effect in maize varied between 300 and 1024 mm in Ankara, Turkey. Under furrow irrigation applications, seasonal effective tillers of maize obtained by Gencoglan and Yazar (2009) was 1026 mm for full irrigation treatment and 410 mm for non irrigated treatment in the Cukurova region of Turkey.

4.1. 5.1. Non-effective tillers plant^{-1}

Non-effective tillers plant^{-1} showed significant effect among the treatments in BARI hybrid maize-7. The effect of irrigations on the non-effective tillers was opposite condition of the effective tillers (Table 01).

In non-effective values increased of irrigation levels decreased non-effective tillers but one and two irrigations statistically no differs between the treatments. Same effect found Igbadun *et al.*, (2008) Shortage in irrigation water supplies in the Marmara region has motivated farmers to find ways to produce none effective tillers of crops, especially maize, with less irrigation water, such as using more efficient irrigation systems and changing from fully irrigated to deficit irrigated cropping systems.

4.1.5.2. Non-effective tillers plant^{-1}

Non-effective tillers showed significant effect among by the irrigation treatment in BARI hybrid maize-9 (Table 02). The non-effective tillers were opposite condition of effective tillers. In irrigation treatments of replication in growth level of non effective values in creased of irrigation level decreased non effective tillers but one and two irrigation statistically not differs among the treatments. Oktem *et al.* (2013) found that seasonal none effective tillers for maize by using drip irrigation method in different conditions of Turkey varied between 104–701 mm depending on irrigation scheduling. The values of seasonal ET obtained in this study are in agreement to those values reported in the previous literature for maize 701 mm depending on irrigation scheduling.

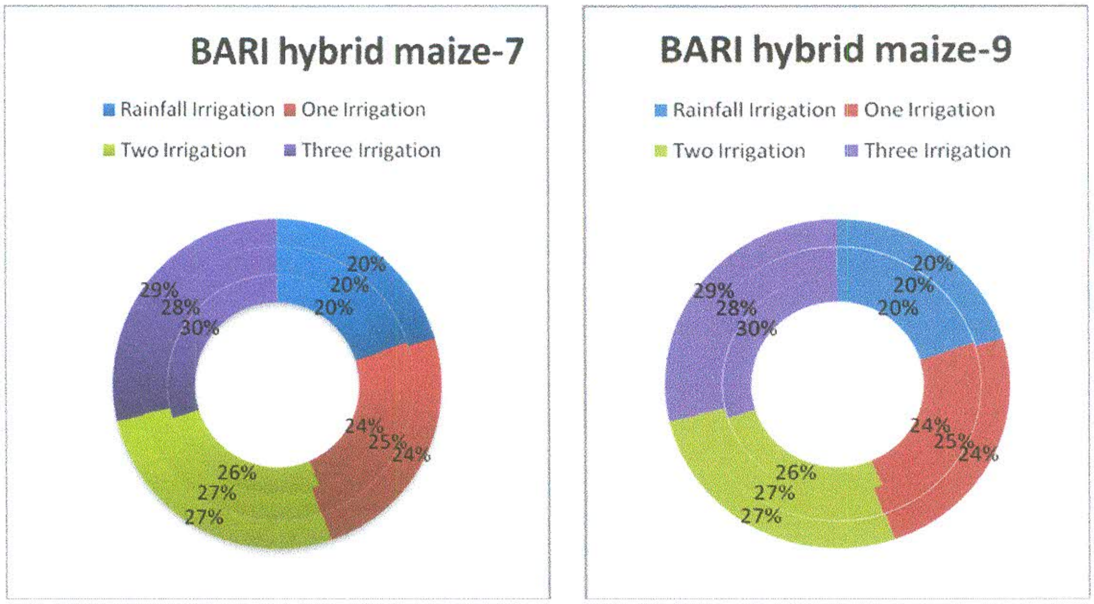


Fig. 03. Effect of irrigation on total roots per plant of experimental varieties

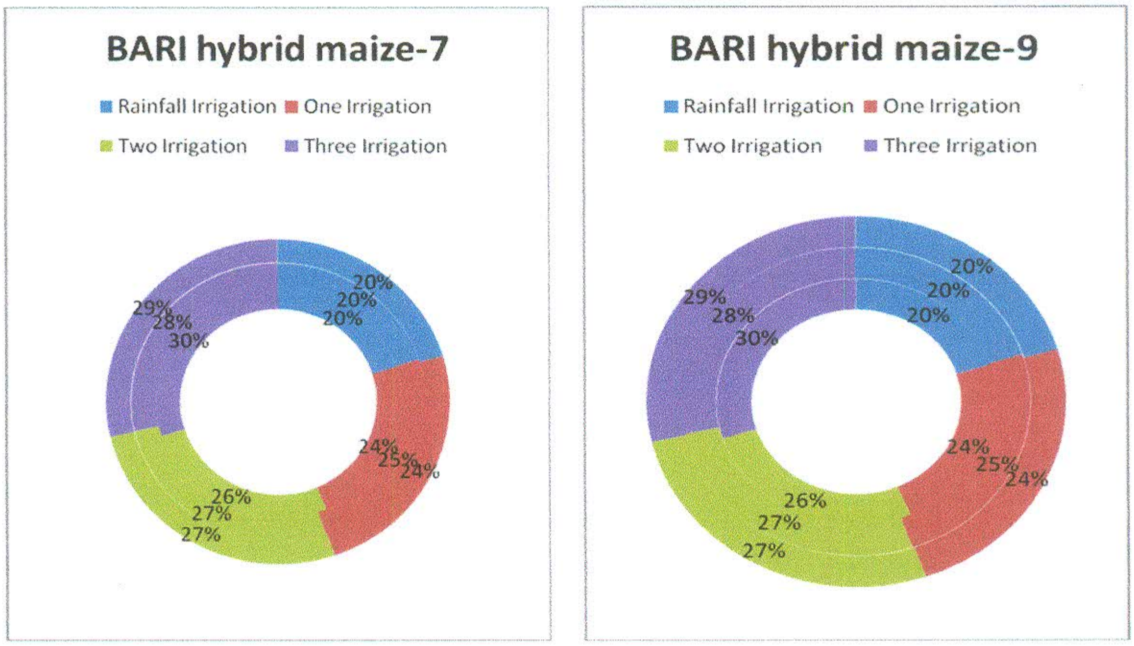


Fig. 04. Effect of irrigation on straw yield ton per ha of experimental varieties

4.1.6.1. Total roots plant^{-1}

Irrigation levels showed significant effect among the treatments in BARI hybrid maize-7. The highest number 50.33 roots produced with three irrigations and the lowest number 43.33 roots produced with no irrigation (Table 01). This result might probably be due to availability of irrigation water more roots production. In graphical curves different irrigation treatments of replication in growth level i.e. total roots plant^{-1} increased more roots production and afterwards the graph started to decline accepts between one and two irrigation (Fig.3). However, water availability is usually the most important natural factor limiting expansion and development of roots production (Yazar *et al*., 2009; Kara and Biber, 2008; Farre and Faci, 2009). Competition for water from other sectors such as industry and domestic use will force irrigation to operate under water scarcity.

4.1. 6. 2. Total roots plant^{-1}

Irrigation levels had significant effect in the total tillers plant^{-1} in BARI hybrid maize-9 (Table 02). The highest numbers roots 50.33 produced with three irrigation and the lowest number 43.32 roots produced with the no irrigation this result probably be due to availability of irrigation water more roots production. In the graphical different irrigation treatments of replication in growth level i.e. total roots plant^{-1} increased irrigation level increased to more roots production (Fig 3). The resulted might probably due availability water supply more roots production. Deficit irrigation, by reducing irrigation water use, can aid in roots production with situations where water supply is restricted. In field crops, a well-designed deficit irrigation regime can optimize water productivity over an area when full irrigation is not possible (Fereres and Soriano, 2007).

4. 1. 7.1. Straw weight plant^{-1}

Irrigation levels significantly were influenced on the straw weight plant^{-1} in BARI hybrid maize-7 (Table 01). The highest straw weight plant^{-1} was 1276.67 g with the three irrigations and the lowest straw weight plant^{-1} 912.67 g with no irrigation. Increased of irrigation levels increased gradually the straw weight plant^{-1} resulted different irrigation treatments in growth level straw weight plant^{-1} values increased with the advancement of irrigation level. This result might probably be due to availability of irrigation water supply more vegetative production. In these conditions, irrigation is the major factor determining straw yield. It is consequently essential to determine the water regimes leading to highest straw yield. Maize has been reported in the literature to have high irrigation requirements (Stone *et al*., 2006; Karam *et al*., 2013).

4.1. 7. 2. Straw weight plant^{-1}

Straw weight plant^{-1} was significantly influenced by irrigation treatments in BARI hybrid maize-9 (Table 02). The highest straw weight plant^{-1} 1322.67 g counted with three irrigations which was differs from any others treatments. The lowest straw weight plant-1 928.28 g found in no irrigation which was also statistically differs from all the treatment. Straw weight plant^{-1} of different irrigation treatments in growth level result showed more irrigation water supply more straw production. Maize straw yield per plant increased significantly by irrigation water amount and irrigation frequency (Yazar *et al*., 2009; Kara and Biber, 2008; Farre and Faci, 2009).

4.1.8.1. Straw yield

There were significant effects among the irrigation the maximum straw yield 66.48 that was three irrigation and the lowest straw yield 485.68 that with the rainfall irrigation in BARI hybrid maize-7 (Table 01). The straw yield cures different irrigation treatments of replication in growth level respective of yield values increased of irrigation levels increased the straw yield the result might probably be due to availability of irrigation increased more vegetative production(Fig. 4). Pandey *et al*. (2010) stated that straw yield reduction (22.6–26.4%) caused by deficit irrigation was associated with a decrease weight. The effects of deficit irrigation for the same crop may vary with location. Climate and soil type of the location are perhaps the most important factors dictating the influence of deficit irrigation (Igbadun *et al*., 2008).

4.1. 8.2. Straw yield

Straw yield t ha-^{1} showed positive effect among the irrigation treatments in BARI hybrid maize-9 (Table 02). The maximum straw yield t ha^{-1} 70.54 was counted at three irrigations which was statistically with two irrigations levels and minimum straw yield t ha-^{1} 49.39 was no irrigation which was statistically differs from all the treatments. But statistically similar results showed in one and two irrigations. The curves different irrigation treatments in growth level i.e. straw yield values increased with the increasing of irrigation levels (Fig. 4). Yazar *et al*. (2012) reported also that the highest average maize straw yield obtained from full irrigation treatment using drip irrigation method. However, Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase straw yields at the important level.

B. Yield parameters of experimental maize varieties with the performance of irrigation

4.1.9.1. Cob length

Cob length showed non-significant effect among the irrigation treatments in BARI hybrid maize-7 (Table 03). The highest cob length 20.67 cm was found with three irrigations and lowest cob length obtained no irrigation levels but both irrigation treatments were statistically similar among the treatments. The cob length large probably due to irrigation level increased not cob length advancement significantly (Fig 5). Igbadun *et al.* (2008) and Pandey *et al.* (2010) reported generally, water uses efficiencies and intensive water uses efficiencies are influenced by cob length potential, irrigation method, estimation and measurement of effective tillers, crop environment, and climatic characteristics of the region. The results related to the efficiencies showed that when irrigation water is limited, 25% deficit irrigation can be applied for increase the water use efficiencies.

4.1.9.2. Cob length

Cob length was non-significant effect influenced by irrigation in BARI hybrid maize-9 (Table 04). The maximum cob length 20.00 cm counted obtained two and three irrigations and minimum 19.67 cm counted with rainfall and one irrigation level (Fig 5). Cob length was non-significantly increased with increasing irrigation levels. Mansouri Far *et al.* (2010) reported that irrigation water can be conserved and cob length maintained in maize plant (as sensitive crop to drought stress) under water limited conditions through improved fertilizer managements and selecting more tolerant hybrids. On the other hand, the feasibility of increasing water uses efficiency is a decision that needs to be based not only on the biophysical response of the crop but also on economic factors.

4.1.10.1. Cob grain frees

Cob grain free length showed positive significant effect influenced among the irrigation treatments in BARI hybrid maize-7 (Table 03). The grain free length 1.33 cm found with no irrigation and the lowest 0.83 cm obtained two and three irrigations. The cob grain free length of different irrigation treatment in replication in yield level decline with increasing irrigation levels. Cob grain free length probably due to sufficient water supply decreased gradually. When water supplies are limiting, the farmer's goal should be to maximize net income per unit water used rather than per land unit. Deficit irrigation, by reducing irrigation water use, can aid in coping with situations where water supply is restricted. In field crops, a well designed deficit irrigation regime can optimize water productivity over an area when full irrigation is not possible (Fereres and Soriano, 2007).

4.1.10.2. Cob grain free

Cob grain free length had non-significant effect among the treatment in BARI hybrid maize-9 (Table 04).The highest similar effect 1.67 cm rainfall, one and two irrigations levels. The lowest cob grain free length with in there irrigation which was not statistically differs from the any other treatments. The cob grain free length resulted might probably due to irrigation levels increased not increasing properly. Often the objective of producers is not to increase cob grain free but to increase profits (Payero *et al*., 2008). Determining the level of irrigation needed to optimize profits can be complex and depends on both biophysical and economic.

4.1.11.1. Cob girth

Cob girth showed positive effect among the irrigation treatments in BARI hybrid maize-7 (Table 03). The largest cob girth 16.00 cm found with three irrigations which was statistically similar in two irrigations. The smallest cob girth 14.33 found obtained no irrigation which was statistically similar with one irrigation level. The cob girth of different irrigation treatments in yield level cob girth values increased with increasing irrigation levels. Cob girth might probably due to sufficient water supply increased gradually. Mansouri–Far *et al.* (2010) reported that irrigation water can be conserved and plant girth maintained in maize plant (as sensitive crop to drought stress) under water limited conditions through improved fertilizer managements and selecting more tolerant hybrids. On the other hand, the feasibility of increasing either the water use efficiency or not is a decision that needs to be based not only on the biophysical response of the crop but also on economic factors.

4.1.11.2. Girth

Cob girth showed influenced by irrigation in BARI hybrid maize-9 (Table 04). The largest cob girth 16.00cm found obtained there irrigation which was statistically similar with two irrigation. Smallest cob girth found with no irrigation which also statistically similar resulted with one irrigation level. The cob girth of irrigation treatment resulted cob girth values gradually increased with increasing of irrigation treatment. It might probably more irrigation water more girth produced. The cob girth value obtained in this study is similar to the literature data (Yildirim *et al.*, 2006; Yazar *et al.*, 2012; Karam *et al.*, 2013; Mengu and Ozgurel, 2008).

4.1.12.1. Grain line cob^{-1}

Grain line cob^{-1} showed influenced among the irrigation treatments in BARI hybrid maize-7 (Table 03). The maximum grain line cob^{-1} 14.00 counted at three irrigations and lowest grain line cob^{-1} 12.33 obtained no irrigation. The grain line cob^{-1} might probably due to non-sufficiently increased. Similar results were reported by Gencoglan and Yazar (2009), Kipkorir *et al*. (2012), Bozkurt *et al*. (2006), and Farre and Faci (2009). However, Payero *et al*. (2006b) reported that there was linear relationship between grain line per cob and seasonal irrigation water amount.

4.1.12.2. Grain line cob^{-1}

Grain line cob was non- significant effect among the irrigation treatments in BARI hybrid maize-9 (Table 04) the max grain line cob^{-1} 14.33 found at one irrigation and lowest 13.33 counted rainfall and two irrigation but here are not statistically differs from any treatment. The grain line cob irrigation treatment result increasing irrigation treatment statistically not increased production. Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase grain yields at the important level.

4.1.13.1. Grain number line^{-1}

Grain number line^{-1} showed significant effect among the irrigation treatments in BARI hybrid maize-7 (Table 03). The maximum grain line^{-1} 49.00 counted at two irrigations and lowest grain number line^{-1} obtained no irrigation. The grain number line^{-1} value respective increasing irrigation significantly increased the production. Pandey *et al*. (2010) stated that

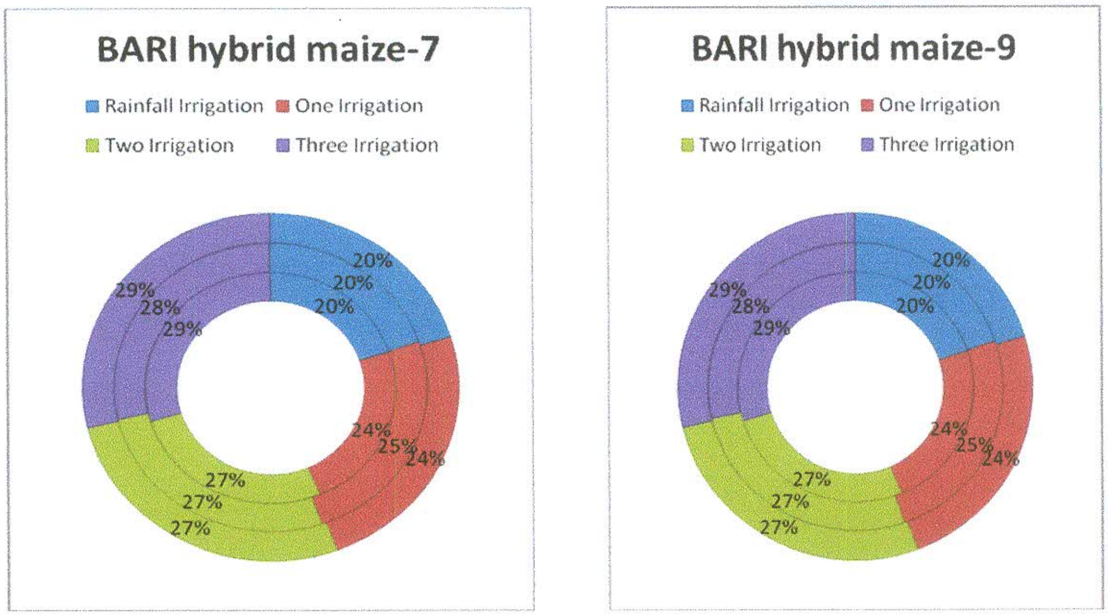


Fig. 05. Effect of irrigation on cob length of experimental varieties

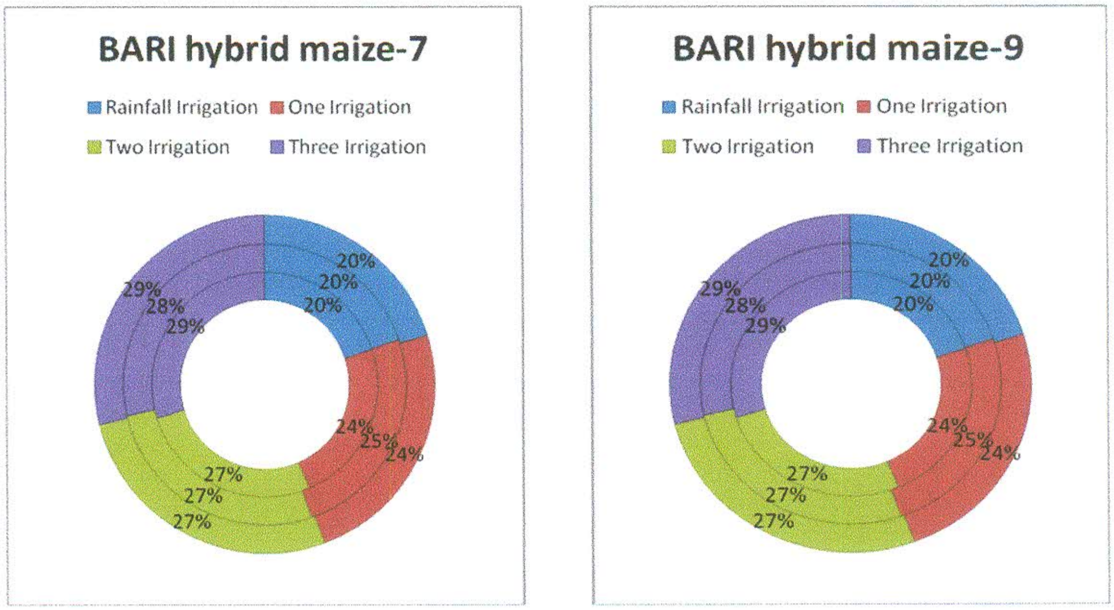


Fig. 06. Effect of irrigation on total grains per cob of experimental varieties

yield reduction (22.6–26.4%) caused by deficit irrigation was associated with a decrease in kernel number and weight. The effects of deficit irrigation for the same crop may vary with location. Climate and soil type of the location are perhaps the most important factors dictating the influence of deficit irrigation (Igbadun *et al*., 2008). Shortage in irrigation water supplies in the Marmara region has motivated farmers to find ways to produce crops, especially maize, with less irrigation water, such as using more efficient irrigation systems and changing from fully–irrigated to deficit irrigated cropping systems.

4.1.13.2. Grain number line^{-1}

Grain number line^{-1} showed positive effect among the irrigation treatment in BARI hybrid maize-9 (Table 04). The maximum grain number line^{-1} 45.67 observed with three irrigations and which was differs from the any other irrigation treatment. The minimum grain number line^{-1} 41.33 counted at two irrigations which were statistically similar with rainfall and one irrigation level. The relationship between applied water and grain number was quadratic.

4.1.14.1. Total grain cob^{-1}

Total grain cob^{-1} was showed influenced by irrigation levels in BARI hybrid maize-7 (Table 03).The maximum total grain cob^{-1} 644.00 produced with three irrigations and it was statistically similar with two irrigations. The minimum total grain cob^{-1} 470.67 found with on irrigation which was statistically differs from any others treatments. Total grain cob^{-1} curves different irrigation treatments of replication in yield level respective with irrigations treatments resulted in a usual graph i.e.

total grain cob^{-1} values increased with the increasing irrigation levels and afterwards inspect of irrigation level decline production (Fig.6). Yazar *et al.* (2012) reported also that the highest average maize grain yield obtained from full irrigation treatment using drip irrigation method. However, Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase grain yields.

4.1.14.2. Total grain cob^{-1}

Total grain cob^{-1} positively influenced by irrigation treatments in BARI hybrid maize-9 (Table 04). The highest total grain cob-^{1} 639.33 observed at three irrigations and it was statistically similar with one irrigation level. The lowest total grain cob^{-1} 52.67 found at no irrigation which also similar with the two irrigations. Total grain cob^{-1} graphs irrespective with irrigation treatments resulted in a usual graph different irrigation treatments of replication in yield level i.e. total grain cob^{-1} values first increased with increasing of irrigation and afterwards increasing irrigation decreased yield and last step increasing irrigation levels significantly positive effect (Fig.6). Yazar *et al.* (2012) reported also that the highest average maize grain yield obtained from full irrigation treatment. However, Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase grain yields at the important level at the important level.

4.1.15.1. 1000 grain weight

Irrigation treatment influenced with 1000 grain weight in BARI maize-7 (Table 03). The highest 1000 grain weight 279.66 g produced with three irrigations which was statistically similar with two irrigation levels. The lowest 1000 grain weight 265.50 g counted with no irrigation and statistically similar with one irrigation. The 1000 grin weight graphs respective of irrigation treatment resulted in a usual graph different irrigation treatments in yield level i.e. 1000 grain weight values increased with the increasing of irrigation levels (Fig.7). Reported by Gencoglan and Yazar (2009), Kipkorir *et al*. (2012), Bozkurt *et al*. (2006), and Farre and Faci (2009), the relationship between applied water and 1000 grain weight was quadratic and small irrigation amounts increased yield, more or less graphs up to a level where the relationship was graphs because part of the water applied is not used in ET. At a point of 1100 mm of irrigation water amount, 1000 weight reached its maximum value and the regression equation showed that additional amounts of irrigation did not increase at any further.

4.1.15.2. 1000 grain weight

Irrigation treatment showed effect with 1000 grain weight in BARI hybrid maize-9 (Table 04).The highest 1000 grain weight 283.96g observed with three irrigations and statistically same effect shown in two irrigation levels. The lowest 1000 grain weight 253.11g found in no irrigation and statistically similar effect with one irrigation level. The1000 grain weight graph respective with irrigation treatments resulted in a usual graph different irrigation treatments in yield level i.e. 1000 grain weight values increased gradually with the increasing of irrigations (Fig.7). The relationship between applied water and 1000 grain yield was quadratic. Small irrigation amounts increased yield, more or less linearly up to a level where the relationship was curvilinear because part of the water applied is not used in ET. At a point of 1100 mm of irrigation water

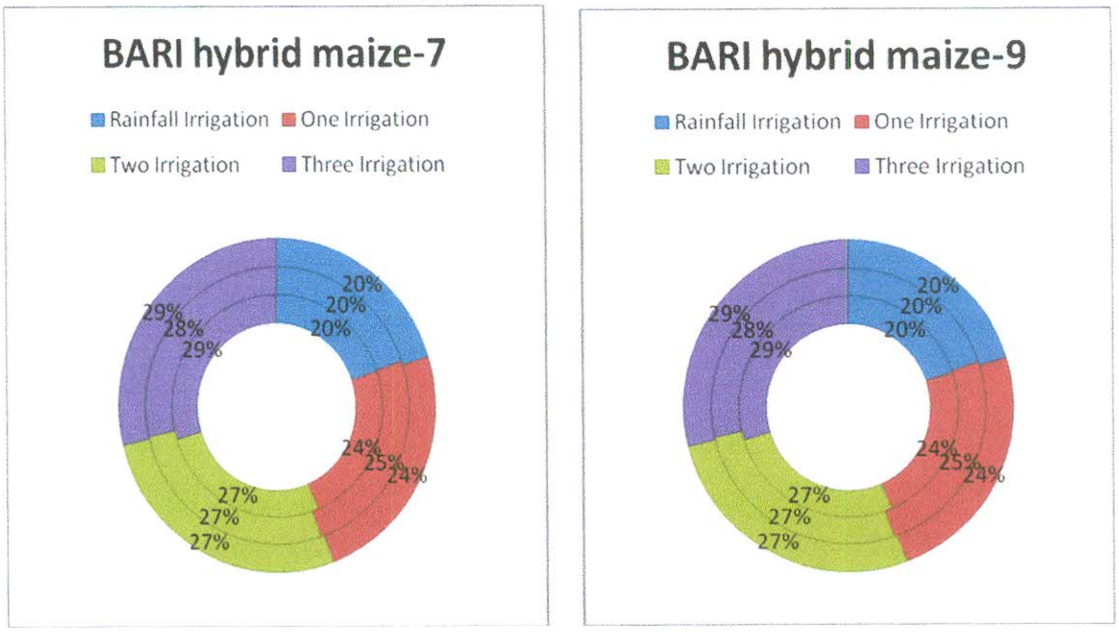


Fig. 07. Effect of irrigation on 1000 grains weight per cob of experimental varieties

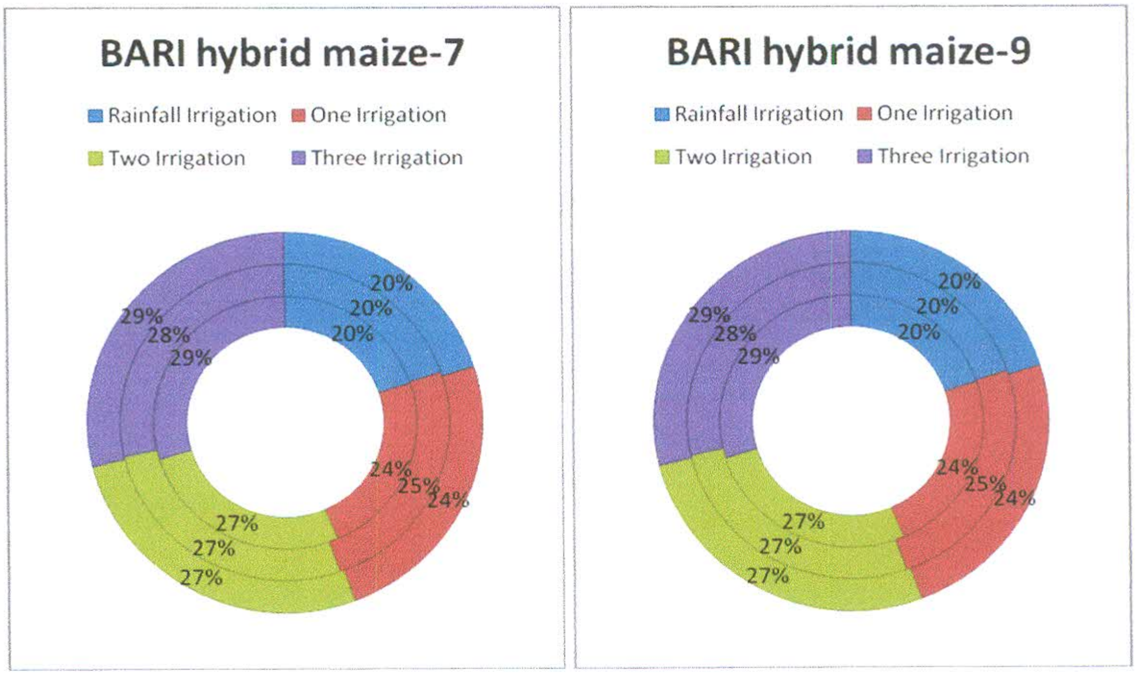


Fig. 08. Effect of irrigation on grain yield ton per ha of experimental varieties

amount, yield reached its maximum value (16730 kg ha^{-1}). Moreover, the regression equation showed that additional amounts of irrigation did not increase it any further (Fig.34). Nonlinear relationships have also been reported by Gencoglan and Yazar (2009), Kipkorir *et al.* (2002), Bozkurt *et al.* (2006), and Farre and Faci (2009). However, Payero *et al.* (2006b) reported that there was linear relationship between grain yield and seasonal irrigation water amount.

4.1.16.1. Grain weight cob^{-1}

Grain weight cob^{-1} significantly affected by irrigation treatment in BARI hybrid maize-7 (Table 03). The maximum grain weight cob^{-1} 176.00 g with three irrigations which was statistically similar with one and two irrigations levels. The minimum grain weight cob^{-1} 125.66 g counted with no irrigation. Grain weight cob^{-1} values increased with the increasing of irrigation levels. It was conformed that irrigation water supply increased grain weight cob^{-1}. However, the drip irrigation method is becoming more popular because of numerous advantages over other methods (Hanson *et al.*, 2007). Some advantages of drip irrigation over other irrigation methods include improved water and nutrient management, improved saline water management, potential for improved yields and crop quality, reducing the incidence of diseases and weeds in dry row middles, greater control on applied water resulting in less water and nutrient loss through deep percolation, and reduced total water.

Table-3 : Effect of irrigation on the yield and yield performance of BARI hybrid maize-7

Treatments	Cob length (cm)	Cob grain free (cm)	Cob girth (cm)	Grain line cob^{-1} (no)	Grain number $line^{-1}$ (no)	total grain $cob-^{1}$ (no)	Grain weight $cob-^{1}$ (g)	1000 Grain weight cob^{-1} (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
No irrigation (I_0)	20.00	1.33	14.33	12.33	38.33	470.67	265.50	124.00	6.61	48.68	55.29	0.12
One irrigation (I_1)	21.67	1.33	15.00	12.67	44.00	557.00	269.58	153.67	9.01	57.10	66.11	0.14
Two irrigation (I_2)	20.33	0.83	15.67	13.00	49.00	636.33	276.15	170.00	9.97	61.95	71.93	0.14
Three irrigation (I_3)	20.33	0.83	16.00	14.00	46.00	644.00	279.60	176.00	10.32	66.49	76.81	0.13
Sd	0.74	0.29	0.74	0.72	4.50	81.07	6.35	23.28	1.67	7.62	9.26	0.01
Cv(%)	3.59	26.65	4.85	5.54	10.14	14.05	2.33	14.93	18.62	13.01	13.71	6.52
Level of significance	NS	*	*	*	NS	**	**	*	*	**	**	NS

In a column figures having common letters(s) do not differ significant as per DMRT
**Indicates 1 % and * indicates 5% level of probability
NS indicates not significant

4.1.16.2. Grain weight cob^{-1}

Grain weight cob^{-1} was significantly affected by irrigation treatments in BARI hybrid maize-9 (Table 04).The maximum grain weight cob-^{1} observed 178.00 g with three irrigations and similar resulted in two irrigations levels. The minimum grain weight cob^{-1} found with no irrigation which was statistically differs with any others irrigation level. Grain weight cob^{-1} values increased with increasing of irrigation levels. Yazar *et al*. (2012) reported also that the highest average maize grain yield obtained from full irrigation treatment. However, Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase grain yields at the important level.

4.1.17.1. Grain yield

Irrigation treatment influenced with grain yield t ha^{-1} in BARI maize-7 (Table 03).The highest grain yield t ha^{-1} 10.32 produced with three irrigations which was statistically similar with one and two irrigations levels. The lowest grain yield t ha^{-1} 6.61counted with no irrigation and statistically differs from any others treatments. The grain yield t ha^{-1} graphs respective of irrigation treatment resulted in a usual curve different irrigation treatments in yield level i.e. grain yield values increased with the increasing of irrigation levels (Fig.8). **I**ts resulted might probably due to irrigation levels increased the grain production**.** In these conditions, irrigation is the major factor determining yield. It is consequently essential to determine the water regimes leading to highest yield. Maize has been reported in the literature to have high irrigation requirements (Stone *et al*., 2006; Karam *et al*., 2013). Maize grain yield increased significantly by irrigation water amount and irrigation frequency (Yazar *et al.*, 1999; Kara and Biber, 2008; Farré and Faci, 2009). However, water availability is usually the most important natural factor limiting expansion and development of agriculture in Marmara region of Turkey. Competition for water from other sectors such as industry and domestic use will force irrigation to operate under water scarcity.

4.1.17.2. Grain yield

Grain yield t ha^{-1} significantly influenced with irrigation treatments in BARI hybrid maize-9 (Table 04). The highest grain yield t ha-^{1} 10.44 observed in two and three irrigations. The lowest grain yield t ha-^{1} 6.68 counted at rainfall irrigation which was statistically differs from any others treatments. Grain yield curves respective in irrigation treatment resulted in a usual curve different irrigation treatments of replication in yield level i.e. grain yield values increased with increasing of irrigation levels. Afterwards inspect of increasing irrigation levels same yield shown (Fig.8). It was conformed that increasing of irrigation treatment increased yield in an optimum level. Lamm *et al.* (2005) stated that it is difficult to plan deficit irrigation for maize without causing yield reduction. Payero *et al.* (2006) reported that trying to increase crop water productivity by imposing deficit irrigation for maize might not be a beneficial strategy in a semiarid climate. Karam *et al.* (2013) found that grain and dry matter yield, and leaf area index was reduced by severity of water stress.

Table-4 : Effect of irrigation on the yield and yield performance of BARI hybrid maize-9

Treatments	Cob length (cm)	Cob grain free (cm)	Cob girth (cm)	Grain line cob^{-1} (no)	Grain number line^{-1} (no)	total grain cob-^{1} (no)	Grain weight cob-^{1} (g)	1000 Grain weight cob^{-1} (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
No irrigation (I_0)	19.67	1.67	14.33	12.33	41.67	520.67	263.11	125.00	6.68	49.39	56.05	0.12
One irrigation (I_1)	19.67	1.67	14.67	14.33	41.67	597.00	253.92	151.33	8.87	58.90	67.77	0.13
Two irrigation (I_2)	20.00	1.67	15.33	13.33	41.33	551.67	282.86	173.00	10.14	64.98	75.13	0.13
Three irrigation (I_3)	20.33	1.33	16.00	14.00	45.67	639.33	283.96	178.00	10.44	70.54	80.99	0.13
Sd	0.32	0.50	0.74	0.88	2.06	51.96	14.86	24.17	1.71	9.06	10.75	0.01
Cv(%)	1.60	46.15	4.90	6.53	4.84	9.00	5.49	15.41	18.92	14.86	15.36	5.02
Level of significance	NS	NS	*	NS	**	**	**	*	**	**	**	NS

In a column figures having common letters(s) do not differ significant as per DMRT

**Indicates 1 % and * indicates 5% level of probability

NS indicates not significant

4.1.18.1. Straw yield

Straw yield showed positive effect by irrigation treatments in BARI hybrid maize-9 (Table 04). The most straw yield t ha^{-1} 7.54 observed in three irrigation levels it was statistically similar result shown in two irrigation levels. The lowest straw yield t ha^{-1} 49.39 found at natural (no) irrigation. Straw yield t ha^{-1} graphs respective in usual graph different irrigation treatments of replication in yield level i.e. straw yield values increased gradually with increasing of irrigation treatments (Fig.9). It was conformed sufficient of irrigation more vegetative production. Yazar *et al.* (2012) reported also that the highest average maize straw yield obtained from full irrigation treatment using drip irrigation method. However, Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase grain yields at the important level.

4.1.18.2. Straw yield

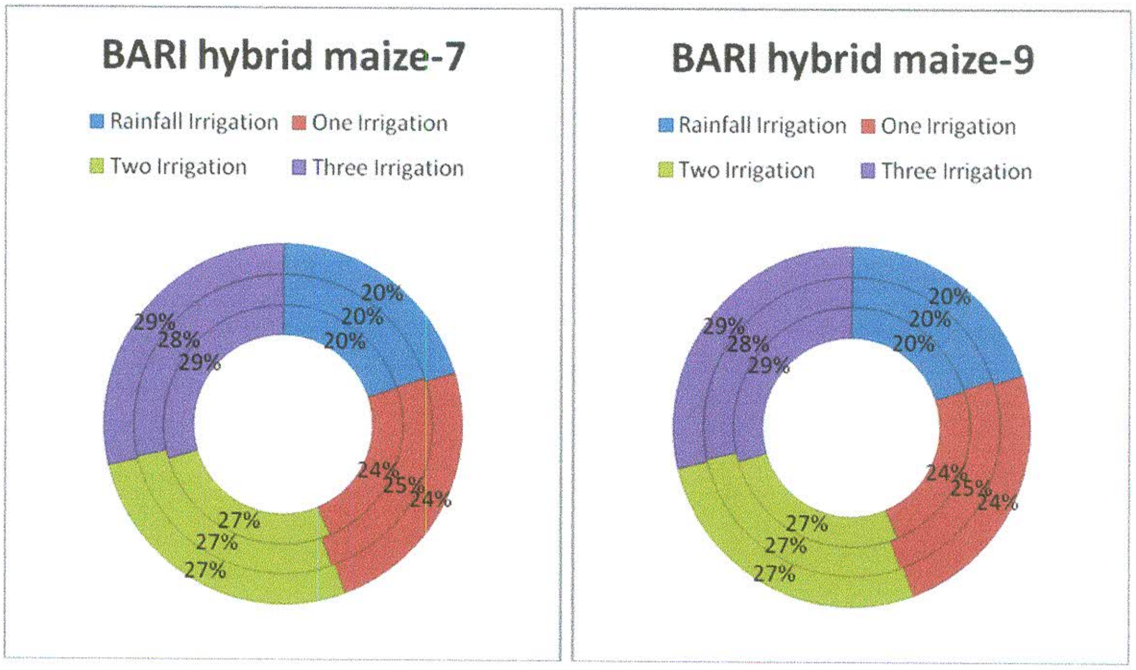
Straw yield t ha^{-1} positively affected among the treatments straw yield t ha^{-1} in BARI maize-7 (Table 03).The most vegetative yield t ha^{-1} 66.49 produced with three irrigations which was statistically similar with two irrigations levels. The lowest vegetative yield t ha^{-1} 48.64 counted with no irrigation and statistically differs from any others treatments. The straw yield t ha^{-1} curves respective of irrigation treatment resulted in a usual graph different irrigation treatments of replication in yield level i.e. straw yield values increased with the increasing of irrigation levels (Fig. 9). Its resulted might probably due to irrigation levels increased the straw production. Yazar *et al.* (2012) reported also that the highest average maize straw yield obtained from full irrigation treatment using drip irrigation method. However, Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase straw and grain yields at the important level.

4.1.19.1. Biological yield

Biological yield t ha^{-1} of BARI hybrid maize-7 showed significant effect by irrigation treatments (Table 03).The maximum biological yield t ha^{-1} 76.81 produced obtained irrigations which was statistically similar with two irrigations levels. The lowest vegetative yield t ha^{-1} 55.00 counted with no irrigation and statistically differs from any others treatments. The biological yield t ha-^{1} graph respective of irrigation treatment resulted in a usual graph different irrigation treatments of replication in yield level i.e. straw yield values increased with the increasing of irrigation levels (Fig.10). Its resulted might probably due to irrigation levels increased the biological production. Hanson *et al*., (2007) observed some advantages of drip irrigation over other irrigation methods include improved water and nutrient management, improved saline water management, potential for improved yields and crop quality, reducing the incidence of diseases and weeds in dry row middles, greater control on applied water resulting in less water and nutrient loss through deep percolation, and reduced total water requirements.

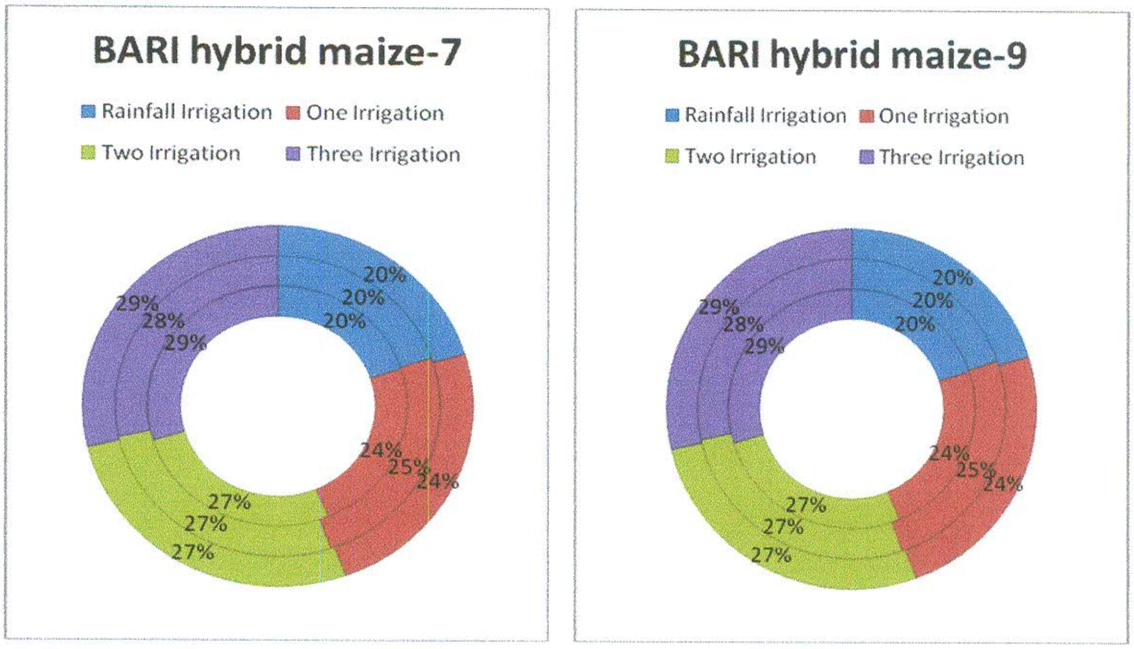
4.1.19. 2. Biological yield

Biological yield had significantly positive effect by the irrigation treatments in BARI hybrid maize-9 (Table 04). The highest biological yield t ha^{-1} 80.99 observed with tree irrigation which was statistically similar resulted in two irrigations. The lowest biological yield t ha-^{1} 56.05


BARI hybrid maize-7

BARI hybrid maize-9

Fig. 09. Effect of irrigation on straw yield ton per ha of experimental varieties


BARI hybrid maize-7

BARI hybrid maize-9

Fig. 10. Effect of irrigation on biological yield ton per ha of experimental varieties

found with no irrigation and statistically same resulted in one irrigation levels. Biological yield t ha^{-1} curves respective in irrigation treatments resulted in a usual graph different irrigation treatments of replication in yield level i.e. biological yield values gradually increased with the increasing of irrigation treatments (Fig.10). Biological yield resulted probably due to irrigation treatment increased more vegetative and reproductive yield increased in an optimum levels. Lamm *et al.* (2005) stated that it is difficult to plan deficit irrigation for maize without causing yield reduction. Payero *et al.* (2006) reported that trying to increase crop water productivity by imposing deficit irrigation for maize might not be a beneficial strategy in a semiarid climate. Karam *et al.* (2003) found that grain and dry matter yield, and leaf area index was reduced by severity of water stress.

4.1.20.1. Harvest index

Harvest index showed significant effect on irrigation levels in BARI hybrid maize-7(Table 03).The maximum harvest index 0.14 obtained with one and two irrigations and minimum harvest index 0.12 found with no irrigation and statistically differs from any others treatments. The harvest index of irrigation treatment resulted harvest index values increased with the increasing of irrigation levels and afterwards decline the values. The application of deficit irrigation requires thorough understanding of the yield response to water stress and of the economic impact of reductions in harvest (English, 1990). However, maize has been reported to be very sensitive to drought (Otegui *et al.* 2005).

4.1.20.2. Harvest index

Harvest index showed non-significant effect on irrigation treatments in BARI hybrid maize-9 (Table 04). In the observation all the treatments same harvest index (0.13) shown of the experimental phase. It might probably due to irrigation treatment result there were not variation in the parameter. Payero *et al*., (2008) the feasibility of increasing either the water uses efficacy or intensive water uses efficacy is a decision that needs to be based not only on the biophysical response of the crop but also on economic factors. Often the objective of producers is not to increase harvest index but to increase profits.

Chapter-FOUR

Results and Discussion

(Effect of nitrogen)

The effects of nitrogen were been presented in Table 05--08 and graphical presentation of different parameters were been presented in Figs 11-20. Data on different growth parameters such as plant height, plant girth, total tillers plant^{-1}, effective tillers plant^{-1}, non-effective tillers plant^{-1}, total roots plant^{-1}, straw weight plant^{-1}, straw yield t ha^{-1} and data on different yield parameters such as cob length, cob grain free length, cob girth, grain line cob^{-1}, grain number line^{-1}, total grains cob^{-1}, grain weight cob^{-1}, 1000 grain weight cob^{-1}, grain yield t ha^{-1}, straw yield t ha^{-1}, biological yield t ha^{-1} and harvest index (%). The analysis of variance in respect of all the selected parameters under the study together with sources of variation and corresponding degrees of freedom were been presented here.

4.2. Effect of nitrogen on growth and yield of BARI hybrid maize-7 and BARI hybrid maize-9

A. Growth parameters of experimental maize varieties with the performance of nitrogen

4.2.1.1 Plant height

Nitrogen treatments significantly influenced on plant height in BARI hybrid maize-7. The highest plant height 262.00 cm was obtained with 345 kg/ha^{-1}nitrogen which was far from any other treatments. The lowest plant height 235.67 cm was obtained with no nitrogen uses (Table 05). The plant height graph different nitrogen treatments of replication in growth level i.e. plant height values increased within the increasing of nitrogen levels (Fig.11). Jat *et al.* (2009) found that in sweet corn plant height was significantly increased with increase in level of fertilizer from 50 per cent (60:30:30 kg NPK ha^{-1}) to 100 percent RDF (120:60:60 kg NPK ha^{-1}). They also reported that application of 100 per cent RDF significantly produced more dry matter (137.95 g plant^{-1}) than 75 and 50 per cent RDF.

4.2.1.2 Plant height

Nitrogen levels showed significant positive effect on plant height in BARI hybrid maize-9 (Table 06). The highest plant height 271.67 cm obtained 345 kg/ha^{-1}nitrogen levels which were differs from the others treatments and the lowest plant height 247.50 cm was 115 kg/ha nitrogen levels. Nitrogen plays a vital role in vegetative growth of plant causing increased plant height. Plant height curves nitrogen treatment resulted in an usual curve different nitrogen treatments of replication in growth level i.e. plant height values increased gradually with the increasing of nitrogen levels (Fig11). A field experiment conducted during rainy season at Almora, envisaged that among three levels of N tried 120 kg N ha^{-1} resulted in maximum plant height of baby corn. Sunder Singh (2011) revealed that in baby corn during summer season there was a significant increase in plant height with every increment dose of N up to 150 kg ha^{-1} where as during kharif season the significant difference in plant height was observed only up to 120 kg ha^{-1}.

Table-5: Effect of nitrogen on the growth and growth performance of BARI hybrid maize-7

Treatments	Plant height (cm)	Plant girth (cm)	Total tiller plant^{-1} (no.)	Effective tiller plant^{-1} (no.)	Non-effective tiller plant^{-1} (no.)	Total roots plant^{-1} (no.)	Straw weight plant^{-1} (g)	Straw yield (t ha^{-1})
No nitrogen (N_0)	235.67	8.17	12.00	8.33	3.67	41.33	849.33	42.00
115 kg/ha nitrogen (N_1)	255.33	7.67	12.67	11.33	1.33	40.00	1009.67	63.49
230 kg/ha nitrogen (N_2)	249.00	8.00	12.67	11.67	1.00	41.33	1265.67	72.06
345 kg/ha nitrogen (N_3)	262	12	12	11	8	45	1302	77.60
Sd	11.22	2.04	0.38	4.95	3.23	2.15	215.30	15.64
Cv (%)	4.48	22.75	3.12	61.29	92.17	5.13	19.46	24.52
Level of significance	**	**	NS	*	**	*	**	**

In a column figures having common letters(s) do not differ significant as per DMRT

**Indicates 1 % and * indicates 5% level of probability

NS indicates not significant

4.2.2.1 Plant girth

Nitrogen levels showed significant positive effect on plant girth in BARI hybrid maize-7. The highest plant girth 10.00 cm was with 345 kg/ha nitrogen levels which was statistically similar with no nitrogen used and 230 kg/ha. The smallest plant girth 7.67 was with 115 kg/ha nitrogen which statistically differs from 345 kg/ha nitrogen levels (Table 05). The plant girth values increased with the increasing of nitrogen levels. Afterwards the curves started decline. Ashok Kumar *et al.* (2008) observed that in maize, growth parameters were found to be the highest plant girth with the application of 120 kg nitrogen through urea and 30 kg nitrogen through poultry manure per hectare.

4.2.2.2 Plant girth

Plant girth had significant effect with nitrogen levels in BARI hybrid maize-9 (Table 06). The largest plant girth 8.50 cm obtained 345 kg/ha^{-1}nitrogen levels which was differs from any others treatments and the lowest plant girth found within 115 kg/ha nitrogen levels which was similar with plant girth resulted might probably be due to availability of water supply produced largest of plant girth. Plant girth of different nitrogen treatments with replication in growth level values increased gradually with increasing irrigation levels. Suryavanshi *et al*. (2008) reported that application of 150 kg nitrogen ha^{-1} was found significantly effective over 50 and 100 kg nitrogen ha^{-1} in increasing plant girth of maize from 149.20 cm to 185.61 cm in black soil during kharif season at Parbhani.

Table-6: Effect of nitrogen on the growth and growth performance of BARI hybrid maize-9

Treatments	Plant height (cm)	Plant girth (cm)	Total tiller plant^{-1} (no.)	Effective tiller plant^{-1} (no.)	Non-effective tiller plant^{-1} (no.)	Total roots plant^{-1} (no.)	Straw weight plant^{-1} (g)	Straw yield (t ha^{-1})
No nitrogen (N_0)	247.5	7.75	13	11.5	1.5	41	848	42.16
115 kg/ha nitrogen (N_1)	244.33	7.33	12.33	11.33	1.00	40.67	1049.67	64.59
230 kg/ha nitrogen (N_2)	259.33	7.83	13.00	11.33	1.67	46.00	1396.00	73.91
345 kg/ha nitrogen (N_3)	271.67	8.50	14.00	12.67	1.33	48.00	1430.00	77.64
Sd	12.44	0.48	0.69	0.64	0.28	3.66	280.69	15.92
Cv(%)	4.87	6.15	5.25	5.50	20.70	8.32	23.77	24.65
Level of significance	**	*	NS	*	*	**	**	**

In a column figures having common letters(s) do not differ significant as per DMRT

**Indicates 1 % and * indicates 5% level of probability

NS indicates not significant

4.2.3.1 Total tillers plant^{-1}

Total tillers plant^{-1} showed insignificant effects among the treatments of nitrogen in BARI hybrid maize-7 (Table 5). The highest total tiller plant-^{1} 12.67 was produced with115 kg/ha and 230 kg/ha which was not statistically differs from others nitrogen levels. The lowest total tillers 12.00 produced with no nitrogen used and 345 kg/ha nitrogen levels which also not statistically differ from others nitrogen levels. The tillers plant^{-1} was increased with the increasing of nitrogen levels and afterward decline in the total tillers plant^{-1} production (Fig.12). Thakur *et al.* (2007) studied the response of baby corn to different levels of nitrogen and found that growth parameters viz., plant height, leaf area and dry matter accumulation were increased with increasing levels of nitrogen application up to 150 kg N ha^{-1}. Nitrogen fertilization had noticeable influence on crop growth and yield of baby corn. Significant increase in plant height was observed up to 120 kg N ha^{-1} (Sahoo and Panda, 2009). Thakur and Sharma (2009) reported that plant height of baby corn was found significantly increased up to 200 kg N ha^{-1}.

4.2.3.2 Total tillers plant^{-1}

Total tillers plant^{-1} had non-significant positive effects among the treatment in BARI hybrid maize-9 (Table 06). The highest total tillers plant^{-1} 14.00 were produced with 345 kg/ha nitrogen levels and the lowest total tillers plant^{-1} 12.17 with 115 kg/ha nitrogen which both treatments were not statistically differs from any others treatments. Shanti *et al.* (2007) reported advancement of silking by 7.9 and 8.4 days, respectively due to 120 and 160 kg N/ha in comparison with the

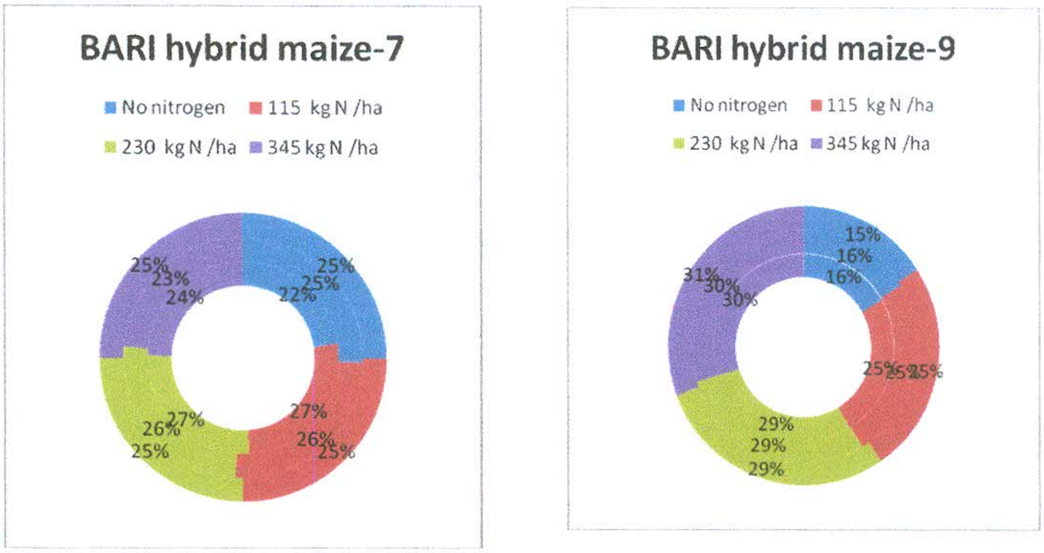


Fig. 11. Effect of nitrogen on plant height of experimental maize varieties

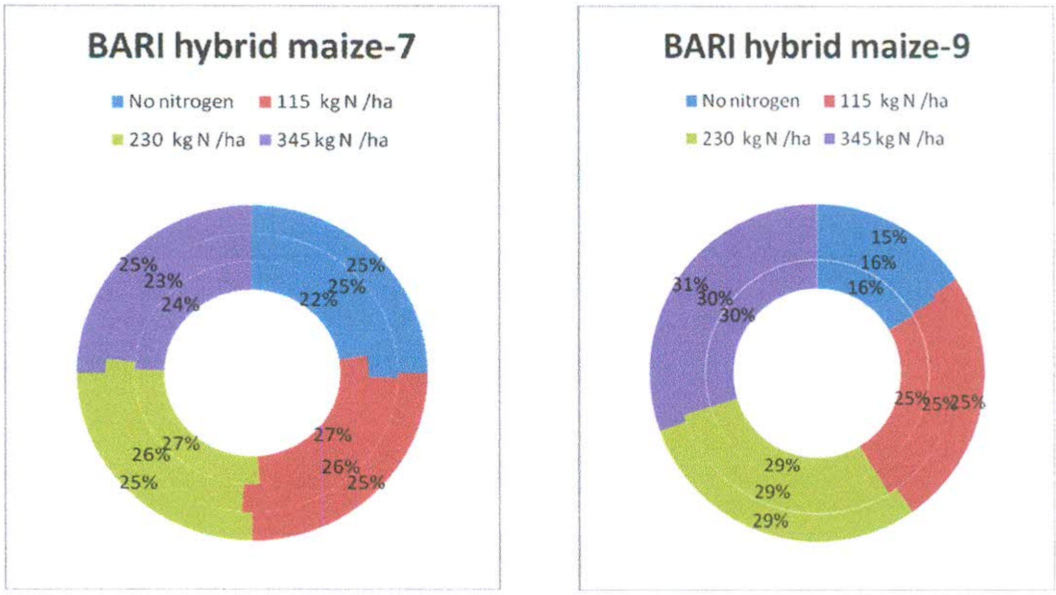


Fig.12. Effect of nitrogen on total tiller per plant of experimental maize varieties

crop in no nitrogen treatment (control) (Fig.12). Earlier appearance of silks (60.6 to 56.2 days) was also observed with increase in nitrogen level from 80 to 160 kg ha^{-1} by Muniswamy *et al*. (2007).

4.2.4.1 Effective tillers $plant^{-1}$

Effective tillers $plant^{-1}$ t ha^{-1} showed not significant with nitrogen treatments in BARI hybrid maize-7 (Table 05). The highest effective tillers $plant^{-1}$ t ha^{-1} 11.00 produced with 345 kg/ha and the lowest effective tillers $plant^{-1}$ t ha^{-1} 8.33 were produced with the no nitrogen treatment which both treatments were statistically not differs with others nitrogen levels. The result might be probably availability soil nitrogen not significantly effective tillers $plant^{-1}$ produced. Bindhani *et al*. (2007) stated that in baby corn, application of 120 kg N ha^{-1} resulted in tallest plant with maximum dry matter yield and leaf area index, which were significantly higher than those at remaining lower

4.2.4. 2 Effective tillers $plant^{-1}$

Effective tillers had not significant positive effect among the nitrogen treatments in BARI hybrid maize-9 (Table 06). The maximum effective tillers $plant^{-1}$12.67 found in 345 kg/ha nitrogen levels and the minimum effective tillers $plant^{-1}$ 11.33 obtained 115 kg/ha nitrogen levels which both treatments were not statistically differs from any others treatments. Effective tillers $plant^{-1}$ might probably due to increased nitrogen level not significantly advanced more effective tillers $plant^{-1}$production. Shanti *et al.* (2007) envisaged that in maize, among five levels of nitrogen tried, 160 kg N ha^{-1} resulted in maximum leaf area index and dry matter accumulation per plant.

4.2.5.1 Non-effective tillers plant^{-1}

Non-effective tillers plant^{-1} showed not significant effect among the treatments in BARI hybrid maize-7. The effect of nitrogen on the non-effective tillers was opposite condition of the effective tillers (Table 05). The highest non-effective tillers plant^{-1} 3.67 was produced with no nitrogen level and the lowest non-effective tillers 1.00 produced with 345 kg/ha^{-1}nitrogen levels which also not statistically differ from others nitrogen levels. Nath *et al*. (2009) observed that in sweet corn the dry matter accumulation increased significantly by enhancing the fertility level up to 90 kg N + 45 kg P2O5 /ha.

4.2.5.2 Non-effective tillers plant^{-1}

Non-effective tillers had not significant effect among the nitrogen treatment in BARI hybrid maize-9 (Table 06). The non-effective tillers plant^{-1} was opposite condition of effective tillers plant^{-1}. It was conformed non-effective values increased with nitrogen level decreased non-significantly. Mhamoud and Sharnappa (2012) recorded maximum none effective leaf of maize crop with 150 kg N ha^{-1}. The result of the experiment conducted by Muniswamy *et al.* (2007) at Bangalore during kharif season indicated that plant height of maize increased (151.3 to 175.2 cm) significantly with each increment of nitrogen from 80 to 160 kg ha^{-1}.

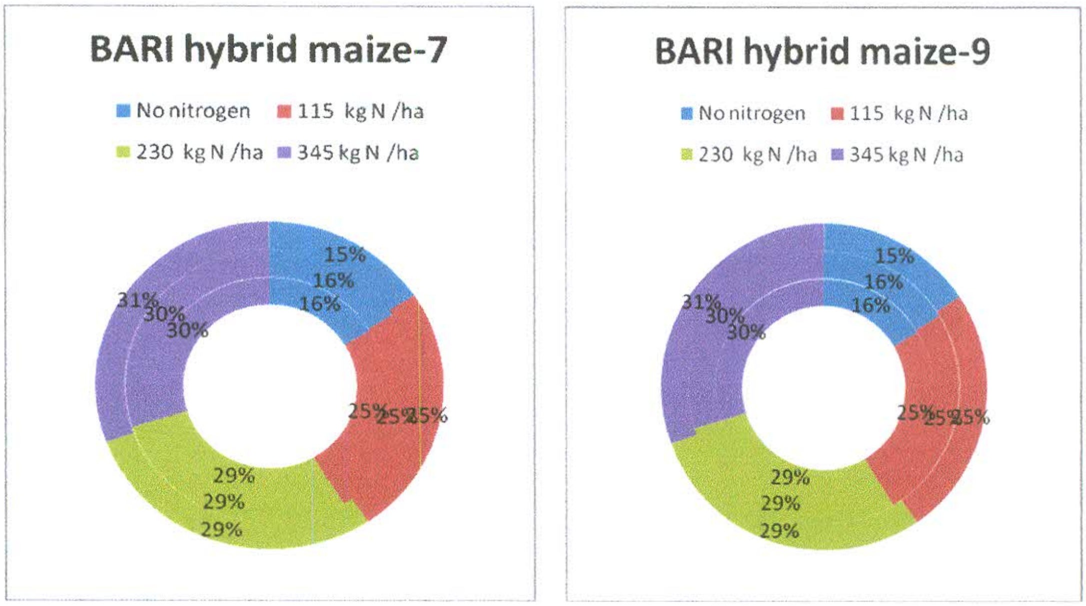


Fig.13. Effect of nitrogen on total roots per plant of experimental maize varieties

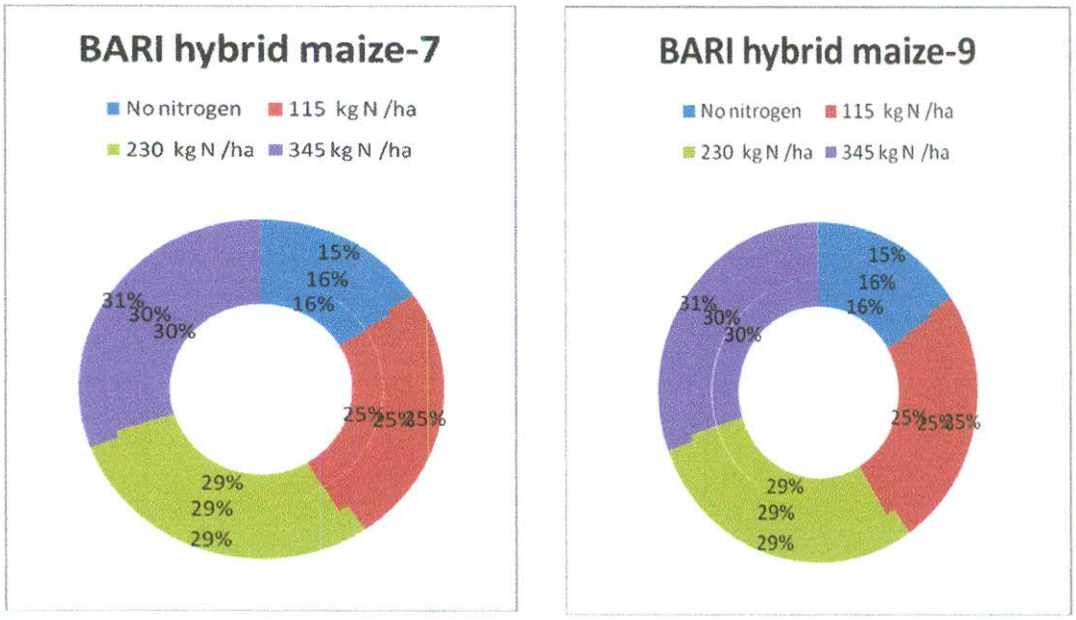


Fig. 14. Effect of nitrogen on straw yield ton per ha of experimental maize varieties

4.2.6.1 Total roots plant^{-1}

Nitrogen levels showed not significant effect among the treatments in BARI hybrid maize-7(Table 05). The highest number 42.00 roots produced with 345 kg/ha nitrogen levels and the lowest number 41.33 roots produced with no nitrogen level. This result might probably be due to availability of nitrogen more roots production non-significantly (Fig.13). Fast development of corn plants roots during middle vegetative stage (growth stage V6 and later) results in maximum N uptake, meaning that even N-deficient corn should be able to respond to delayed N application (Binder *et al*., 2010).

4.2.6.2 Total roots plant^{-1}

Nitrogen levels showed positive effect in the total tillers plant^{-1} in BARI hybrid maize-9 (Table 06). The highest numbers roots 48.00 produced with 345 kg/ha nitrogen levels and the lowest number 41.00 roots produced with the no nitrogen use. This result might probably be due to availability of nitrogen supply more roots production. In the graphical presentation of different nitrogen treatments with in growth level i.e. total roots plant^{-1} increased nitrogen level advanced roots production (Fig.13). The resulted might probably due availability nitrogen supply more roots production. Bruns and Abbas (2005) stated that application of full amounts of N fertilizer prior to planting may result in better roots development than carrying out split N applications. They concluded that the economic loss due to decreased grain yield may be insignificant when compared to additional production costs associated with split fertilization, such as several trips to the field.

4.2.7.1 Straw weight plant^{-1}

Nitrogen effect was significantly influenced on the straw weight plant^{-1} in BARI hybrid maize-7 (Table 05). The highest straw weight plant^{-1} 1302.00 g was with 345 kg/ha nitrogen levels and the lowest straw weight plant^{-1} 849.33 g with no nitrogen use. Increased of nitrogen levels increased gradually the straw weight plant^{-1} respective of nitrogen treatments resulted in different nitrogen treatments of straw weight plant values increased with the advancement of nitrogen levels. This result might probably be due to availability of nitrogen supply more vegetative production. Ashok Kumar (2009) found that each successive increment in nitrogen level from 0 to 120 kg/ha markedly improved plant height as well as dry weight plant^{-1} in pop corn at New Delhi.

4.2.7.2 Straw weight plant^{-1}

Straw weight plant^{-1} was significantly influenced by nitrogen treatments in BARI hybrid maize-9 (Table 06). The highest straw weight plant^{-1} 1430.00 g counted with 345 kg/ha nitrogen levels which were statistically similar with 230 kg/ha nitrogen levels. The lowest straw weight plant^{-1} 848.00 g found in no nitrogen use which was also statistically differs from all the treatments. Straw weight plant^{-1} graphs of different nitrogen treatments within growth level resulted shown more nitrogen supply more straw production. According to Wells and Blitzer (2014) and Wells *et al*. (2012), the most efficient time for N application is at growth stage V6, when corn plants active development significantly increases N plant needs. Nitrogen uptake rate is known to be affected by many factors such as weather, planting date, and time of fertilizer application but is usually highest between V8 and V12 (Russelle *et al*. 2011).

4.2.8.1 Straw yield

There were significant effects among the nitrogen level in BARI hybrid maize-7 (Table 05). The maximum straw yield t ha^{-1} 77.60 was with 345 kg/ha and the lowest straw yield t ha^{-1} 485.68 with the no nitrogen use. The straw yield respective of different nitrogen treatments in growth level yield values increased of nitrogen levels increased the straw yield. The result might probably be due to arability of nitrogen increased more vegetative production (Fig. 14). Suryavanshi *et al.* (2008) reported significantly higher gross returns, net monetary returns and benefit: cost ratio with 150 kg nitrogen ha^{-1} as compared to either 50 and 100 kg nitrogen ha^{-1}.

4.2.8.2 Straw yield

Straw yield t ha^{-1} was significantly positive effect among the nitrogen treatments in BARI hybrid maize-9 (Table 06). The maximum straw yield t ha-^{1} 77.67 was counted at 345 kg/ha nitrogen levels which were statistically similar with 115kg/ha and 230 kg/ha nitrogen levels The minimum straw yield t ha-^{1} 42.16 found no nitrogen use which was statistically differs from all the treatments. The graphs of different nitrogen treatments within growth level i.e. straw yield values increased with the increasing of nitrogen levels (Fig. 14). It might probably due to increasing nitrogen levels increased vegetative growth an optimum level and afterwards decreased production. There was marked improvement in net returns with each successive increase in nitrogen level from 0 to 120 kg ha^{-1}. The maximum net returns of Rs. 49.57 thousands ha^{-1} were noticed with 120 kg N ha^{-1}, which was 560.9, 64.5 and 10.0% higher over 0, 40 and 80 kg N ha^{-1}. The net returns rupee^{-1} invested was also enhanced with higher nitrogen levels, but significant improvement was found up to 80 kg N ha^{-1} (Ashok Kumar, 2009).

B. Yield parameters of experimental maize varieties with performance of nitrogen

4.2.9.1 Cob length

Cob length had significant effect among nitrogen the treatments in BARI hybrid maize-7 (Table 07). The highest cob length 27.00 cm was found with 230 kg/ha^{-1} nitrogen levels and statistically similar result shown 115 kg/ha and 345 kg/ha. The lowest cob length found obtained no nitrogen levels which was statistically differs from any others treatments. The cob length curves irrespective nitrogen treatment resulted in a usual curve of different nitrogen treatments with replication in yield level i.e. cob length values increased with increasing nitrogen levels. Afterwards advancement of nitrogen levels stared to decline cob length (Fig.15). The cob length probably due to nitrogen level increased advancement an optimum levels. Thakur and Sharma (2009) registered higher number of baby corn cobs per plant and length of baby corn with 200 kg N ha^{-1} as compared to 100 kg N ha^{-1}. Contrary to this, significant differences were not observed in the weight of cob when nitrogen was applied at 100, 150 and 200 kg ha^{-1} to baby corn. (Thakur and Sharma, 2009).

4.2.9.2 Cob length

Cob length showed positive effect influenced on nitrogen levels in BARI hybrid maize-9 (Table 08). The maximum cob length 27.20 cm counted obtained 345 kg/ha and statistically similar effect shown 115 kg/ha and 230 kg/ha^{-1}nitrogen levels. The minimum 24.00 cm counted with no nitrogen levels which was statistically differs from any others treatments. The cob length graphs irrespective of nitrogen treatment resulted in a usual graph of different nitrogen treatments with replication in yield level i.e. straw yield values increased with the increasing of nitrogen levels (Fig.15). Afterwards the curves started to decline with increasing of nitrogen levels. Its resulted might probably due to nitrogen levels increased the cob length in an optimum nitrogen levels. Pandey *et al.* (2010) reported that the number of baby corn cobs per plant and cob weight were highest with 120 kg N ha^{-1} than at 60 and 90 kg Nha^{-1} but did not observe any significant difference in the length of baby corn with increased of nitrogen from 60 to 120 kg N/ ha.

4.2.10.1 Cob grain free

Cob grain free length showed insignificant effect influenced among the nitrogen treatments in BARI hybrid maize-7 (Table 07). The grain free length 1.67 cm found with no nitrogen use and 230kg/ha nitrogen levels. The lowest 1.33 cm obtained 115kg/ha and 345 kg/ha nitrogen levels. Cob grain free length might probably due to sufficient nitrogen supply non-significantly affected. Singh *et al.* (2010) found significant increase in nitrogen uptake with successive increment of nitrogen up to 100 kg ha^{-1}, beyond which the increase was only marginal up to 200 kg ha^{-1}.

4.2.10.2 Cob grain free

Cob grain free length showed significant effect among the nitrogen treatment in BARI hybrid maize-9 (Table 08). The highest cob grain free length 2.33 cm with no nitrogen level and it was statistically differ from any others treatment. The lowest cob grain free 0.67 cm with in 115 kg/ha nitrogen levels and 345 kg/ha nitrogen levels. The cob grain free values decreased with the increasing of nitrogen levels. Afterwards the started increased with increasing of nitrogen levels. The cob grain free length resulted might probably due to nitrogen levels increased shortest cob grain free in an optimum levels. Kar *et al*. (2006) revealed that uptake of N in grain and stover increased significantly with successive increase in nitrogen. It ranged between 20.41 kg in control to 91.11 kg ha^{-1} at 80 kg N application.

4.2.11.1 Cob girth

Cob girth was significant effect influenced among the nitrogen treatments in BARI hybrid maize-7 (Table 07). The largest cob girth 15.33 cm found with 230 kg/ha and 345 kg/ha which counted statistically similar in the 115 kg/ha^{-1} nitrogen level. The smallest cob girth 13.33 cm found obtained no nitrogen which was statistically differs with all nitrogen level. The cob girth values increased with increasing nitrogen levels. Cob girth might probably due to sufficient nitrogen supply increased yield production. Singh *et al*. (2010) reported that significant increase in baby corn weight, cobs per plant, baby corn girth was observed with the application of 180 + 38.7 + 74.7 kg N+P+K ha^{-1} compared to 60 + 12.9 + 24.9 kg N + P + K ha^{-1}.

4.2.11.2 Cob girth

Cob girth showed significant influenced by nitrogen levels in BARI hybrid maize-9 (Table 08). The largest cob girth 15.67.00 cm found obtained 345 kg/ha^{-1} nitrogen levels which was statistically similar with 115 kg/ha and 230 kg/ha nitrogen levels. The smallest cob girth found with no nitrogen levels which was statistically differs resulted with others nitrogen levels. The cob girth values gradually increased with increasing of nitrogen levels treatment. It might probably more nitrogen supply more girth produced. Raja (2011) reported that increase in nitrogen levels from 0 to 120 kg N/ha significantly increased the cob length as well as cob girth of sweet corn.

4.2.12.1 Grain line cob^{-1}

Grain line cob^{-1} showed significant effect influenced among the nitrogen treatments in BARI hybrid maize-7 (Table 07). The maximum grain line cob^{-1} 14.00 counted with the 345 kg/ha and it was statistically similar 230 kg/ha nitrogen levels. The lowest grain line cob^{-1} 12.33 obtained no nitrogen use. The grain line cob^{-1} might probably due to non-sufficiently increased. The grain line cob^{-1} values increased with different nitrogen levels. Kang *et al.* (2005) noticed that 100 kg N ha^{-1} was optimum for maximum cob yield of sweet corn and the increase in green cob yield beyond 120 kg N ha^{-1} was not appreciable.

4.2.12.2 Grain line cob^{-1}

Grain line cob was significant effect among the nitrogen treatments in BARI hybrid maize-9 (Table 08). The maximum grain line cob^{-1} 14.33 found at 345 kg/ha nitrogen levels and it was statistically differs from any others treatments. The lowest 13.00 counted no nitrogen levels but it also statistically differs from any treatment. The grain line values gradually increased with increasing of nitrogen levels treatment. It might probably more nitrogen supply more girth produced. Singh (2006) reported that application of 90 + 45 kg N and P_2O_5 ha^{-1} in pop corn significantly improved grain yield over 60 + 30 kg N and P_2O_5 ha^{-1}. Further increase in fertilizer dose failed to get a significant improvement.

4.2.13.1 Grain number line^{-1}

Grain number line^{-1} had highly significant effect among nitrogen treatments in BARI hybrid maize-7 (Table 07). The maximum grain line^{-1} 50.00 counted at 230 kg/ha which was statistically similar result shown in 345 kg/ha nitrogen levels. The lowest grain number line^{-1} obtained no nitrogen use. The grain number line^{-1} values respective increasing nitrogen levels significantly increased the production. Najundappa *et al.* (2014) found that increased nitrogen uptake by grain was increased up to 150 kg nitrogen ha^{-1}, which was found at with 225 kg nitrogen ha^{-1}. Application of 175 kg N ha^{-1} significantly increased the N-uptake as compared to lower levels (Selvaraju and Iruthayaraj, 2014).

4.2.13.2 Grain number line^{-1}

Grain number line^{-1} had positive effect among the nitrogen treatments in BARI hybrid maize-9 (Table 08). The maximum grain number line^{-1} 56.00 observed with 345 kg/ha nitrogen levels which were similar with 230 kg/ha^{-1} nitrogen levels. The minimum grain number line^{-1} 45.00 counted at no nitrogen level which was statistically similar with 115 kg/ha^{-1} nitrogen levels .The grain number line^{-1} values increasing of nitrogen levels increased grain number line^{-1} and afterward decline. It was conformed that increasing

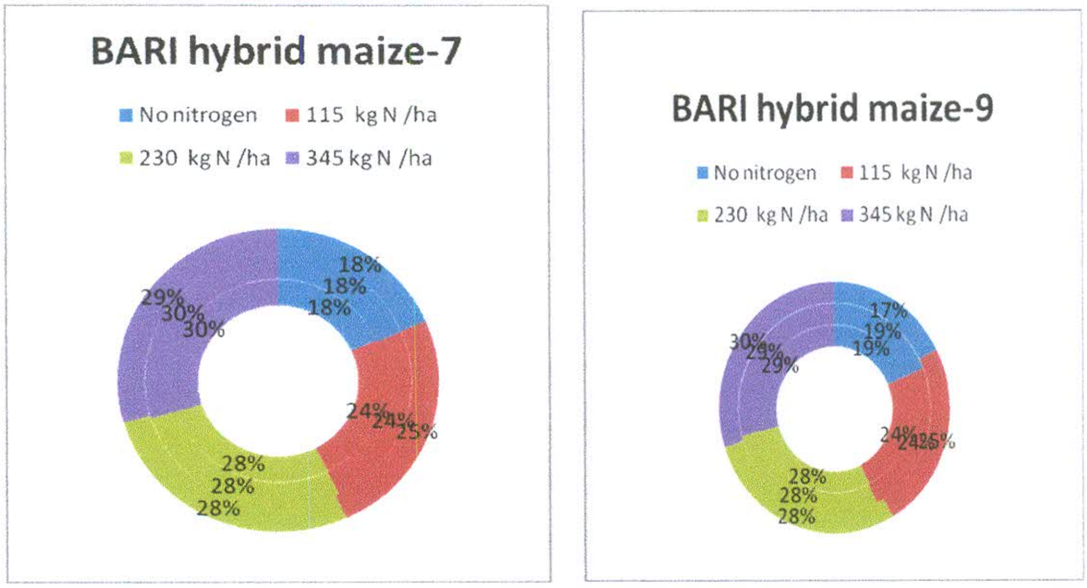


Fig. 15. Effect of nitrogen on cob length of experimental maize varieties

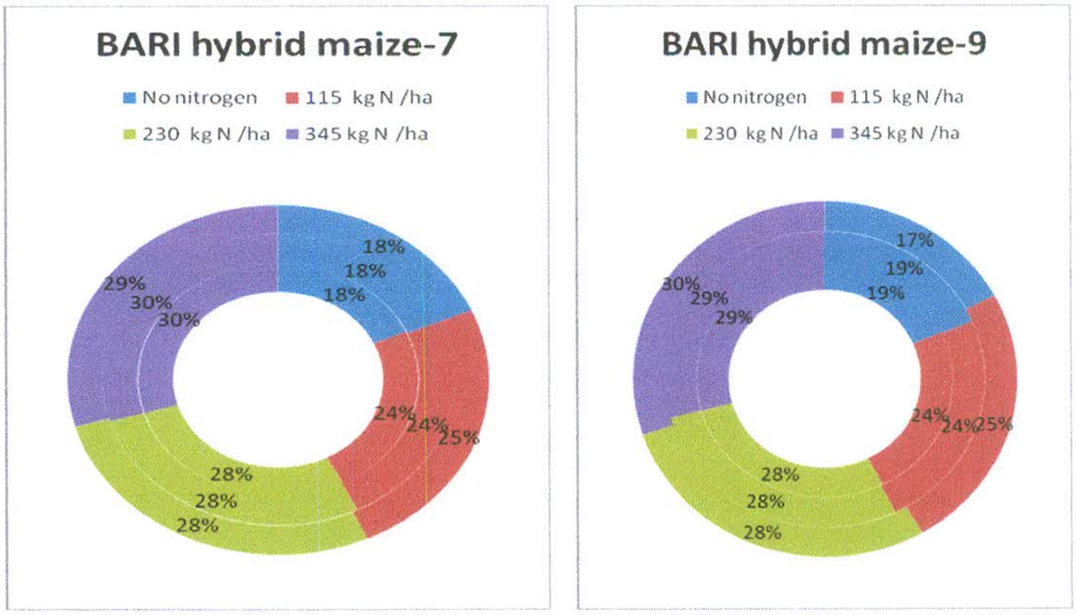


Fig. 16. Effect of nitrogen on total grain per cob of experimental maize varieties

nitrogen level increased yield in an optimum level. Application of 120 kg N ha-^{1} resulted in the maximum grain number per line of baby corn without husk compared to other levels of N tried viz., 0, 20, 40, 60, 80 and 100 kg N ha^{-1} (Sahoo and Panda, 2007).

4.2.14.1 Total grain cob^{-1}

Total grain cob^{-1} positively influenced by nitrogen levels in BARI hybrid maize-7 (Table 07). The maximum total grain cob^{-1} 744.00 produced with 230 kg/ha nitrogen and it was statistically similar with 345 kg/ha. The minimum total grain cob^{-1} 515.33 found with on nitrogen use which was statistically differs from any others treatments. Total grain cob^{-1} curves respective with nitrogen treatments resulted in a usual graphs of different nitrogen treatments with replication in yield level i.e. total grain cob^{-1} values increased with the increasing nitrogen levels and afterwards inspect of irrigation level decline production (Fig.16). Baby corn yield recorded with 120 kg N ha^{-1} was found to be significantly higher than that with 60 and 90 kg N ha^{-1} (Pandey *et al.,* 2010). Application of 120 kg N ha-1 in baby corn resulted in the highest baby corn yield, which was 28.6, 52.2 and 178.7% higher than that of 80, 40 kg N ha^{-1} and the no nitrogen respectively (Bindhani *et al.,* 2007).

4.2.14.2 Total grain cob^{-1}

Total grain cob^{-1} had significantly influenced by nitrogen levels in BARI hybrid maize-9 (Table 08). The highest total grain cob^{-1} 746.67 observed at 345 kg/ha nitrogen levels and it was statistically similar with 115 kg/ha^{-1} and 230 kg/ha nitrogen levels. The lowest total grain cob^{-1} 541.33 found at no nitrogen levels which was differs with all nitrogen levels. Total grain cob^{-1} graphs respective with nitrogen levels resulted in a usual graph of different nitrogen treatments with replication in yield level i.e. total grain cob^{-1} values first increased with increasing of nitrogen levels significantly and afterwards increasing nitrogen levels not yield increased significantly positive effect (Fig.16). Significant increases in baby cob and grain yield were observed with the application of 180 kg N ha^{-1} compared to 60 kg N ha^{-1}(Singh *et al*., 2010).

4.2.15.1 1000 grain weight

Nitrogen treatment had significantly influenced with 1000 grain weight in BARI maize-7 (Table 07). The highest 1000 grain weight 272.60 g produced with 345 kg/ha nitrogen which was statistically similar 230 kg/ha nitrogen. The lowest 1000 grain weight 244.78 g counted with no nitrogen and statistically similar with 115 kg/ha nitrogen levels. The 1000 grin weight graphs respective of nitrogen treatment resulted in a usual graph of different nitrogen treatments with replication in yield level i.e. 1000 grain weight values increased with the increasing of nitrogen levels (Fig.17). It might be probably due to nitrogen levels increased 1000 grain weight advanced. Thakur *et al*. (2007) noticed increased 1000 grain weight of baby corn cobs per plant with 200 kg N ha^{-1} compared to no nitrogen on alfisols of Bajura, Kullu valley, Himachal Pradesh.

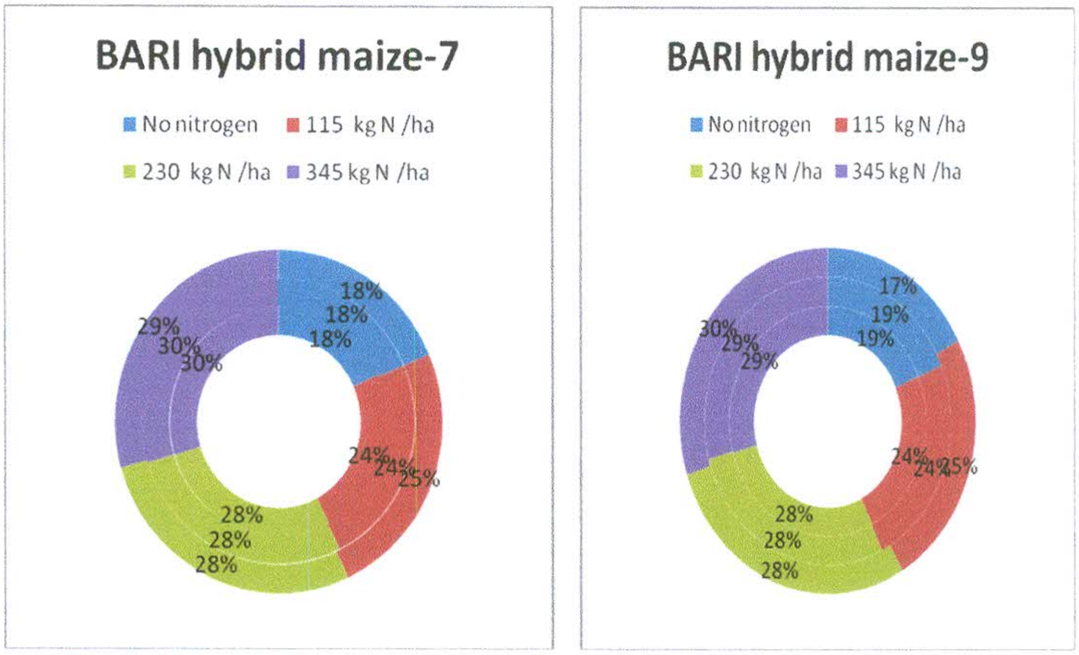


Fig.17. Effect of nitrogen on 1000 grain weight of experimental maize varieties

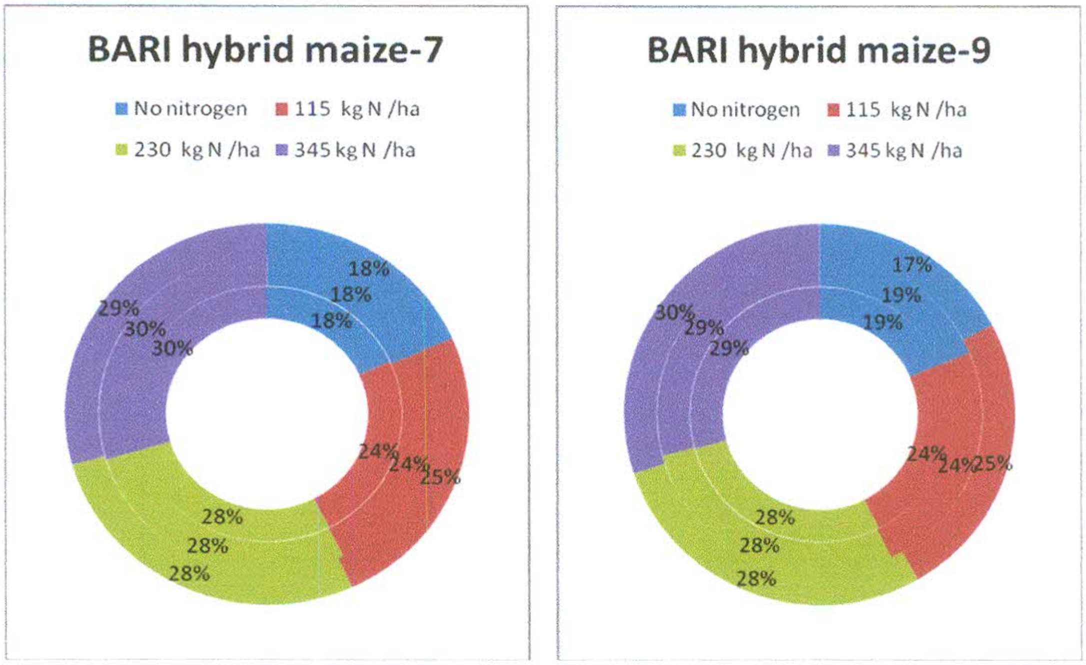


Fig. 18. Effect of nitrogen on grain yield ton per ha of experimental maize varieties

4.2.15.2 1000 grain weight

Nitrogen treatments had significant effect with 1000 grain weight in BARI hybrid maize-9 (Table 08). The highest 1000 grain weight 273.35 g observed with 345 kg/ha nitrogen levels and statistically differs with all treatments. The lowest 1000 grain weight 252.13 g found in no nitrogen levels and statistically dissimilar effect with all nitrogen levels. The1000 grain weight graphs respective with nitrogen levels resulted in a usual graph of different nitrogen treatments with replication in yield level i.e. 1000 grain weight values increased gradually with the increasing of nitrogen levels (Fig.17). It was conformed nitrogen level increased 1000 grain weight. Thakur *et al.* (2007) demonstrated that baby corn weight with and without husk was found increased significantly with successive increase in N levels up to 100 kg N ha^{-1}. Length of baby corn, weight of ear and number of ears per plant were found to be the highest with 120 kg N ha^{-1}(Sahoo and Panda, 2009).

4.2.16.1 Grain weight cob^{-1}

Grain weight cob^{-1} was significant affected by nitrogen treatment in BARI hybrid maize-7(Table 07). The maximum grain weight cob^{-1} 202.67 g with 345 kg/ha^{-1} nitrogen which were statistically similar with 345 kg/ha nitrogen and 230 kg/ha nitrogen. The minimum grain weight cob^{-1} 127.33 g counted with no nitrogen use. Grain weight cob^{-1} values increased with the increasing of nitrogen levels. It was conformed that nitrogen supply increased grain weight cob^{-1}. Mullins *et al.* (2009) observed that application of 112 kg N ha^{-1} was sufficient for sweet corn, where as Akthar and Silva (2009) obtained maximum weight of green cobs with 150 kg N ha^{-1} which was on par with 120 kg N ha^{-1}.

Table-7: Effect of nitrogen on the yield and yield performance of BARI hybrid maize-7

Treatments	Cob length (cm)	Cob grain free (cm)	Cob girth (cm)	Grain line cob^{-1} (no)	Grain number line^{-1} (no)	total grain cob-^{1} (no)	Grain weight cob-^{1} (g)	1000 Grain weight cob^{-1} (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
No nitrogen (N_0)	23.00	1.67	13.83	12.33	44.67	515.33	127.33	244.76	6.19	42.00	48.22	0.13
115 kg/ha nitrogen (N_1)	26.33	1.33	15.00	13.33	49.33	667.67	172.00	256.68	9.12	53.55	63.40	0.14
230 kg/ha nitrogen (N_2)	27.00	0.67	15.33	13.67	54.67	744.00	194.33	261.37	10.31	62.49	72.47	0.14
345 kg/ha nitrogen (N_3)	26.00	1.33	15.33	14.33	50.00	742.67	202.67	272.60	10.77	66.51	77.29	0.14
Sd	1.77	0.42	0.71	0.83	4.09	107.48	33.75	11.53	2.06	10.87	12.79	0.01
Cv(%)	6.93	33.55	4.79	6.21	8.24	16.10	19.39	4.45	22.63	19.37	19.57	4.08
Level of significance	**	**	**	*	**	**	**	*	**	**	**	NS

In a column figures having common letters(s) do not differ significant as per DMRT
**Indicates 1 % and * indicates 5% level of probability
NS indicates not significant

4.2.16.2 Grain weight cob^{-1}

Grain weight cob^{-1} was significantly affected by nitrogen levels in BARI hybrid maize-9 (Table 08). The maximum grain weight cob^{-1} observed 204.44 g with 345 kg/ha nitrogen levels and similar resulted in 230 kg/ha nitrogen levels. The minimum grain weight cob^{-1} found with no nitrogen levels which was statistically differs with any others nitrogen levels. Grain weight cob^{-1} values increased with increasing of nitrogen levels. It was variation in nitrogen level and no nitrogen use. Sahoo and Mahapatra (2014) observed that increase in levels of nitrogen, increased green cob yield from 8.88 t ha^{-1} (60 kg ha^{-1}) to 10.53 t ha^{-1} (180 kg ha^{-1}). Kar *et al.* (2006) noticed that green cob yield of sweet corn was significantly increased with increase in nitrogen from 0 to 80 kg ha^{-1}.

4.2.17.1 Grain yield

Nitrogen treatment showed positive effect with grain yield t ha^{-1} in BARI maize-7 (Table 07).The highest grain yield t ha^{-1} 10.37 produced with 345 kg/ha nitrogen and 230 kg/ha nitrogen levels which was statistically similar with 115kg/ha nitrogen levels. The lowest grain yield t ha^{-1} 6.19 counted with no nitrogen levels and statistically differs from any others treatments. The grain yield t ha^{-1} graphs respective of nitrogen treatment resulted in a usual graph of different nitrogen treatments with replication in yield level i.e. grain yield values increased with the increasing of nitrogen levels (Fig.18). Its resulted might probably due to nitrogen levels increased the grain production. Sahoo and Mahapatra (2014) concluded that in an experiment conducted in sweet corn at Jashipur, increase in levels of nitrogen from 60 to 120 kg ha^{-1} increased the number of cobs per hectare, length and weight of cob.

4.2.17.2 Grain yield

Grain yield t ha^{-1} had significantly influenced with nitrogen levels in BARI hybrid maize-9 (Table 08). The highest grain yield t ha^{-1} 10.87 observed in 345 kg/ha nitrogen levels and statistically same resulted 230 kg/ha nitrogen levels. The lowest grain yield t ha^{-1} 6.22 counted at no nitrogen levels which was statistically differs from any others treatments. Grain yield graphs respective in nitrogen levels resulted in a usual graph of different nitrogen treatments with replication in yield level i.e. grain yield values increased with increasing of nitrogen levels. Afterwards inspect of increasing nitrogen levels same yield shown (Fig.18). It was conformed that increasing of nitrogen levels increased yield in an optimum level. Shanti *et al.* (2007) observed that application of 160 kg N ha^{-1} recorded the highest number of cobs per plant in maize which was however, statistically on par with that of 120 kg N ha^{-1} and significantly superior to other N levels (0, 40 and 80 kg N ha^{-1}). Application of 160 kg N ha^{-1} in maize significantly increased the number of cobs per plant (1.62 to 2.12) as compared to 80 kg N ha^{-1} (Muniswamy *et al.,* 2007).

4.2.18.1 Straw yield

Straw yield t ha^{-1} showed positive positively among the nitrogen treatments in BARI maize-7 (Table 07). The most vegetative yield t ha^{-1} 66.51 produced with 345 kg/ha nitrogen levels which was statistically similar with 230 kg/ha nitrogen levels. The lowest vegetative yield t ha^{-1} 48.22 counted with no nitrogen levels and statistically differs from any others treatments. The straw yield t ha^{-1} graphs respective of nitrogen levels treatment resulted in a usual graph of different nitrogen treatments with replication in yield level i.e. straw yield values increased with the increasing of nitrogen levels (Fig.19). Its resulted might probably due to nitrogen levels increased the straw production. Sahoo and Mahapatra (2007) reported that a plant population of 83,300 per hectare & fertility level of 120 kg N/ha with P2O5 and K2O at 26.2 kg ha^{-1} and 50 kg ha^{-1} respectively should be adopted to obtain the maximum green cob yield and net profit from sweet corn. In a field experiment conducted during Kharif season at Pune, it was reported that application of 100 per cent RDF (120:60:60 kg NPK ha^{-1}) recorded maximum cob yield (Jat *et al.*, 2009).

4.2.18.2 Straw yield

Straw yield showed positive effect by nitrogen levels in BARI hybrid maize-9 (Table 08). The most straw yield t ha^{-1} 66.77 observed in345 kg/ha^{-1} nitrogen levels and it was statistically similar result shown in 230 kg/ha^{-1} nitrogen levels. The lowest straw yield t ha^{-1} 41.53 found at natural (no) nitrogen levels. Straw yield t ha^{-1} graphs respective in a usual graph of different nitrogen treatments with replication in yield level i.e. straw yield values increased gradually with increasing of nitrogen levels (Fig.19). It was conformed sufficient of nitrogen levels more vegetative production. Thakur and Sharma (2009) reported significant increase in green forage yield of baby corn with increase in nitrogen dose from 100 to 200 kg ha^{-1}.

Table-8 : Effect of nitrogen on the yield and yield performance of BARI hybrid maize-9

Treatments	Cob length (cm)	Cob grain free (cm)	Cob girth (cm)	Grain line cob^{-1} (no)	Grain number $line^{-1}$ (no)	total grain $cob-^{1}$ (no)	Grain weight $cob-^{1}$ (g)	1000 Grain weight cob^{-1} (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
No nitrogen (N_0)	24.00	2.33	13.83	13.00	45.00	541.33	131.67	252.13	6.22	41.53	47.75	0.13
115 kg/ha nitrogen (N_1)	27.00	1.33	15.00	13.67	49.33	674.33	171.33	259.04	9.14	54.95	63.59	0.14
230 kg/ha nitrogen (N_2)	26.33	0.67	15.33	13.67	56.00	741.67	195.67	263.22	10.38	63.62	74.00	0.14
345 kg/ha nitrogen (N_3)	27.33	1.33	15.67	14.33	53.00	746.67	204.00	273.35	10.87	66.77	77.66	0.14
Sd	1.50	0.69	0.80	0.54	4.75	95.64	32.44	8.88	2.09	11.29	13.40	0.01
Cv(%)	5.74	48.51	5.33	3.98	9.34	14.15	18.47	3.39	22.79	19.91	20.38	3.82
Level of significance	**	*	**	*	**	**	**	*	**	**	**	NS

In a column figures having common letters(s) do not differ significant as per DMRT

**Indicates 1 % and * indicates 5% level of probability

NS indicates not significant.

4.2.19.1 Biological yield

Biological yield t ha^{-1} of BARI hybrid maize-7 showed positive effect influenced by nitrogen treatments (Table 07).The maximum biological yield t ha^{-1} 77.29 produced obtained 345 kg/ha nitrogen levels which was statistically similar with 230 kg/ha levels. The lowest vegetative yield t ha^{-1} 48.22 counted with no nitrogen use and statistically differs from any others treatments. The biological yield t $ha-^{1}$ curves respective of nitrogen treatment resulted in a usual curve of different nitrogen treatments with replication in yield level i.e. biological yield values increased with the increasing of nitrogen levels (Fig.20). It resulted due to nitrogen levels increased the biological production. Ashok Kumar (2009) found that successive increase in levels of nitrogen from 0 to 120 kg ha^{-1} recorded markedly higher green cob yield amounting 119.6, 200.0 and 222.4 % with application of 40, 80 and 120 ha^{-1} respectively over control.

4.2.19.2 Biological yield

Biological yield showed positive effect by the nitrogen levels in BARI hybrid maize-9 (Table 08). The highest biological yield t ha^{-1} 77.66 observed with 345 kg/ha nitrogen level which was statistically similar resulted in 230 kg/ha nitrogen levels. The lowest biological yield t ha^{-1} 47.75 found with no nitrogen levels and statistically dissimilar resulted within all nitrogen levels. Biological yield t ha^{-1} graphs respective in nitrogen levels resulted in a usual graph of different nitrogen treatments with replication in yield level i.e. biological yield values gradually increased with the increasing of nitrogen levels (Fig.20). Biological yield resulted probably due to

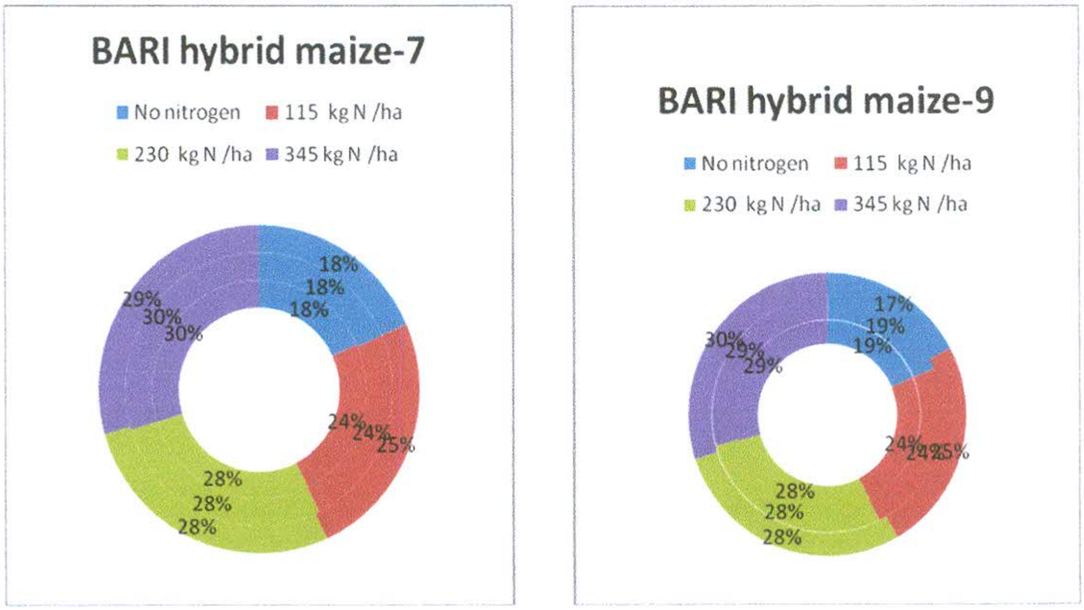


Fig. 19. Effect of nitrogen on straw yield ton per ha of experimental maize varieties

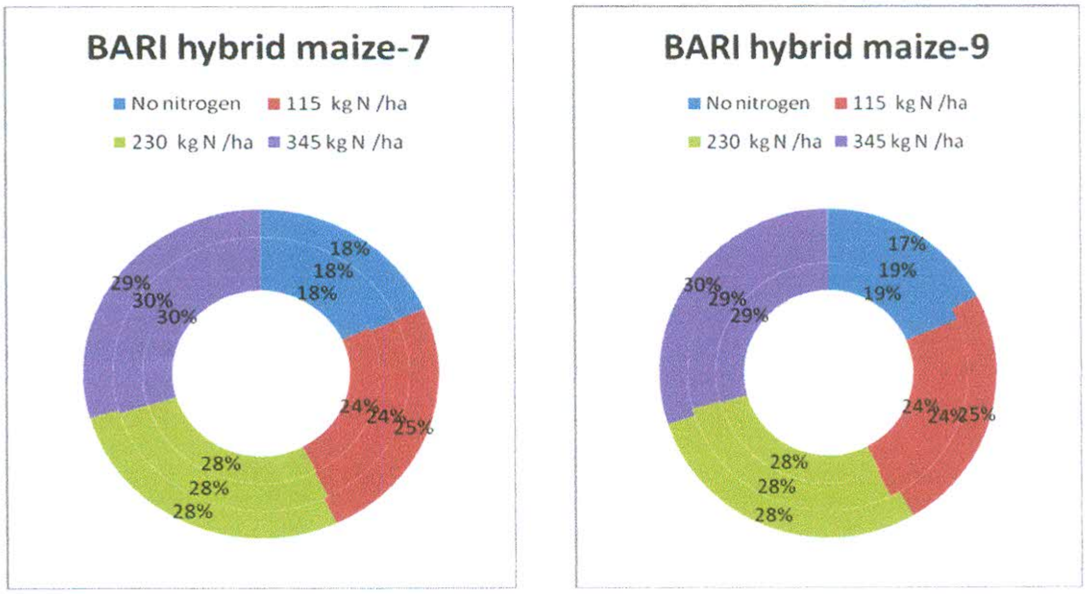


Figure. 20. Effect of nitrogen on biological yield ton per ha of experimental maize varieties

nitrogen levels increased more vegetative and reproductive yield increased in an optimum levels. Rao and Padmaja (2014) reported that yield of sweet corn, pop corn and hybrid maize increased significantly up to 150 kg N ha^{-1}. Kumar and Singh (2012) revealed that grain yield in Maize increased significantly with increasing levels of nitrogen (0– 150kg ha^{-1}) and highest was obtained at 150kg ha^{-1}.

4.2.20.1 Harvest index

Harvest index had non-significant effect influenced by nitrogen levels in BARI hybrid maize-7(Table 07). The maximum harvest index 0.14 obtained with all the nitrogen levels accept no nitrogen use and minimum harvest index 0.13 found with no nitrogen levels and statistically differs from any others treatments. It resulted due to nitrogen levels increased the harvest index not significantly increased. Increasing the nitrogen dose up to 90 kg ha^{-1} increased the nitrogen and phosphorus uptake by grain and fodder maize (Singh *et al.*, 2012).

4.2.20.2 Harvest index

Harvest index showed non-significant effect by nitrogen levels in BARI hybrid maize-9 (Table 08). In the observation all the treatments same harvest index (0.13) shown of the experimental phase. It might probably due to nitrogen levels treatment result there were not variation in the parameter. The nitrogen concentration (%) in grain and stover of maize at harvest was increased with increase in levels of nitrogen from 50 to 100 kg ha^{-1} (Roy and Thripathi, 2007).

Chapter-FOUR

Results and Discussion

(Interaction in Irrigation and Nitrogen)

The results of irrigation, nitrogen and interaction on BARI hybrid maize-7 and BARI hybrid maize-9 obtained from this experiment have been presented and discussed in this chapter. The result on the effect of interaction (irrigation and nitrogen) effects were been presented in Table 08--12 and graphical presentation of different parameters were been presented in Figs 21--25. Data on different growth parameters such as plant height, plant girth, total tillers plant^{-1}, effective tillers plant^{-1}, non-effective tillers plant^{-1}, total roots plant^{-1}, straw weight plant^{-1}, and straw yield t ha^{-1}, cob length, cob grain free length, cob girth, grain line cob^{-1}, grain number line^{-1}, total grain cob^{-1}, grain weight cob^{-1}, 1000 grin weight cob^{-1}, grain yield t/ ha, straw yield t/ha, biological yield t ha^{-1} and harvest index (%) were presented. The analysis of variance in respect of all the selected parameters under the study together with sources of variation and corresponding degrees of freedom were been presented here.

4.3. Interaction effect of irrigation and nitrogen on growth and yield of BARI hybrid maize-7 and BARI hybrid maize-9

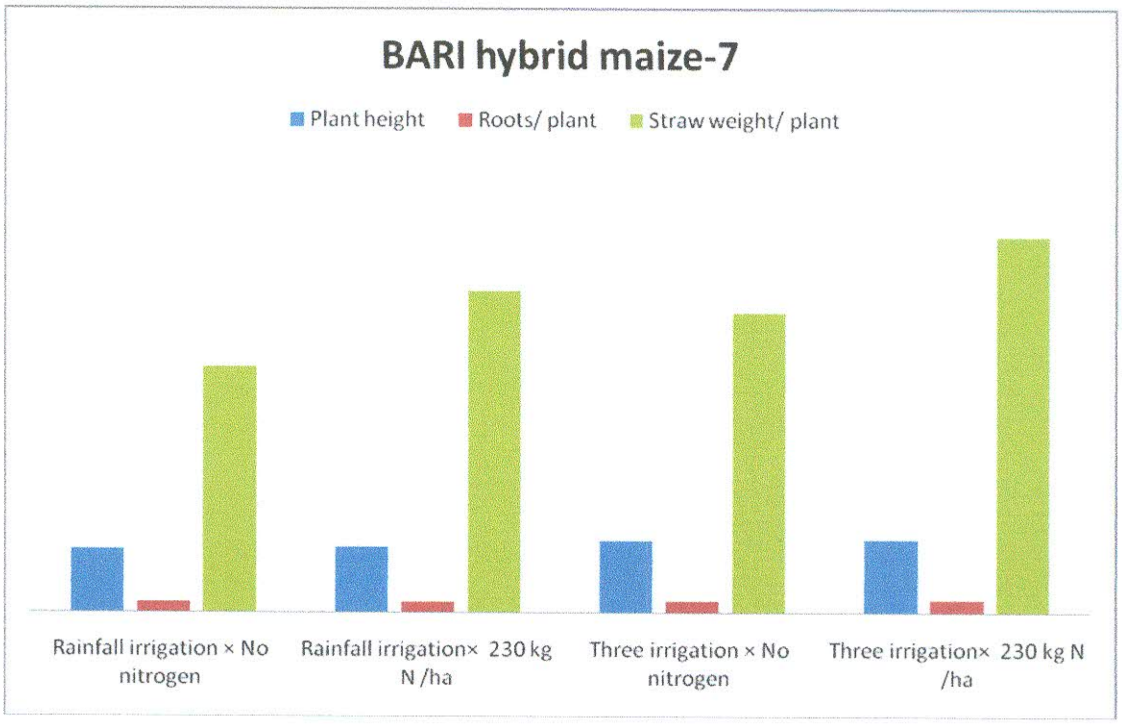
A. Growth parameters of experimental maize varieties with performance of irrigation and nitrogen

4.3.1.1. Plant height

Interaction effect had significantly influenced of irrigation and nitrogen treatments had significant influenced on plant height in BARI hybrid maize-7 (Table 09). The highest plant height 256.67 cm was obtained with three irrigation levels and 230 kg/ha^{-1}nitrogen which was statistically similar with three irrigations levels with no nitrogen level. The lowest plant height 225.67 cm was obtained rainfall irrigation level with no nitrogen use. The plant height graph of different irrigation and nitrogen treatments within growth level i.e. plant height values increased within the advancement of irrigation and nitrogen levels in an optimum level (Fig.21). Water is further required to provide constant turgor pressure that supports the plant and facilitates cell enlargement after cell division has been initiated. Hence, plant growth and survival depend on adequate water availability. Irrigation also improves the efficiency of fertilizer utilization by the crop. Increases in irrigation frequency increased N, P and K uptake by maize (Prasad & Prasad, 1988). Gokmen et al. (2001) reported that in pop corn the maximum plant height was observed with the highest dose of nitrogen i.e., 250 kg ha^{-1} while lowest values were recorded at control level 0 or 50 kg N ha^{-1}. Application of 90 kg N/ ha in pop corn significantly improved dry matter per plant at harvest over 60 kg N ha^{-1}. Further increase in fertilizer dose failed to get a significant improvement (Choudhary and Singh, 2006).

4.3.1.2. Plant height

Interaction showed positive effect of irrigation and nitrogen treatments had significant influenced on plant height in BARI hybrid maize-9 (Table 10). The highest plant height 271.17 cm was obtained with three irrigation levels and 230 kg/ha nitrogen which was statistically similar with three irrigations levels with no nitrogen level. The lowest plant height 233.59 cm was obtained rainfall irrigation level with no nitrogen use. The plant height [1]graph of different irrigation and nitrogen treatments within growth level i.e. plant height values increased within the advancement of irrigation and nitrogen levels in an optimum level (Fig.21). Dogan and Kirnak., (2010) examined the effect of different irrigation amounts applied with drip irrigation on plant height, water use efficiency, total production cost and net return of maize grown in a sub-humid climate of Turkey. Konuskan et al. (2010) reported positive effect of increased nitrogen application on plant height of popcorn and the highest value was obtained with 240 kg N ha^{-1}.



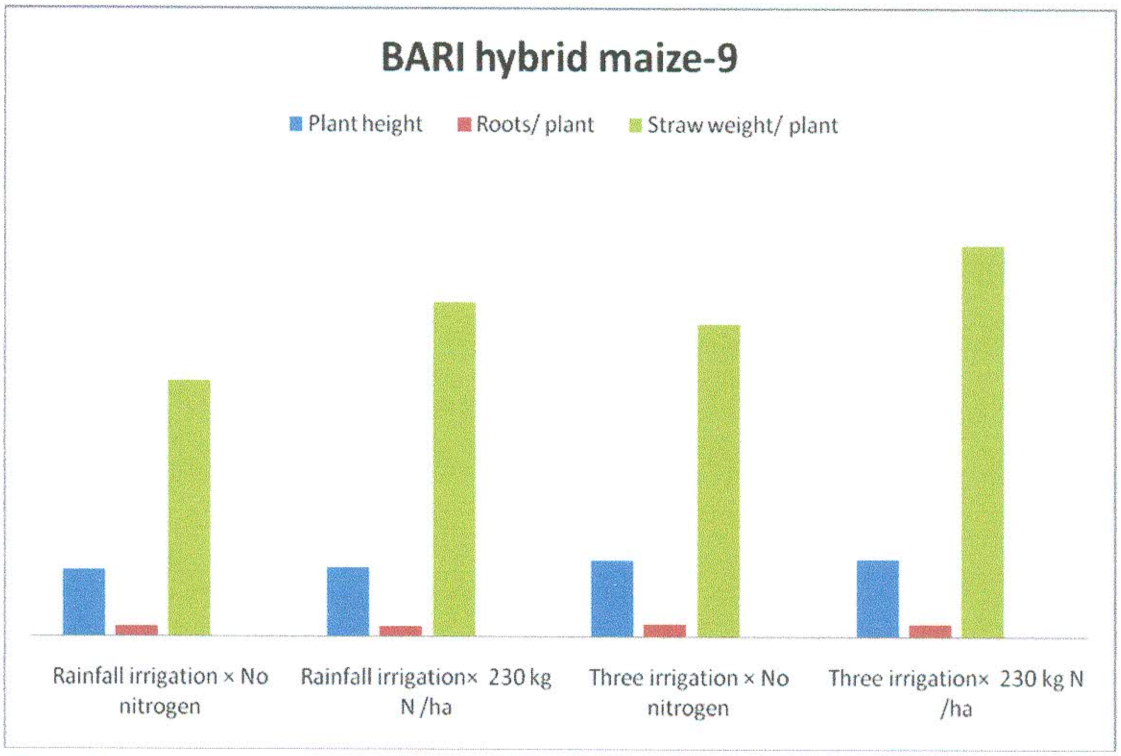


Fig. 21. **Interaction effect of between irrigation and nitrogen on plant height, roots /plant and straw weight /plant of experimental maize varieties**

4.3.2.1. Plant girth

Interaction effect of irrigation and nitrogen treatments showed significant positive effect on plant girth in BARI hybrid maize-7 (Table 09). The highest plant girth 9.33 cm was in three irrigations with 230 kg/ha nitrogen levels which was statistically similar in three irrigation levels with no nitrogen use. The smallest plant girth 7.17 was with in rainfall irrigation with no nitrogen which statistically similar in no irrigation with 230 kg/ha nitrogen levels. The plant girth respective of irrigation and nitrogen treatment resulted of different irrigation and nitrogen treatments within growth level girth values increased with the increasing of irrigation and nitrogen levels. Nitrogen fertilizer had noticeable influence on crop growth, girth and yield of baby corn. Significant increase in plant height was observed up to 120 kg N ha^{-1}. Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase plant girth at the important level. Thakur and Sharma (2009) reported that plant height of baby corn was found significantly increased up to 200 kg N ha^{-1}.

4.3.2.2. Plant girth

Interaction effect of irrigation and nitrogen treatments showed non-significant effect on plant girth in BARI hybrid maize-9 (Table 10). The highest plant girth 8.00 cm in three irrigations with 230 kg/ha nitrogen levels which was statistically similar in three irrigation levels with no nitrogen use. The smallest plant girth 7.50 cm was with in rainfall irrigation with 230 kg/ha nitrogen which statistically similar in no irrigation with no nitrogen levels. The plant girth graph irrespective of irrigation and nitrogen treatment resulted in a usual graph of different

Table- 9 : Interaction effect of irrigation and nitrogen on the growth and growth performance of BARI hybrid maize-7

Treatments	Plant height (cm)	plant girth (cm)	Total tiller plant^{-1} (no.)	Effective tiller plant^{-1} (no.)	Non-effective tiller plant^{-1} (no.)	Total roots plant^{-1} (no.)	Straw weight plant^{-1} (g)	Straw yield (t ha^{-1})
No Irrigation and No nitrogen	225.5	7.66	42.33	13.17	8.5	4.67	881	45.32
No Irrigation and 230 kg/ha nitrogen	232.66	7.58	42.33	13.5	10.17	3.34	1089.17	60.37
Three Irrigation and no nitrogen	254.66	8.16	45.83	14	10.17	3.83	1063	54.25
Three Irrigation and 230 kg/ha nitrogen	261.35	8.09	45.33	14.33	11.83	2.5	1271.17	69.28
Sd	1.88	0.51	10.09	1.35	0.90	159.64	159.64	10.09
Cv(%)	4.29	3.75	17.61	13.37	25.33	14.83	14.83	17.61
Level of significance	**	**	**	*	**	**	*	*

In a column figures having common letters(s) do not differ significant as per DMRT

**Indicates 1 % and * indicates 5% level of probability

NS indicates not significant

irrigation and nitrogen treatments within growth level i.e. plant girth values increased with the increasing of irrigation and nitrogen levels. Ayars et al., (2009), found local information from the Marmara region of Turkey on the response of maize in plant girth with drip irrigation is very limited, especially dealing with the effect of limited water allocations. In Marmara climatic region, little attempt has been made to assess the water yield relationships and optimum water management programs of maize for recently developed hybrids. Sunder and Singh (2001) revealed that in baby corn during summer season there was a significant increase in plant height and girth with every increment dose of N up to 150 kg ha^{-1} where as during kharif season the significant difference in plant height was observed only up to 120 kg ha^{-1}.

4.3.3.1. Total tillers plant^{-1}

Total tillers plant^{-1} had the effects among the treatments of interaction effect of irrigation and nitrogen levels in BARI hybrid maize-7 (Table 09). The highest total tillers plant^{-1}11.83 was produced three irrigations levels with 230 kg/ha nitrogen which were similar in three irrigation with no nitrogen and rainfall irrigation with 230 kg/ha nitrogen levels. The lowest total tillers plant^{-1} 8.5 produced in rainfall irrigation with no nitrogen use which was statistically differ from others treatments. The total tillers plant^{-1}graph respective of irrigation and nitrogen treatment resulted in a usual graph of different irrigation and nitrogen treatments within growth level i.e. total tillers plant^{-1} values increased with the increasing of irrigation and nitrogen levels which shown Fig.22. Application of nitrogen and irrigation gives faster rate of leaf expansion (Wright, 2012), increased leaf area index, leaf area duration, photosynthetic rate and increased radiation interception and radiation use efficiency (Muchow & Davis, 2008; Sinclair & Horie, 2009; Connor et al., 2013).

Table- 10 : Interaction effect of irrigation and nitrogen on the growth and growth performance of BARI hybrid maize-9

Treatments	Plant height (cm)	Plant girth (cm)	Total tiller plant^{-1} (no.)	Effective tiller plant^{-1} (no.)	Non-effective tiller plant^{-1} (no.)	Total roots plant^{-1} (no.)	Straw weight plant^{-1} (g)	Straw yield (t ha^{-1})
No Irrigation and No nitrogen	233.59	7.51	2.25	39.17	12.59	2.25	888.17	45.78
No Irrigation and 230 kg/ha nitrogen	239.25	7.5	2.33	41.66	12.83	2.33	1162.17	61.25
Three Irrigation and no nitrogen	265.25	8	2.25	46.33	15.09	2.25	1085.33	56.35
Three Irrigation and 230 kg/ha nitrogen	271.17	8	2.43	48.33	14.83	2.43	1359.33	72.23
Sd	18.65	0.51	0.27	4.81	1.30	0.27	194.89	10.98
Cv (%)	7.39	4.09	11.56	10.79	9.44	11.56	17.34	18.64
Level of significance	*	NS	NS	*	*	NS	**	**

In a column figures having common letters(s) do not differ significant as per DMRT

**Indicates 1 % and * indicates 5% level of probability

NS indicates not significant

4.3.3.2. Total tillers plant^{-1}

Total tillers plant^{-1} had significant effects among the treatments of interaction effect of irrigation and nitrogen levels in BARI hybrid maize-9 (Table 10). The highest total tillers plant-^{1}14.83 produced three irrigations levels with 230 kg/ha nitrogen which was similar in three irrigations with no nitrogen level. The lowest total tillers plant^{-1} 12.59 was produced in rainfall irrigation with no nitrogen use which was statistically in rainfall irrigation with 230 kg/ha nitrogen levels. The total tillers plant^{-1}graphs respective of irrigation and nitrogen treatment resulted in a usual curve of different irrigation and nitrogen treatments with replication in growth level i.e. total tillers plant^{-1} values increased with the increasing of irrigation and nitrogen levels which shown Fig. 22. The total tillers plant^{-1} was increased with the increasing of irrigation and nitrogen levels in an optimum and afterward decline in the total tillers plant^{-1} production. Payero et al. (2006) reported that trying to increase crop water productivity by imposing deficit irrigation for maize might not be a beneficial strategy in a semiarid climate. Karam et al. (2013) found that grain and dry matter yield, and leaf area index was reduced by severity of water stress.

4.3.4.1. Effective tillers plant^{-1}

Effective tillers plant^{-1} had interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-7(Table 09). The highest effective tillers plant^{-1} 9.33 produced in three irrigations with 230 kg/ha^{-1} nitrogen levels which was statistically differs from any others treatments. The lowest effective tillers plant^{-1} 3.33 produced in rainfall irrigation with the no nitrogen treatment which was statistically differs with others irrigation and nitrogen levels. The effective tillers plant^{-1}graph respective of irrigation and nitrogen treatment resulted in a usual graph of different irrigation and nitrogen treatments with replication in growth level i.e. effective tillers plant^{-1} values increased with the increasing of irrigation and nitrogen levels which shown Fig. 22. The effective tillers plant^{-1} was increased with the increasing of irrigation and nitrogen levels in an optimum and afterward decline in the effective tillers plant^{-1} production. Both irrigation, nitrogen deficiency and excess affects assimilate partitioning between vegetative and reproductive organs (Donald & Hamblin, 2006).

4.3.4.2. Effective tillers plant^{-1}

Effective tillers plant^{-1} had no significant interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-9 (Table 10). The highest effective tillers plant^{-1} 11.84 produced in three irrigations with no nitrogen levels which was not statistically differs from any others treatments. The lowest effective tillers plant^{-1}10.34 produced in rainfall irrigation with the no nitrogen treatment which was also not statistically differs with others treatments. The effective tillers plant^{-1} was increased with the increasing of irrigation and nitrogen levels in an optimum and afterward decline in the effective tillers plant^{-1} production. Yildirim and Kodal (2008) reported that seasonal effective tiller in maize varied between 300 and 1024 mm in Ankara, Turkey. Under furrow irrigation applications, seasonal effective tiller of maize obtained by Gencoglan and Yazar (2009) was 1026 mm for full irrigation treatment and 410 mm for non–irrigated treatment in the Cukurova region of Turkey.

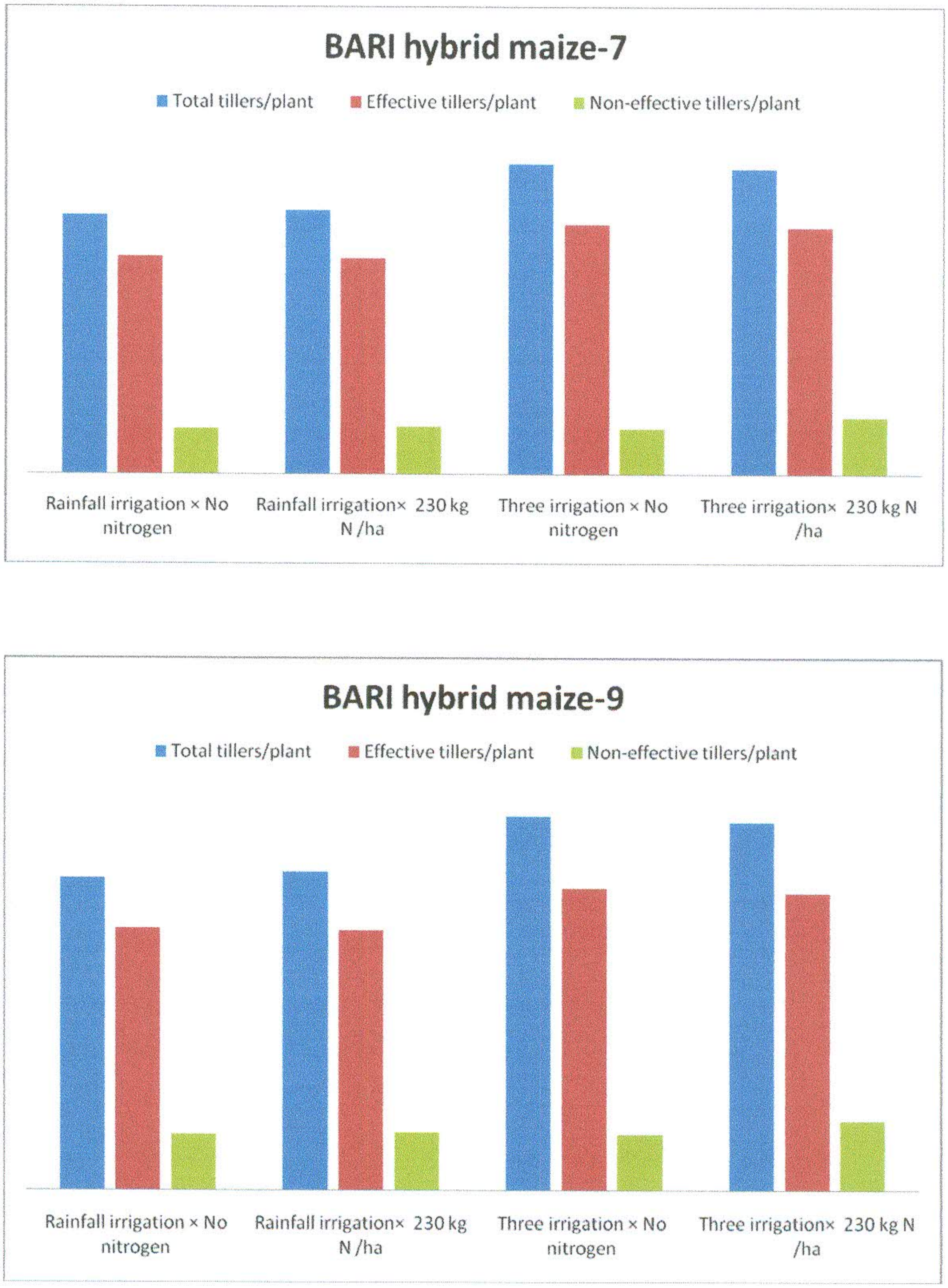


Fig. 22. Interaction effect of between irrigation and nitrogen on total tillers /plant, effective tillers/plant and non-effective tillers /plant of experimental maize varieties

4.3.5.1. Non-effective tillers plant^{-1}

Non-effective tillers plant^{-1} had significant effect among the interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-7 (Table 09). The effect of irrigation levels and nitrogen on the non-effective tillers plant^{-1} was opposite condition of the effective tillers plant^{-1}. The highest non-effective tillers plant-^{1} 5.17 produced in rainfall irrigation with no nitrogen level which was statistically differs with others irrigation and nitrogen levels. The lowest non-effective tillers 2.00 produced in three irrigations with 230 kg/ha^{-1}nitrogen levels which also statistically differs from others irrigation and nitrogen levels. The non-effective tillers plant^{-1} graph respective of irrigation and nitrogen treatment resulted in a usual graph of different irrigation and nitrogen treatments with replication in growth level i.e. non-effective tillers plant^{-1} values decreased with the increasing of irrigation and nitrogen levels which shown Fig. 22. The non-effective tillers plant^{-1} was decreased with the increasing of irrigation and nitrogen levels in an optimum. Results showed higher none effective tillers values in lower irrigation and nitrogen rates. This could be due to increase in sterile plants and barrenness in ears as noted by others (Bangarwa et al., 2008; Rasheed, 2012).

4. 3. 5. 2. Non-effective tillers plant^{-1}

Non-effective tillers plant^{-1} had in significant effect among the interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-9(Table 10). The effect of irrigation levels and nitrogen on the non-effective tillers plant^{-1} was opposite condition of the effective tillers plant^{-1}. The highest non-effective tillers plant^{-1} 2.33 produced in rainfall irrigation with 230 kg/ha^{-1}nitrogen levels nitrogen level which was not statistically differs with others irrigation and nitrogen levels. The lowest non-effective tillers 2.13 produced in three irrigations with 230 kg/ha nitrogen levels which also statistically not differs from others irrigation and nitrogen levels. The non-effective tillers plant^{-1} was decreased with the increasing of irrigation and nitrogen levels in an optimum. Igbadun et al., (2008) observed shortage in irrigation water supplies in the Marmara region has motivated farmers to find ways to produce none effective tillers of crops, especially maize, with less irrigation water, such as using more efficient irrigation systems and changing from fully irrigated to deficit irrigated cropping systems.

4.3. 6. 1. Total roots plant^{-1}

Interaction effect of irrigation and nitrogen levels had significant effect among the treatments in BARI hybrid maize-7(Table 09). The highest number roots 69.28 produced in three irrigations with 230 kg/ha nitrogen levels which was statistically similar in no irrigation and 230 kg/ha nitrogen levels. The lowest number roots 45.32 produced in rainfall irrigation with no nitrogen level. Total roots plant^{-1}graph irrespective of irrigation and nitrogen treatments resulted in a usual ^{1}graph of different irrigation and nitrogen treatments within growth level i.e. total roots plant^{-1} values increased with the increasing of irrigation and nitrogen levels in an optimum levels and afterward decline in the total roots plant^{-1} production (Fig.21). Reasons for using irrigation scheduling are to reduce water applications, energy consumption and deep percolation of water below the crop root zone (Ritter & Manager, 1985). Mishra et al. (2001) reported that in eastern Uttar Pradesh, among the three levels of nitrogen tried viz., 0, 75, and 150 kg N ha^{-1}, 150 kg N ha^{-1} recorded maximum roots in winter maize. Vadivel et al. (2011) observed that with index and dry matter of maize increased significantly.

4.3.6.2. Total roots plant^{-1}

Interaction effect of irrigation and nitrogen levels had significant effect among the treatments in BARI hybrid maize-9 (Table 10). The highest number 48.33 roots produced in three irrigations with 230 kg/ha^{-1}nitrogen levels which was statistically similar in three irrigations and no nitrogen level. The lowest number 39.17 roots produced in rainfall irrigation with no nitrogen level which was similar in rainfall irrigation with 230 kg/ha nitrogen levels nitrogen level. Total roots plant^{-1} graphs respective of irrigation and nitrogen treatments resulted in a usual graphs of different irrigation and nitrogen treatments within growth level i.e. total roots plant^{-1} values increased with the increasing of irrigation and nitrogen levels in an optimum levels and afterward decline in the total roots plant^{-1} production (Fig.21). This result might be due to availability of irrigation and nitrogen more roots production. Similar response to increased level of irrigation increased total roots per plant was reported by Shivay et al. (2009), Pantnagar, Muniswamy et al. (2007) from Bangalore and Suryavanshi et al. (2008) from Parbhani. Sunder Singh (2001) reported that in baby corn, increasing nitrogen levels recorded significant increase at roots production in maize up to 150 kg ha^{-1} but it was comparable with 180 kg ha^{-1} both in kharif and summer seasons.

4.3.7.1. Straw weight plant^{-1}

Interaction effects of irrigations and nitrogen levels significantly influenced by the straw weight plant^{-1} in BARI hybrid maize-7 (Table 09). The highest straw weight plant^{-1} 1271.17 g was with 230 kg/ha nitrogen levels and the lowest straw weight plant^{-1} 849.33 g with no nitrogen use. Application of high nitrogen doses increased gradually the straw weight plant^{-1} graph respective of irrigation and nitrogen treatments resulted in a usual graph of different irrigation and nitrogen treatments within growth level i.e., straw weight plant^{-1} values increased with the advancement of irrigation and nitrogen levels. This result might be due to availability of irrigation and nitrogen supply more vegetative production (Fig.21). This favorable environment resulted in greater LAI with higher CGR. Total biomass yield (11-15 t ha^{-1}) achieved in this study is similar to other work (Bangarwa, 2008; Muchow, 2009; Ahmad, 2008; Shah, 2011; Rasheed, 2012), reported elsewhere or in Pakistan. Sahoo and Mahapatra (2004) observed significant higher net profit (Rs 20,700 ha^{-1}) due to 180 kg N ha^{-1} over 60 kg N ha^{-1}(Rs 15,300 ha^{-1}.

4.3.7.2. Straw weight plant^{-1}

Interaction effects of irrigations and nitrogen levels significantly influenced by the straw weight plant^{-1} in BARI hybrid maize-9 (Table 10). The highest straw weight plant^{-1} 1359.33 g was in three irrigations with 230 kg/ha nitrogen levels which was differs from with any others treatments. The lowest straw weight plant^{-1} 888.17 g in rainfall irrigation with no nitrogen use. Straw weight plant^{-1} values increased with the advancement of irrigation and nitrogen levels. This result might probably be due to availability of irrigation and nitrogen supply more vegetative production (Fig21). Oktem et al. (2013) found that seasonal straw weight per plant for maize by using drip irrigation method in Sanliurfa conditions of Turkey varied between 1040–701 mm depending on irrigation scheduling. Bindhani et al. (2007) concluded that in baby corn net returns and benefit : cost ratio were highest with 120 kg N ha^{-1}, which resulted in significant increase of 289.2, 69.8 and 39.15 per cent in net returns and 235.2, 57.7 and 34.1 per cent in benefit : cost ratio compared to that of the no nitrogen, 40 and 80 kg N ha^{-1} respectively.

4.3.8.1. Straw yield

There were the interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-7 (Table 09). The maximum straw yield t ha^{-1} was 69.28 with three irrigations with 345 kg/ha nitrogen levels which were same resulted in rainfall irrigation with 230 kg/ha^{-1} nitrogen levels. The lowest straw yield t ha^{-1} was 69.28 in rainfall irrigation with no nitrogen use. The straw yield irrespective yield values of different irrigation and nitrogen treatments within growth level increasing of irrigation and nitrogen levels increased the straw yield. The result might probably be due to availability of nitrogen increased more vegetative production. Pandey et al. (2010) stated that straw yield reduction (22.6–26.4%) caused by deficit irrigation was associated with a decrease in leaves number and weight. The effects of deficit irrigation for the same crop may vary with location.

4.3.8.2. Straw yield

There were the interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-9 (Table 10). The maximum straw yield t ha^{-1} 72.23 was three irrigations with 230 kg/ha nitrogen levels which was statistically same resulted in rainfall irrigation with 230 kg/ha nitrogen levels. The lowest straw yield t ha^{-1} 45.78 was in rainfall irrigation with the no nitrogen use which was differs from any others treatments. The straw yield graph irrespective yield values of different irrigation and nitrogen treatments with replication in growth level increased of irrigation and nitrogen levels increased the straw yield. The result might be due to availability of irrigation and nitrogen increased more vegetative production in an optimum level and afterwards decline production. Yazar et al. (2002) reported also that the highest average maize straw yield obtained from full irrigation treatment using drip irrigation method.

B. Yield parameters of experimental maize varieties with performance of irrigation and nitrogen

4.3.9.1. Cob length

Cob length had significant effect among interaction of irrigation and nitrogen treatments in BARI hybrid maize-7 (Table 11). The highest cob length 23.66 cm was found in three irrigations with 230 kg/ha nitrogen levels and statistically similar result shown in rainfall irrigation with 230 kg/ha. The lowest cob length 21.50 found obtained rainfall irrigation with no nitrogen levels which was similar resulted in three irrigations with no nitrogen treatments. The cob length graphs irrespective irrigation and nitrogen treatment resulted in a usual graph of different irrigation and nitrogen treatments with replication in yield level i.e. cob length values increased with increasing irrigation and nitrogen levels. Afterwards advancement of irrigation and nitrogen levels stared to decline cob length (Fig.23). The cob length probably due to irrigation and nitrogen level increased on optimum levels. Irrigation also improved the efficiency of fertilizer utilization by the cob length. Increases in irrigation frequency increased N, P and K uptake by maize (Prasad & Prasad, 2008). Kar et al. (2006) recorded that increased nitrogen application from 20 kg N ha-1 to 80 Kg N ha^{-1} significantly increased the cob length from 14.6 cm to 17.5 cm and cob girth from 13.8 cm to 16.7 cm.

4.3.9.2. Cob length

Cob length had significant effect among interaction of irrigation and nitrogen treatments in BARI hybrid maize-9 (Table 12). The highest cob length 23.33 cm was found in three irrigations with 230 kg/ha^{-1} nitrogen levels and it was statistically similar result shown in rainfall irrigation with 230 kg/ha nitrogen levels. The lowest cob length 21.83 found obtained rainfall irrigation with no nitrogen levels which was statistically similar result in three irrigations with no nitrogen treatments. The cob length curves irrespective irrigation and nitrogen treatment resulted in a usual curve of different irrigation and nitrogen treatments within yield performance i.e. cob length values increased with increasing irrigation and nitrogen levels. Afterwards advancement of irrigation and nitrogen levels stared to decline cob length (Fig.23). The cob length probably due to irrigation and nitrogen level increased an optimum level. Among various management practices, irrigation and nitrogen nutrition play a significant role in realizing the maximum potential of the crop. Irrigation scheduling is the technology for applying the proper amount of water at the right time. Reasons for using irrigation scheduling are to reduce water applications, energy consumption and deep percolation of water below the maize cob length (Ritter & Manager, 2005). Bindhani et al. (2007) observed that in baby corn a significant increase in baby corns/plant, their fresh weight, length and girth were also recorded up to 120 kg N ha^{-1}.

4.3.10.1. Cob grain free

Cob grain free length had not significant effect influenced among the interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-7 (Table 11). The highest grain free length 1.50 cm found in rainfall irrigation with no nitrogen use and the lowest 0.75 cm was obtained three irrigation with 230kg/ha nitrogen levels. The cob grain free length might probably due to more irrigation and nitrogen supply non-significantly affected. Increased application of irrigation and nitrogen gives faster rate of leaf expansion and cob development (Wright, 2012), increased leaf area index, leaf area duration, photosynthetic rate and increased radiation interception and radiation use efficiency (Muchow & Davis, 2008).

4.3.10.2. Cob grain free

Cob grain free length had significant effect influenced among the interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-9 (Table 12). The highest grain free length 1.50 cm found in rainfall irrigation with no nitrogen uses which were similar with three irrigations with no nitrogen level. The lowest grain free length 0.67 cm was obtained three irrigations with 230kg/ha nitrogen level. The cob grain free length graphs respective irrigation and nitrogen treatment resulted in a usual graph of different irrigation and nitrogen treatments within yield performance i.e. cob gain free length values decreased with increasing irrigation and nitrogen levels in an optimum level. Afterwards increasing of irrigation and nitrogen levels stared to decline cob grain free length. The cob grain free length probably due to irrigation and nitrogen level increased shortest an optimum levels. Irrigation and Nitrogen, being an integral part of structural and functional proteins, chlorophyll and nucleic acids such as RNA and DNA as well as essential for proper carbohydrate utilization, plays a vital role in cob development (Tisdale et al., 2010).

4. 3.11.1. Cob girth

Cob girth was significant effect influenced among the interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-7 (Table 11). The largest cob girth 15.57 cm found in three irrigations with 230 kg/ha nitrogen levels which counted statistically differs from any others treatments. The smallest cob girth 14.00 cm found obtained rainfall irrigation with no nitrogen use which was differs with all others treatments. The cob girth curves respective of different irrigation and nitrogen treatments with replication in yield level i.e. cob girth curve values increased with increasing irrigation and nitrogen levels (Fig. 79). Cob girth might probably due to sufficient irrigation and nitrogen supply increased yield production. Nath et al. (2009) reported that in sweet corn an increase of 11.6% and 16.9 in cob length and cob girth were recorded when the fertility level was raised from 50 to 70 kg N ha-1 and an application of 110 kg N ha^{-1} accounted for significant increase (10.1%)

over 70 kg N ha^{-1} in cob girth. Management of crop nutrition includes correct manuring at right time, optimum level and appropriate method of application. Nitrogen and irrigation being an integral part of structural and functional proteins, chlorophyll and nucleic acids such as RNA and DNA as well as essential for proper carbohydrate utilization, plays a vital role in crop development (Tisdale et al., 2010).

4.3.11.2. Cob girth

Cob girth showed significant effect among the interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-9 (Table 12). The largest cob girth 15.67 cm found in three irrigations with 230 kg/ha^{-1} nitrogen levels which counted statistically differs from any others treatments. The smallest cob girth 14.00 cm found obtained rainfall irrigation with no nitrogen use which was statistically similar in no irrigation with 230 kg/ha^{-1} nitrogen levels. The cob girth graphs respective of different irrigation and nitrogen treatments within yield performance i.e. cob girth graphs values increased with increasing irrigation and nitrogen levels (Fig. 23). Cob girth might probably due to sufficient irrigation and nitrogen supply increased cob girth. Anonymous, (2010). Oktem and Oktem (2005) revealed that cob length increased from 16.42 cm at 150 kg N ha^{-1} to 20.88 cm at 350 kg N ha^{-1}. They also concluded that cob girth was increased with application of N up to 250 kg ha^{-1}, and proper water supply beyond the level of 250 kg ha^{-1} there was no significant increased.

4.3.12.1. Grain line cob^{-1}

Grain line cob^{-1} had significant effect among the interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-7 (Table 11). The maximum grain line cob^{-1} 13.83 counted in three irrigations with the 230 kg/ha nitrogen and it was differs from any others treatments. The lowest grain line cob^{-1} 12.33 obtained rainfall irrigation with no nitrogen use which was also from all others treatments. . The cob length respective irrigation and nitrogen treatment resulted grain line cob^{-1} values increased with increasing irrigation and nitrogen levels. Afterwards advancement of irrigation and nitrogen levels stared to decline cob length. The grain line cob^{-1} might probably due to irrigation and nitrogen sufficiently increased the production. Similar results were reported by others (Pearson, 2014; Ahmad, 2009; Rasheed, 2012) who also found higher number of cobs with N application and optimum irrigation.

4.3.12.2. Grain line cob^{-1}

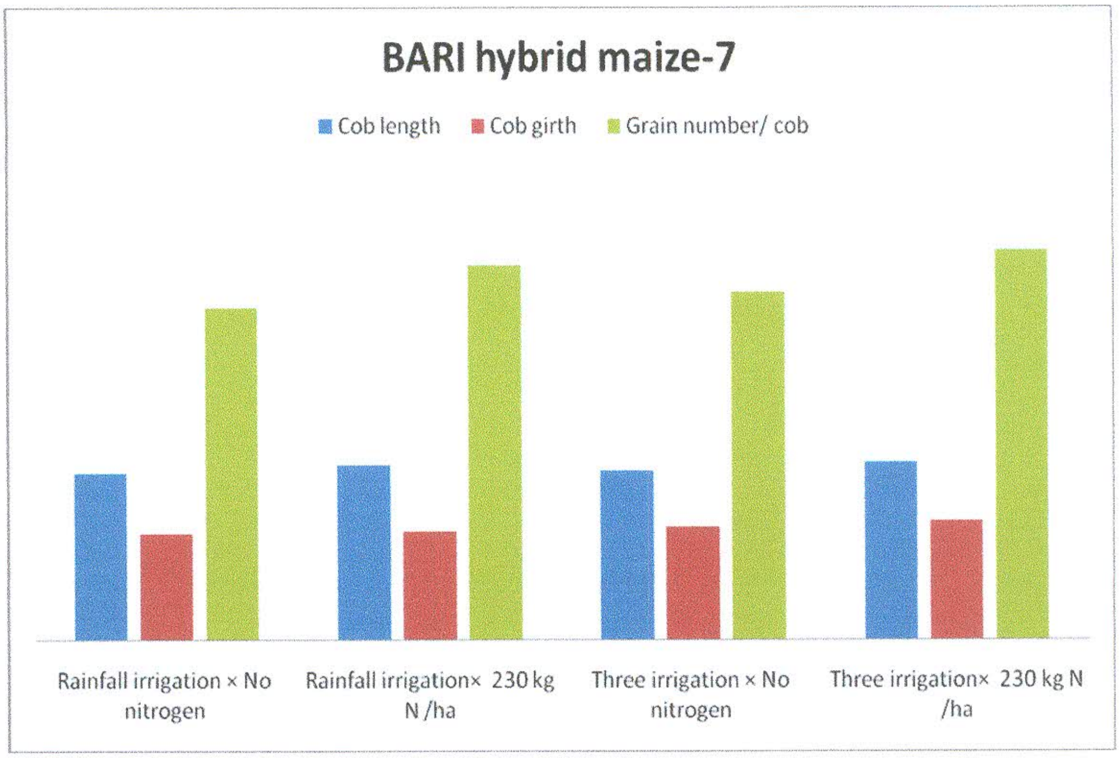
Grain line cob^{-1} had not significant effect influenced among the interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-9 (Table 12). The maximum grain line cob^{-1} 13.83 counted in three irrigations with the 230 kg/ha nitrogen and the lowest grain line cob^{-1} 12.67 obtained rainfall irrigation with no nitrogen use. The grain line cob^{-1} might probably due to increased irrigation and nitrogen level similar resulted. Similar results were reported by others who also noted higher number of cobs m^{-2} with higher rates of irrigation and N application (Ahmad, 2008; Rasheed, 2012), under similar agro-ecological conditions.

4.3.13.1. Grain number line^{-1}

Grain number line^{-1} showed significant effect among interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-7 (Table 11). The maximum grain line^{-1} 50.33 counted in three irrigations with 230 kg/ha^{-1}nitrogen level which was differs from any others treatments. The lowest grain number line^{-1} obtained rainfall irrigation with no nitrogen use which also differs from all others treatments. The grain number line^{-1} graphs of different irrigation and nitrogen treatments within yield level i.e. grain number line^{-1} values respective increasing irrigation and nitrogen levels significantly increased the production (Fig.23). It was conformed increasing irrigations and nitrogen levels increased yield in an optimum level and significantly differs with the treatments apply. Greater number of grains line^{-1} by adequate application of N is in accordance with the findings of others who also reported similar effects of N application proper irrigation on the number of grains line^{-1} (Ahmad, 2008; Shah, 2001; Rasheed, 2012). Gokmen et al. (2011) observed that in popcorn, the kernel number per ear increased by about 6% as nitrogen increased from zero to 250 kg N ha^{-1} and also stated that maximum cob length was obtained from 250 kg N ha^{-1}.

4.3.13.2. Grain number line^{-1}

Grain number line^{-1} showed significant effect among interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-9 (Table 12). The maximum grain line^{-1} 50.83 counted in three irrigations with 230 kg/ha nitrogen level which was similar resulted in no irrigation level with 230 kg/ha nitrogen level. The lowest grain number line^{-1} obtained rainfall irrigation with no nitrogen use which also similar resulted in three irrigations with no nitrogen use. The grain number line^{-1} graphs of different irrigation and nitrogen treatments within yield performance i.e. grain number line^{-1} values respective increasing irrigation and nitrogen levels significantly increased the production (Fig.23). It was conformed increasing irrigations and nitrogen levels increased yield in an optimum level and significantly differs with the treatments apply. Ashok Kumar (2009) observed that in pop corn maximum values of yield attributes viz., cob girth, cob length, grains ear^{-1} and shelling percentage were recorded with the application of 120 kg N ha^{-1}. Cob weight increased with increase in nitrogen application and the heaviest cobs were obtained at 240 kg N ha^{-1}. Konuskan et al.,(2010) found effect of irrigation schedules and nitrogen levels on the number of grains line^{-1} was highly significant in both the seasons.



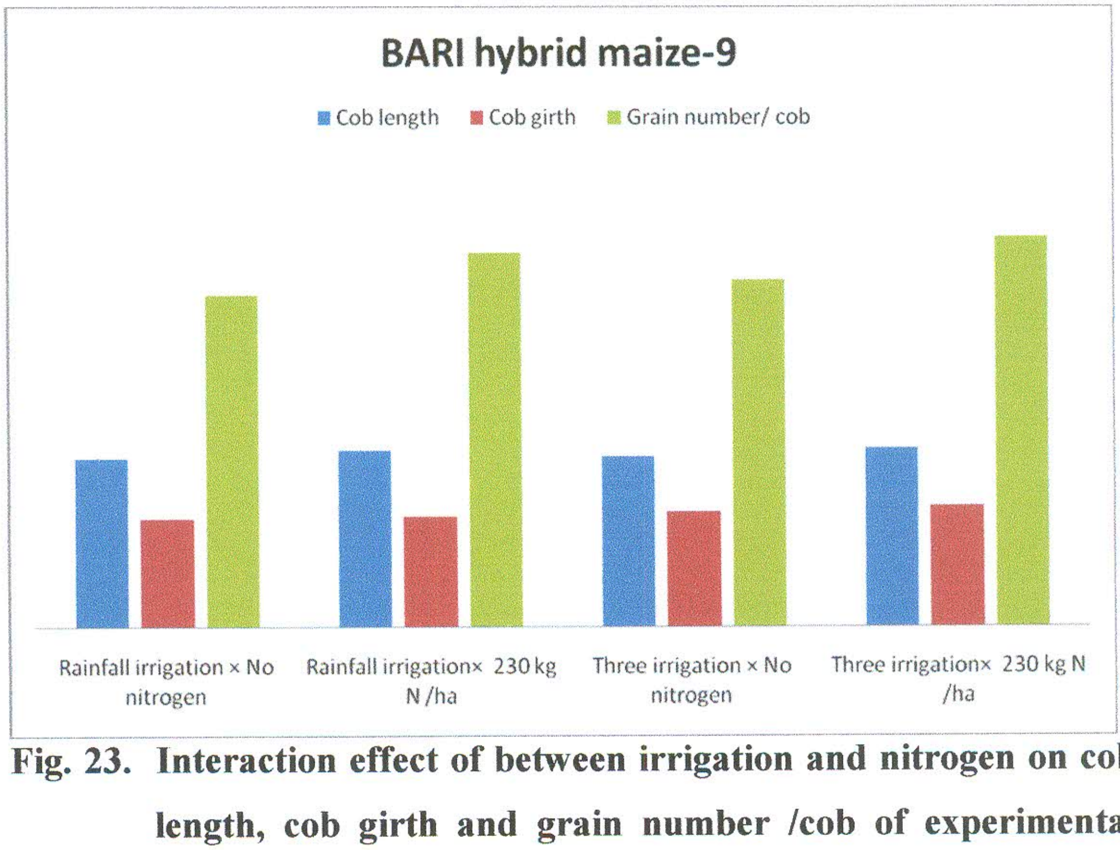


Fig. 23. **Interaction effect of between irrigation and nitrogen on cob length, cob girth and grain number /cob of experimental maize varieties**

4.3.14. 1. Total grain cob^{-1}

Total grain cob^{-1} was highly influenced by interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-7 (Table 11). The maximum total grain cob^{-1} 694.00 produced three irrigations with 230 kg/ha^{-1}nitrogen and it was statistically dissimilar with any others treatments. The minimum total grain cob^{-1} 493.00 found in rainfall irrigation with on nitrogen use which was statistically differs from all others treatments. Total grain cob^{-1} graphs respective in irrigation and nitrogen treatments resulted in a usual graphs of different irrigation and nitrogen treatments within yield level i.e. total grain cob^{-1} values increased with the increasing irrigation and nitrogen levels and afterwards inspect of irrigation level decline production (Fig.24). It might be conformed due to irrigation and nitrogen uses a vitriol role in the BARI hybrid maize-7. Tisdale et al. (2010) found that the optimum level of irrigation schedules and nitrogen rates for enhanced grain yield and its components under semi arid irrigated conditions.

4.3.14.2. Total grain cob^{-1}

Total grain cob^{-1} was highly significant influenced by interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-9 (Table 12). The maximum total grain cob^{-1} 690.50 produced three irrigations with 230 kg/ha nitrogen and it was statistically similar in no irrigation with 230 kg/ha nitrogen treatments. The minimum total grain cob^{-1} 531.00 found in rainfall irrigation with on nitrogen use which was statistically differs from all others treatments. Total grain cob^{-1} graphs respective in irrigation and nitrogen treatments resulted in a usual graphs of different irrigation and nitrogen treatments with replication in yield performance i.e. total grain cob^{-1} values increased with the increasing irrigation and nitrogen levels and afterwards inspect of irrigation level decline production (Fig.24). It might be conformed due to irrigation and nitrogen uses a vitriol role in the BARI hybrid maize-9. Grain production significantly improved under these treatments as compared to lower rates of N application or increasing water stress such as I4 (-12 bars) treatments. Grain yields found in this study (> 7 t ha^{-1}) are similar to the work of Muchow (2008) who also reported grain yield of maize at 7.9 t ha^{-1} under semi arid tropical environment. Gaur et al. (2012) reported significantly higher stover yield due to 120 kg N ha^{-1} at Udaipur during rabi season in vertisols.

4.3.15.1. 1000 grain weight

Interaction effect of irrigation and nitrogen treatments had significant influenced with 1000 grain weight in BARI maize-7 (Table 11).The highest 1000 grain weight 270.19 g produced in three irrigations with 230 kg/ha nitrogen which was statistically differs from with all others treatment. The lowest 1000 grain weight 255.13 g counted rainfall irrigation with no nitrogen use which was also statistically dissimilar with any others treatments. The 1000 grain weight graphs respective of irrigation and nitrogen treatment resulted in a usual graphs of different irrigation and nitrogen treatments within yield level i.e. 1000 grain weight values increased with the increasing of irrigation and nitrogen levels (Fig.24). It might be probably due to irrigation and nitrogen levels increased 1000 grain weight advanced. Yildirim and Kodal (2008) stated that applications of excessive irrigation water did not increase 1000 grain yields at the important level. The relationship between applied water and 1000 grain yield was quadratic.

4.3.15.2. 1000 grain weight

Interaction effect of irrigation and nitrogen treatments had significant influenced with 1000 grain weight in BARI maize-9 (Table 12). The highest 1000 grain weight 273.59 g produced in three irrigations with 230 kg/ha nitrogen which was statistically similar in three irrigations with no nitrogen level. The lowest 1000 grain weight 252.62 g counted rainfall irrigation with no nitrogen use which was also statistically similar in no irrigation with 230 kg/ha^{-1}nitrogen treatments. The 1000 grin weight graphs respective of irrigation and nitrogen treatment resulted in a usual graph of different irrigation and nitrogen treatments with replication in yield performance i.e. 1000 grain weight values increased with the increasing of irrigation and nitrogen levels (Fig24). It might be probably due to irrigation and nitrogen levels increased 1000 grain weight advanced.

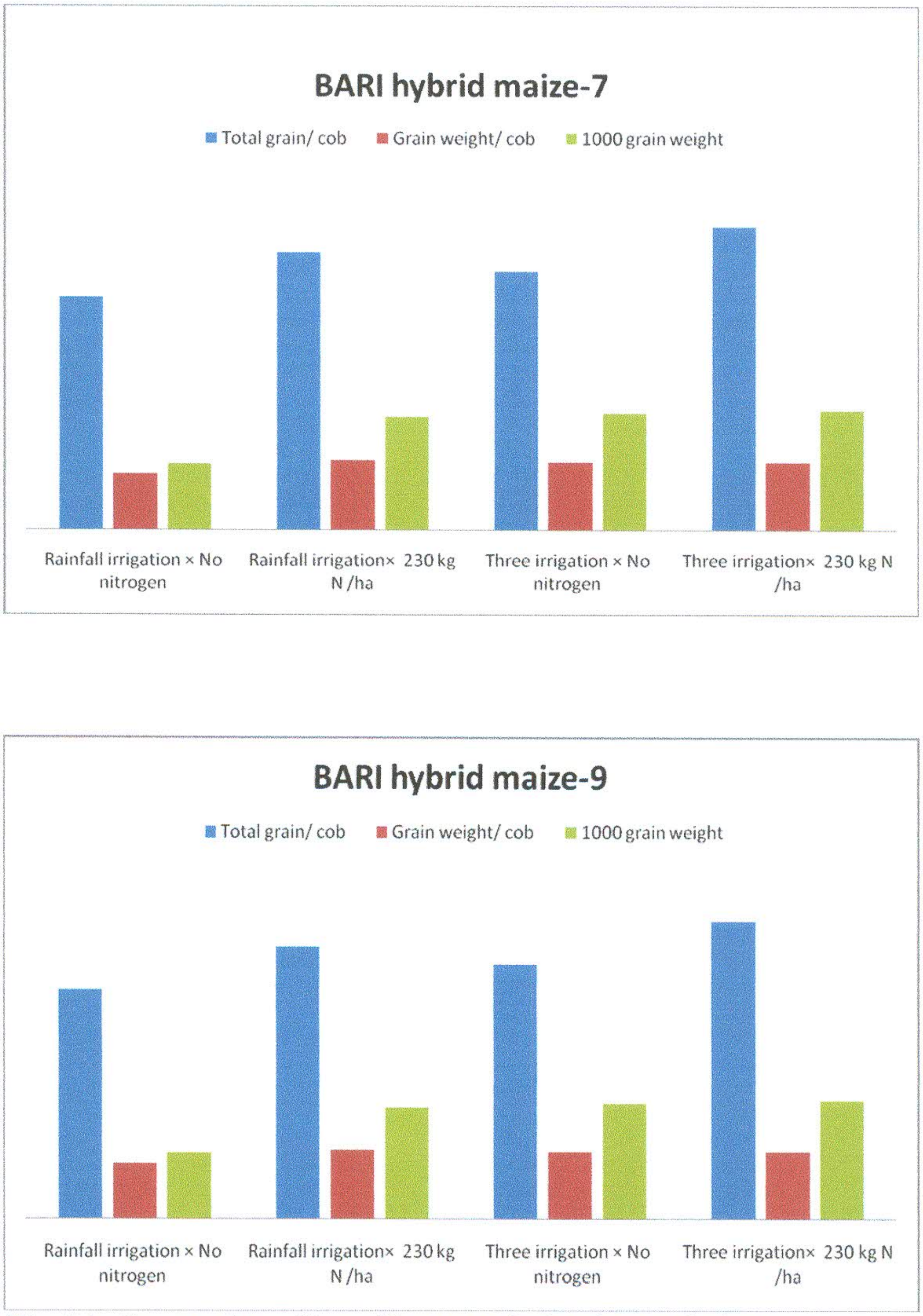


Fig. 24. Interaction effect of between irrigation and nitrogen on total grain /cob, grain weight /cob and 1000 grain weight of experimental maize varieties

4.3.16.1. Grain weight cob^{-1}

The interaction effects of irrigation and nitrogen treatments in BARI hybrid maize-7(Table 11). The maximum grain weight cob^{-1} 185.17 g in three irrigations with 230 kg/ha nitrogen which were statistically differs from any others treatments. The minimum grain weight cob^{-1} 125.66 g counted in rainfall irrigation with no nitrogen use which was differs from all others treatments. Grain weight cob^{-1} graphs respective of irrigation and nitrogen treatment resulted in a usual curve of different irrigation and nitrogen treatments within yield level i.e. grain weight cob^{-1} values increased with the increasing of irrigation and nitrogen levels (Fig.24). It was conformed that irrigation and nitrogen supply increased grain weight cob^{-1}. Ashok Kumar (2009) observed that in pop corn maximum values of yield attributes viz., cob girth, cob length, grains ear^{-1} and shelling percentage were recorded with the application of 120 kg N ha^{-1}. Cob weight increased with increase in nitrogen application and the heaviest cobs were obtained at 240 kg N ha^{-1} (Konuskan et al., 2010).

4.3.16.2. Grain weight cob^{-1}

Grain weight cob^{-1} was significant affected by interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-9 (Table 12). The maximum grain weight cob^{-1} 186.83 g in three irrigations with 230 kg/ha nitrogen which were statistically differs from any others treatments. The minimum grain weight cob^{-1} 128.33 g counted in rainfall irrigation with no nitrogen use which was statistically differs from all others treatments. Grain weight cob^{-1} graphs respective of irrigation and nitrogen treatments resulted in a usual graph of different irrigation and

Table-11 : Interaction effect of irrigation and nitrogen on the yield and yield performance of BARI hybrid maize-7

Treatments	Cob length (cm)	Cob grain free (cm)	Cob girth (cm)	Grain line cob^{-1} (no)	Grain number $line^{-1}$ (no)	total grain $cob-^{1}$ (no)	Grain weight cob^{-1} (g)	1000 Grain weight cob^{-1} (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
No Irrigation and No nitrogen	21.5	1.5	14	12.33	41.5	493	125.66	255.13	6.4	45.33	51.75	0.13
No Irrigation and 230 kg/ha nitrogen	23.5	1.17	14.83	13	46.5	607.33	159.17	263.44	8.46	55.58	63.88	0.13
Three Irrigation and no nitrogen	21.66	1.25	14.92	13.17	45.33	579.66	151.66	261.67	8.25	54.24	62.32	0.13
Three Irrigation and 230 kg/ha nitrogen	23.66	0.75	15.57	13.83	50.33	694	185.17	270.19	10.32	64.49	74.64	0.14
Sd	1.15	0.32	0.64	0.61	3.63	82.83	24.48	6.19	1.60	7.84	9.36	0.005
Cv(%)	5.13	28.68	4.34	4.71	7.91	13.95	15.75	2.35	19.17	14.27	14.83	3.77
Level of significance	*	NS	*	*	**	**	**	*	**	**	**	NS

In a column figures having common letters(s) do not differ significant as per DMRT
**Indicates 1 % and * indicates 5% level of probability
NS indicates not significant

nitrogen treatments within yield performance i.e. grain weight cob^{-1} values increased with the increasing of irrigation and nitrogen levels (Fig.24). It was conformed that irrigation and nitrogen supply increased grain weight cob^{-1}. The higher grain weight in these treatments over control rate of N application proper water supply was because of adequate supply of nitrogen to the plants. These results substantiates the findings of Tiway et al. (2010) who also observed higher grain weight by nitrogen fertilizer in maize crop.

4. 3.17.1. Grain yield

Interaction effect of irrigation and nitrogen treatments had highly significant influenced with grain yield t ha^{-1} in BARI maize-7 (Table 11). The highest grain yield t ha^{-1} 10.32 produced in three irrigations with 230 kg/ha nitrogen which was dissimilar with any others treatments. The lowest grain yield t ha^{-1} 6.40 counted in rainfall irrigation with no nitrogen levels and statistically differs from any others treatments. The grain yield t ha^{-1} graphs irrespective of irrigation and nitrogen treatment resulted in a usual graph of different irrigation and nitrogen treatments with replication in yield performance i.e. grain yield values increased with the increasing of irrigation and nitrogen levels (Fig.25). Maximum grain yield and greater water use efficiency were achieved when irrigating to 100% of field capacity (Mbagwu & Osuigwu, 2005). Highest grain yield was obtained with 120 kg K2O ha^{-1} and irrigation at 25% depletion of available soil moisture (Patel et al., 2005).

4.3.17.2. Grain yield

Interaction effect of irrigation and nitrogen treatments showed highly significant with grain yield t ha^{-1} in BARI maize-9 (Table 12).The highest grain yield t ha^{-1} 10.32 produced in three irrigations with 230 kg/ha nitrogen which was dissimilar with any others treatments. The lowest grain yield t ha^{-1} 6.45 counted in rainfall irrigation with no nitrogen levels and statistically differs from any others treatments. The grin yield t ha^{-1} curves irrespective of irrigation and nitrogen treatment resulted in a usual graph of different irrigation and nitrogen treatments within yield performance i.e. grain yield values increased with the increasing of irrigation and nitrogen levels (Fig.25). Both, Ahmad (2008) and Rasheed (2012) also noted higher mean grain weight with adequate application of irrigation and nitrogen in maize working under similar agro-ecological conditions. Sahoo and Panda (2009) observed increased baby corn yield with increased levels of nitrogen from 80 to 160 kg ha^{-1} and the increase was more during winter than in wet season.

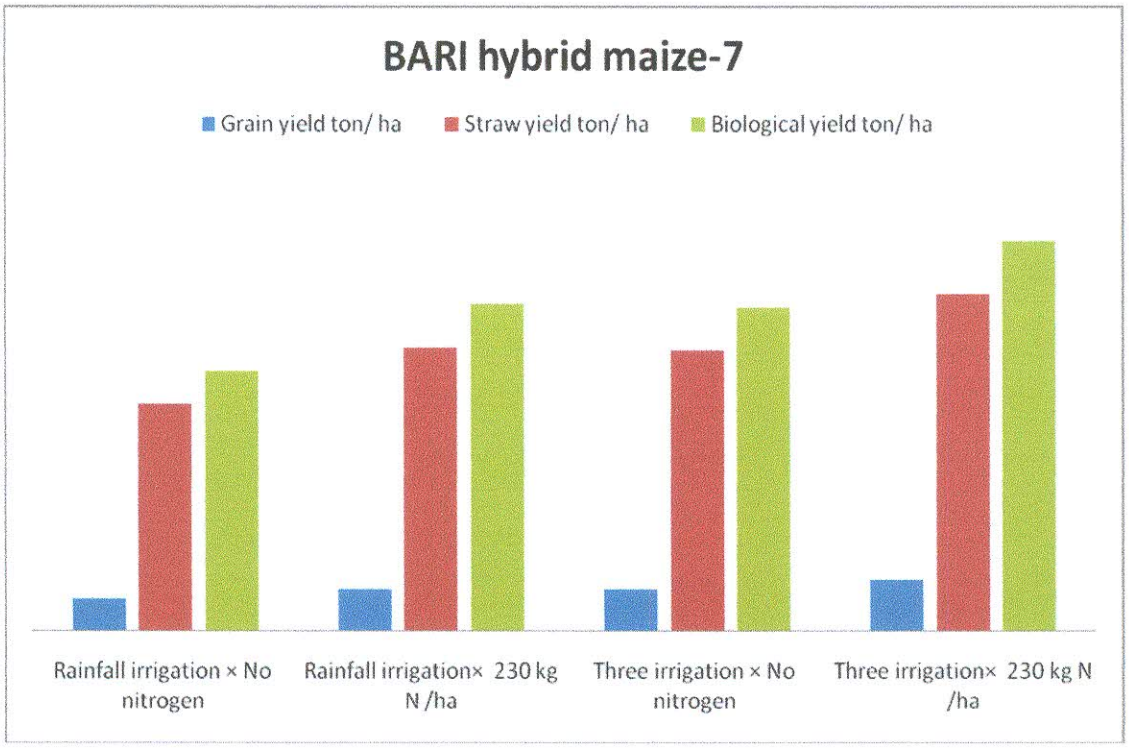
4.3.18.1. Straw yield

Straw yield t ha^{-1} was showed positive effect positively among the interaction effect of irrigation and nitrogen treatments in BARI maize-7 (Table 11).The most vegetative yield t ha^{-1} 64.49 produced in three irrigations with 230 kg/ha nitrogen levels which was statistically dissimilar with others treatments. The lowest vegetative yield t ha^{-1} 45.33 counted in rainfall irrigation with no nitrogen levels and statistically differs from any others treatments. The straw yield t ha^{-1} graphs irrespective of nitrogen levels treatment resulted in a usual graph of different irrigation and nitrogen treatments within yield performance i.e. straw yield values increased with the increasing of nitrogen levels

(Fig.25). Its resulted probably due to irrigation and nitrogen levels increased the straw production in an optimum level. Afterwards inspective of increased of irrigation and nitrogen level decline the straw production. Tisdale et al., (2010) found the study was therefore, undertaken to determine the optimum level of irrigation schedules and nitrogen rates for enhanced straw yield and its components under semi arid irrigated conditions. Gaur (2011) reported higher stover yield at 60 kg "N" $ha^{-1.}$

4.3.18.2. Straw yield

Straw yield t ha^{-1} showed significant positive effect among the interaction effect of irrigation and nitrogen treatments in BARI maize-9 (Table 12). The most vegetative yield t ha^{-1} 67.08 produced in three irrigations with 230 kg/ha nitrogen level which was dissimilar with others treatments. The lowest vegetative yield t ha^{-1} 45.41 counted in rainfall irrigation with no nitrogen levels and it also differs from any others treatments. The straw yield t ha^{-1} graphs irrespective of irrigation and nitrogen levels treatment resulted in a usual curve of different irrigation and nitrogen treatments with replication in yield performance i.e. straw yield values increased with the increasing of irrigation and nitrogen levels (Fig.25). Its resulted might probably due to irrigation and nitrogen levels increased the straw production in an optimum level. Afterwards inspective of increased of irrigation and nitrogen level decline the straw production. Total biomass yield achieved in this study is similar to other work (Bangarwa, 2008; Muchow, 2009; Ahmad, 2008; Shah, 2011; Rasheed, 2012).



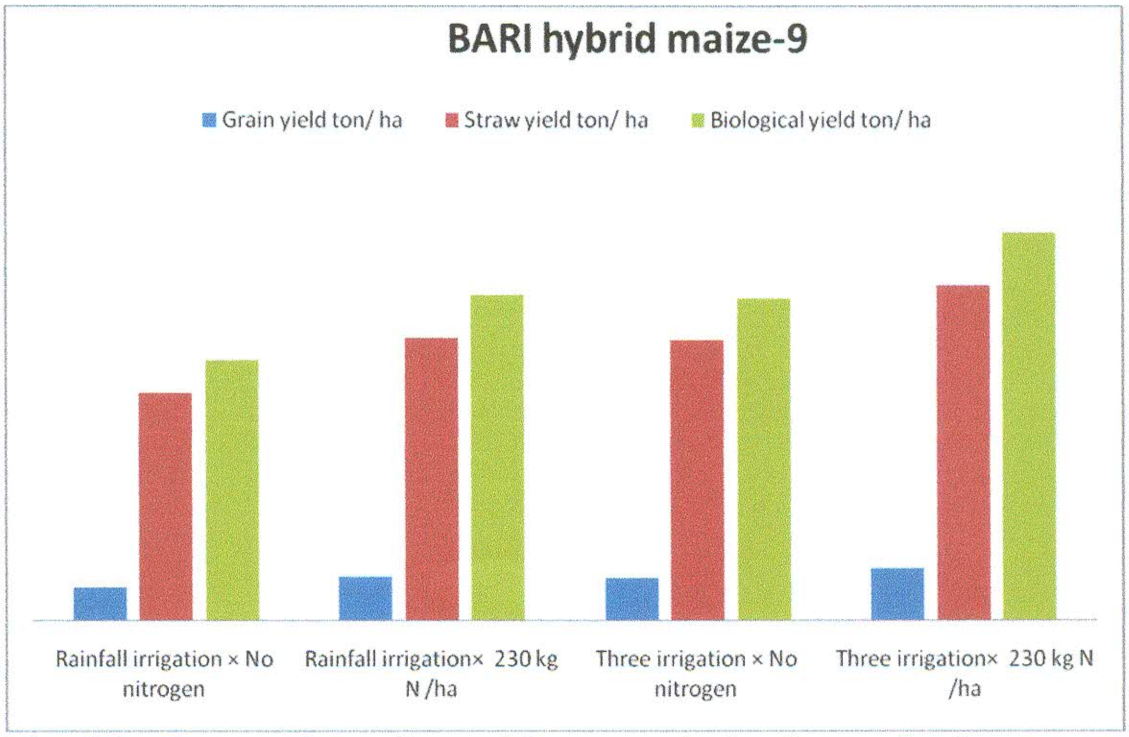


Fig. 25. Interaction effect of between irrigation and nitrogen on grain yield ton /ha, straw weight ton /ha and biological yield ton /ha of experimental maize varieties

4.3.19.1. Biological yield

Biological yield t ha^{-1} of BARI hybrid maize-7 showed significant effect on by interaction of irrigation and nitrogen treatments (Table 11).The maximum biological yield t ha^{-1} 74.64 obtained three irrigations with 230 kg/ha^{-1}nitrogen levels which was statistically differs from any others treatments. The lowest vegetative yield t ha^{-1} 51.75 counted rainfall irrigation with no nitrogen use and differs from any others treatments. The biological yield t ha^{-1} graphs irrespective in irrigation and nitrogen treatment resulted in a usual graphs i.e. biological yield values increased with the increasing of irrigation and nitrogen levels (Fig.25). Afterwards inspective of increasing irrigation and nitrogen levels decline the biological yield. Maximum biological yield and greater water use efficiency were achieved when irrigating to 100% of field capacity (Mbagwu & Osuigwu, 2005). Highest biological yield was obtained with 120 kg K2O ha^{-1} and irrigation at 25% depletion of available soil moisture (Patel et al., 2005).

4.3.19.2. Biological yield

Biological yield t ha^{-1} of BARI hybrid maize9 was significant effect influenced by interaction effect of irrigation and nitrogen treatments (Table 12). The maximum biological yield t ha^{-1} 77.50 obtained three irrigations with 230 kg/ha nitrogen levels which was statistically differs from any others treatments. The lowest vegetative yield t ha^{-1} 51.75 counted rainfall irrigation with no nitrogen use and it also statistically differs from any others treatments. The biological yield t ha-^{1} graphs irrespective in irrigation and nitrogen treatment resulted in a usual curve of different irrigation and nitrogen treatments within yield performance

Table-12 : Interaction effect of irrigation and nitrogen on the yield and yield performance of BARI hybrid maize-9

Treatments	Cob length (cm)	Cob grain free (cm)	Cob girth (cm)	Grain line cob^{-1} (no)	Grain number line^{-1} (no)	total grain cob-^{1} (no)	Grain weight cob^{-1} (g)	1000 Grain weight cob^{-1} (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
No Irrigation and No nitrogen	21.83	1.5	14	12.67	43.33	531	128.33	152.62	6.45	45.41	51.9	0.13
No Irrigation and 230 kg/ha nitrogen	23	0.67	14.33	13.25	48.83	631.17	160.33	258.17	8.53	56.5	65.03	0.14
Three Irrigation and no nitrogen	22.17	1.83	14.92	13.5	45.33	590.17	154.83	268.02	8.33	56.04	64.37	0.13
Three Irrigation and 230 kg/ha nitrogen	23.33	1	15.67	13.83	50.83	690.5	186.83	273.59	10.41	67.08	77.5	0.14
Sd	0.69	0.51	0.73	0.51	3.37	67.23	23.98	57.34	1.61	8.84	10.45	0.03
Cv(%)	3.09	41.25	4.97	3.89	7.17	11.00	15.22	24.08	19.20	15.72	16.151	4.27
Level of significance	*	*	**	NS	**	**	*	**	**	**	**	NS

In a column figures having common letters(s) do not differ significant as per DMRT
**Indicates 1 % and * indicates 5% level of probability
NS indicates not significant

i.e. biological yield values increased with the increasing of irrigation and nitrogen levels (Fig.25). Afterwards inspective of increasing irrigation and nitrogen levels decline the biological yield (Shah, S.A.H., 2011). Thakur and Sharma (2009) concluded that the application of nitrogen @ 150 and 200 kg ha^{-1} gave 29.2 and 37.6 percent higher biological yield, respectively over 100 kg N ha^{-1}.

4.3.20.1. Harvest index

Interaction effect of irrigation and nitrogen treatments harvest index showed insignificant effect in BARI hybrid maize-7(Table 11). The maximum harvest index 0.14 obtained three irrigations with 230 kg/ha nitrogen levels. The minimum harvest index 0.13 found with all the treatments accept three irrigations with 230 kg/ha nitrogen levels and statistically differs from any others treatments. Its resulted due to irrigation and nitrogen levels increased with the harvest index not significantly increased. Results showed lower harvest index values in lower nitrogen and irrigation rates. Bindhani et al. (2007) reported that the nitrogen content both in baby corn and green fodder not increased significantly with increasing N levels up to 120 kg ha^{-1}. Nitrogen application also enhanced nitrogen uptake and harvest index up to 120 kg ha^{-1} (Ashok Kumar, 2009).

4. 3.20. 2. Harvest index

Harvest index had insignificant effect influenced by interaction effect of irrigation and nitrogen treatments in BARI hybrid maize-9 (Table 12). The maximum harvest index 0.14 obtained three irrigations with 230 kg/ha nitrogen levels and no irrigation with 230 kg/ha nitrogen levels. The minimum harvest index 0.13 found in irrigation with. 230 kg/ha nitrogen levels with all the above treatments were not statistically differ from any others. Its resulted probably due to irrigation and nitrogen levels increased with the harvest index not significantly increased. According to Muchow (2008) higher grain yield in maize was associated with higher HI. Since higher HI depends on the proportion of pre-and post-anthesis growth and its partitioning to grains, the differences in HI may simply be a consequence of their respective growth stage duration.

Chapter Five

Summary and Conclusion

Chapter-FIVE

Summary and Conclusion

5.1 Summary

5.1.1 Effect of irrigation:

Effect of irrigation brought out significant variations on growth and yield of BARI hybrid maize-7 significantly affected by irrigation of maize growth and yield characters viz. plant height, plant girth, total tillers plant^{-1}, effective tiller plant^{-1}, non-effective tiller plant^{-1}, total roots plant^{-1}, straw weight plant^{-1}, straw yield t ha^{-1}, cob grain free length, cob girth, grain number line^{-1}, total grain cob^{-1}, grain weight cob^{-1}, 1000 grain weight cob^{-1}, grains yield t ha^{-1}, straw yield t ha^{-1}, and biological yield t ha^{-1} but irrigation not response in cob length, grain line cob^{-1} and harvest index (%) (Table 1 and 3). In the other variety of BARI hybrid maize-9 significantly affected by irrigation data on different growth and yield parameters such as plant height, plant girth, total tillers plant^{-1}, effective tiller plant^{-1}, non-effective tiller plant^{-1}, total roots plant^{-1}, straw weight plant^{-1}, straw yield t ha^{-1}, cob girth, grain number line^{-1}, total grain cob^{-1}, grain weight cob^{-1}, 1000 grin weight cob^{-1}, grains yield t ha^{-1}, straw yield t ha^{-1} and biological yield t ha^{-1} but irrigation not response in cob length, cob grain free length, grain line cob^{-1} and harvest index (%) (Table 2 and 4). In this study, higher values of growth and yield obtained when irrigation was scheduled at three time available soil moisture depletion.

The higher values of growth attributes under two and all three irrigations were recorded as better soil moisture maintained in readily available range might have favored the progressive growth of plant in terms of growth characters. Similar results were also reported by Silvakumar and Iruthayaraj (2008) for plant height, Herbst et al., (2011) for number of leaves plant $^{-1}$, Silvakumar and Iruthayaraj (2008) for plant girth. Significantly higher grain and stover yields were noticed under all three irrigation than alternate and other irrigation but the differences in values of grain and stover yields between all three and two irrigations methods were remarkable (Table 2). In three irrigation, plant can utilize the applied water effectively thus induce better nutrient uptake and also provides barrier by acting as soil mulch to direct movement of water from the field, resulting in increased infiltration of water into the soil and decreased loss of water through evaporation from the parts that are covered by large canopy. All these might have provided favorable conditions to the crop, as a result, growth attributes like plant height, number of leaves plant^{-1}, stem girth and dry matter accumulation plant^{-1} showed an increase and consequently brought out a cumulative effect on grain and stover yields and resulted in higher grain and cob yields under all three and two irrigations as compared to rest methods of irrigation. These results are in conformity with the results reported by Silvakumar and Iruthayaraj (2008), Herbst et al., (2011) and Ahmad et al. (2008).

5.1.2 Effect of nitrogen

The observations we had find out that different growth and yield parameters in BARI hybrid maize-7 influenced significantly affected by nitrogen viz. plant height, plant girth, straw weight plant^{-1}, straw yield t ha^{-1}, cob length and harvest index (%) but nitrogen no response in total tillers plant^{-1}, effective tiller plant^{-1}, non-effective tiller plant-^{1}, total roots plant^{-1}, cob grain free length and harvest index (%) (Table 05 and 07). In the other variety BARI hybrid maize-9 the observations different growth and yield parameters influenced significantly affected by nitrogen viz. plant height, plant girth, total roots plant-^{1}, straw weight plant^{-1}, straw yield t ha^{-1}, cob length, cob grain free length, cob girth, grain line cob^{-1}, grain number line^{-1}, total grain cob^{-1}, grain weight cob^{-1}, 1000 grain weight cob^{-1}, grains yield t ha^{-1}, straw yield t ha^{-1} and biological yield t ha^{-1} but nitrogen no response total tillers plant^{-1}, effective tiller plant^{-1}, non-effective tiller plant^{-1} and harvest index (%)(Table 6 and 8).

Nitrogen levels had pronounced effect on growth and grain yield. Nitrogen application @ 230 kg ha^{-1} being at par with no nitrogen uses and 115 kg ha^{-1} produced significantly higher among four irrigation levels growth and grain yield but no statistically differs 345 kg/ha (Table 05, 06, 07 and 08). Application of 115 kg N ha^{-1} registered the low and no nitrogen uses showed lowest growth and grain yield. It was observed that nitrogen application significantly influenced dry matter production, chiefly by increasing the total tillers plant^{-1}. Hence, the variation in growth and grain yield due to different levels of nitrogen was related to the differences in size of photosynthetic surface and to the relative efficiency of total sink activity. Warrson (2007) stated that nitrogen had far more potent influence on the total photosynthesis of plants through its effect on the total tillers plant^{-1}. All these might have cumulatively produced higher growth and grain yield under the highest level of nitrogen but no differs with over nitrogen doses 345 kg/ha. The present findings lend support from the results of Silvakumar and Iruthayaraj (2008), Singh et al. (2012), Padmaja et al. (2014) and Patel et al. (2009).

5.1.3 Interaction effect of between irrigation and nitrogen

The interaction effect between irrigation and nitrogen levels also brought out significant variations of BARI hybrid maize-7 and BARI hybrid maize-9. The interaction effect of irrigations and nitrogen levels significantly influenced on BARI hybrid maize-7 and BARI hybrid maize-9 of different growth and yield parameters viz. plant height, plant girth, total tillers plant^{-1}, effective tiller plant^{-1}, non-effective tiller plant^{-1}, total roots plant^{-1}, straw weight plant^{-1}, straw yield t ha^{-1}, cob length, cob girth, grain line cob^{-1}, grain number line^{-1}, total grain cob^{-1}, grain weight cob^{-1}, 1000 grin weight cob^{-1}, grain weight cob^{-1}, 1000 grain weight cob^{-1}, grains yield t ha^{-1}, straw yield t ha^{-1} and biological yield t ha^{-1} but no response in cob grain free length and harvest index (%)(Table 9, 10, 11 and 12).

We have been continuously examine the nitrogen fertilizer and irrigation reaction of commonly cultivated maize hybrids for nearly three years at farmer field. Upon evaluating the results, it can be established that year significantly influences on growth and yield. This is more than the effect of irrigation at the applied agro technical elements, the growth and yield increasing effect of nitrogen fertilization is the greatest and can even be greater than the effect of year. The growth and yield increasing effect of nitrogen fertilizer can be reliably detected with small and medium doses, but at higher doses, where it is not worth applying more nutrients. Cultivation with irrigation can only be done with appropriate nutrient supply, due to the positive correlation of the two factors. The positive correlation also means that if the water supply of the plant declines, less fertilizer is needed for safe production. The two factors (irrigation and nitrogen fertilizer) have to be increased or decreased at the same time.

5.2 Conclusion

5.2.1 Effect of Irrigation

This study evaluated the effect of different seasonal irrigation amounts on maize growth, grain yield, water use efficiency, and net return in a sub humid climate during 2012 and 2014. Increased water amounts resulted in a relatively higher yield, since water deficit was the main yield-limiting factor. This finding supported the hypothesis that less water stress would produce higher yield. In those years, seasonal water applied and grain yield of maize exhibited strong quadratic relationships. The average growth and yield response factor, which are indicates the effect of water stress on reducing crop growth and yield. The value of response factor obtained for this study could be used for the purposes of irrigation management and water allocation scheduling over irrigation schemes under limited irrigation water supply. In the research observations data on different growth and yield of BARI hybrid maize-7 and BARI hybrid maize-9 significantly affected by irrigation such as plant height, plant girth, total tillers plant^{-1}, effective tiller/plant, non-effective tiller plant-^{1}, total roots plant-^{1}, straw weight plant^{-1}, straw yield t /ha, cob grain free length, cob girth, grain number line^{-1}, total grain cob^{-1}, grain weight cob-^{1}, 1000 grin weight cob^{-1}, grains yield t ha^{-1}, straw yield t ha^{-1}, and biological yield t ha^{-1} but irrigation statistically not response in cob length, grain line cob^{-1} and harvest index (%)(Table 1, 2, 3 and 4). In this study, higher values of growth and yield obtained when irrigation was scheduled at three time available soil moisture depletion. On the other hand, full irrigation gave the highest net return. Finally, the overall results clearly revealed that in order to obtain higher yield and net income of maize in a sub-humid climate three irrigation levels, crops during the winter season should be irrigated at 100% soil water depletion every irrigation level. The results also suggest that two irrigations approach may be a good strategy for increase water use efficiencies when full irrigation is not possible.

Irrigation levels had significant impact on the growth and root system of maize. Root spread and nutrient uptake were increased under three irrigations practices while rooting depth was more under surface irrigation as a result maize plant growth and yield easily increased. More irrigation with water soluble fertilizer improved the root system by inducing new secondary roots which are succulent and actively involved in physiological responses of growth and yield. Three irrigations had pronounced effect on the growth and root architecture especially in the production of highly fibrous root system and fertilizer uptake. Irrigation promotes the production of intensely branched roots, plant growth and yield that facilitates nutrient acquisition and foraging capacity. On the other hand, conventional method of irrigation and fertilizer application has exhibited limited root spread in the soil surface.

Although the modern irrigation systems such as rainfall, one irrigation, two irrigations and three irrigations have contribution in lowering the water used for maize comparing to the traditional method used in the region, the soil water and rooting depth monitoring for irrigation scheduling led to a considerable reduction in irrigation water compared to the other irrigation system. However, increasing the soil moisture build up within the root zone in long term would be a great concern when considerable water saving is achieved.

One alternative to this short come would be leaching during the precipitation time by flooding the soil with an efficient management program; otherwise the soil moisture build up would be a severing problem.

It was concluded that irrigation method and water quality significantly affected the maize crop yield. Three irrigations system was found very efficient irrigation system over other irrigation system even in marginal and poor water sources. It was concluded that the maize crop yield and water use efficiency was high in optimum irrigation system with good quality water. For good quality water, the three irrigations system produced more crop production over rainfall, one and two irrigation system. Hence, three irrigations system was more efficient for loamy soil. It was also found that in three irrigations and raised-bed the crop production was reduced due to the use of marginal and poor quality and quantity of water. It is recommended that three irrigations could be adopted where groundwater quality and quantity is marginal to hazardous quality to get high crop production and water use efficiency.

5.2.2 Effect of nitrogen

The results revealed that nitrogen sources affected growth parameters at all sampling occasions. Nitrogen enhanced growth and yield of BARI hybrid maize-7 and of BARI hybrid maize-9. Also, Fresh and dry matter yield was significantly affected by nitrogen sources. The observations on different growth and yield parameters in BARI hybrid maize-7 and BARI hybrid maize-9 influenced significantly affected by nitrogen such as plant height, plant girth, straw weight plant^{-1}, straw yield t ha^{-1}, cob length and harvest index (%) but statistically nitrogen no response in total tillers plant^{-1}, effective tiller plant^{-1}, non-effective tiller plant^{-1}, total roots plant^{-1}, cob grain free length and harvest index (%)(Table 5,6,7 and 8).

The results obtained showed that Nitrogen fertilizers influence on the Phenology of varieties under investigation, so emergence of pollen, tassel and inoculation are accelerated with increasing of fertilizer but the dough and physiological maturity of the grain filling time is delayed and this led to reduce in growth period duration and duration of pollination and grain filling increased. Regarding the effect of auxin on the growth of maize Kleoptil (Hatfielt *et al.,* 2011), Gibberellins on accelerating the emergence of growth and development, Change the vegetative to reproductive development and maturation (Evans *et al.,* 2008), and stockings on the growth and development of maize (Herbst et al., 2011). It seems that the nitrogen fertilizer used in the study by this way and production of growth hormone and stopping the activity of ethylene have impact on plant hormone balance and cause chancing in phenological varieties under investigation which was done during experiment years (Mohammoud, 2012).

Maize is a cereal crop and heavy feeder, which requires higher amounts of nutrients to maintain higher production. Use of inadequate quantity of fertilizers coupled with declining native/original soil fertility often leads to nutrient deficiencies and reduced production of this crop. In Bangladesh, numerous studies have been conducted on winter season maize, but there is lack of such studies in winter maize. Among nutrients, N is the most limiting in Bangladesh soils and drastically curtail maize productivity. This is more grain production, when we look at the fact that winter season maize removes 29.9 kg N per ton of grain produced (Shivay *et al.,* 2000). The response of winter maize to N has been reported in different region of northern and western Bangladesh (Singh et al, 2010; Moga *et al.,* 2006). However, the collective influence of N fertilization on winter maize is scanty and least investigated. Nitrogen determines the setting and maintenance of the photosynthetic potential of the canopy and the plant reproductive capacity. Both nutrients must be supplied in adequate amounts and timings to ensure an optimum physiological state at flowering, the stage around which the number of grains per unit surface area is established (Torbert *et al.,* 2011; Grbill *et al.,* 2011). Nitrogen deficiencies reduce grain yield by affecting both grain number and weight. The number of ears per plant and the number of grains per cob are affected by N level (Toosey *et al.,* 2012). The growth is also affected by the quantity and the time of application of N. Though the interaction of these important nutrients has been studied by many workers, their effect on winter maize was least studied. Weather parameters in Bangladesh are highly variable from season to season and region to region, which urges upon location-specific recommendation for higher maize production. This study was designed to assess the impact of fertilization independently and interactively on the productivity, nutrient uptake and economics of maize that was grown in untraditional winter season.

Our results showed that a dose of 230 kg N ha^{-1} can provide significantly higher grain yield of winter maize, it was comparable with 115 kg N ha^{-1}. A combination of 230 kg N ha^{-1} results in significantly higher values of yield attributes, yield, nutrient uptake and economic returns. This may be worth-recommending. But, it would be better, if recommendation is made based on the economic optimum doses for winter maize. The study provides recommendation of N for winter maize based on economics.

5.2.3 Effect of interaction between irrigation and nitrogen

Irrigation water dissolved the nitrogen and made available to the maize crop. The interaction effect between irrigations and nitrogen levels significantly influenced on BARI hybrid maize-7 and BARI hybrid maize-9 observations data of different growth and yield parameters such as plant height, plant girth, total tillers plant^{-1}, effective tiller plant^{-1}, non-effective tiller plant^{-1}, total roots plant^{-1}, straw weight plant^{-1}, straw yield t ha^{-1}, cob length, cob girth, grain line cob^{-1}, grain number line^{-1}, total grain cob^{-1}, grain weight cob^{-1}, 1000 grain weight cob^{-1}, grain weight cob^{-1}, 1000 grin weight cob^{-1}, grains yield t ha^{-1}, straw yield t ha^{-1} and biological yield t ha^{-1} but statistically no response in cob grain free length and harvest index (%) (Table 9, 10, 11 and 12). These results are in conformity with many other scientists. From the above discussion it could be concluded that application of 230 kg N ha^{-1} with three irrigations would be better for growth and yield of maize.

Evaluating the results of the experiment, we found that N fertilizer significantly influenced on the efficiency of irrigated maize production. In irrigated cultivation, the condition of efficient farming is ensuring appropriate nutrient supply. Our experimental data have justified the results of previous researches results according to which, the amount of precipitation or the moisture stored in the soil modifies the fertilizer effect, meaning that less fertilizer is needed with lower water supply. According to the results of the experiment, 230 kg N/ha and three irrigations recommended in any condition, since compared to the no N-dose and rainfall irrigation, it did not increase the yield of maize considerably. In droughty years, it caused a significant yield decrease.

This amount of N fertilizer dose unambiguously results in over-fertilization (345 kg ha^{-1}), it decreases the profitability of maize production significantly and the farmers can expect a great loss as a result. Along with this, it also means a constant, potential source of danger since in irrigated cultivation the high dose of N-fertilizer can multiple the amount of nitrate leaching from the root zone, increasing the harm on ground waters. When determining the optimal amount irrigation, we have to consider the amount of applied N-fertilizer as well as the soil in order to avoid leaching from the upper layer.

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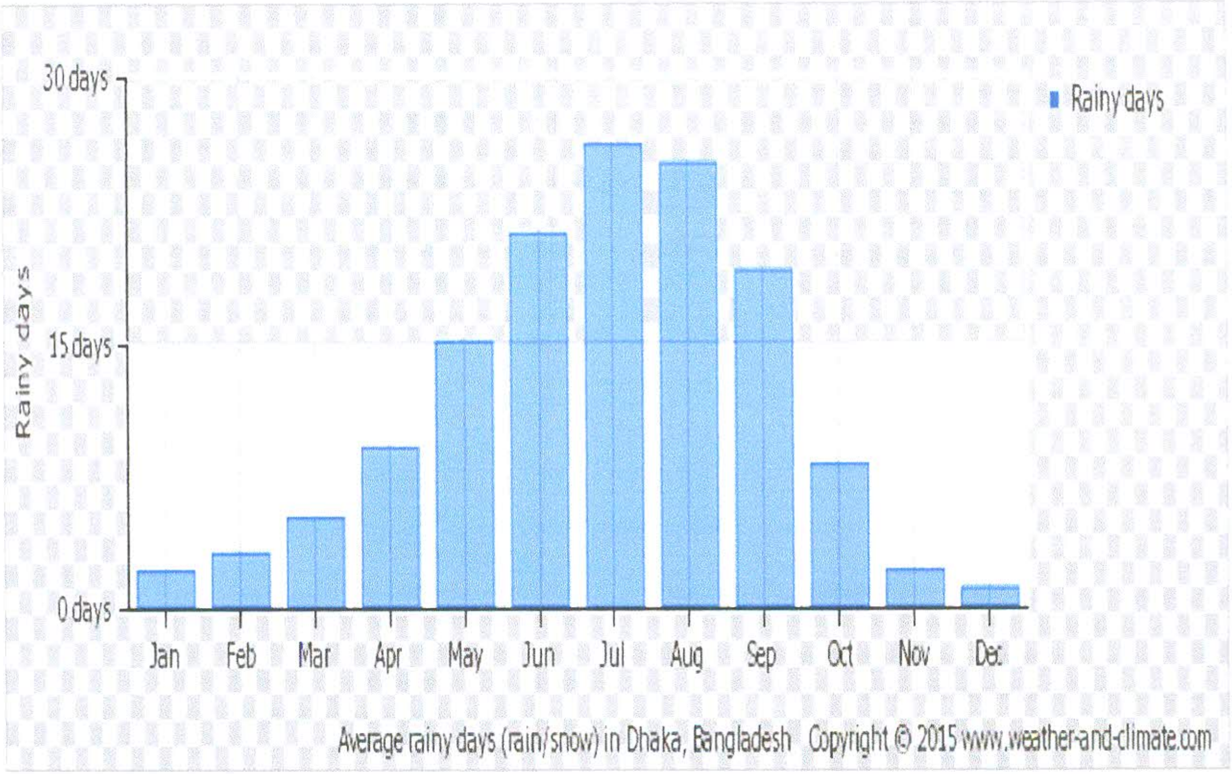
Plate. No. 01. Effect of irrigation on growth and growth performance of BARI hybrid maize-7

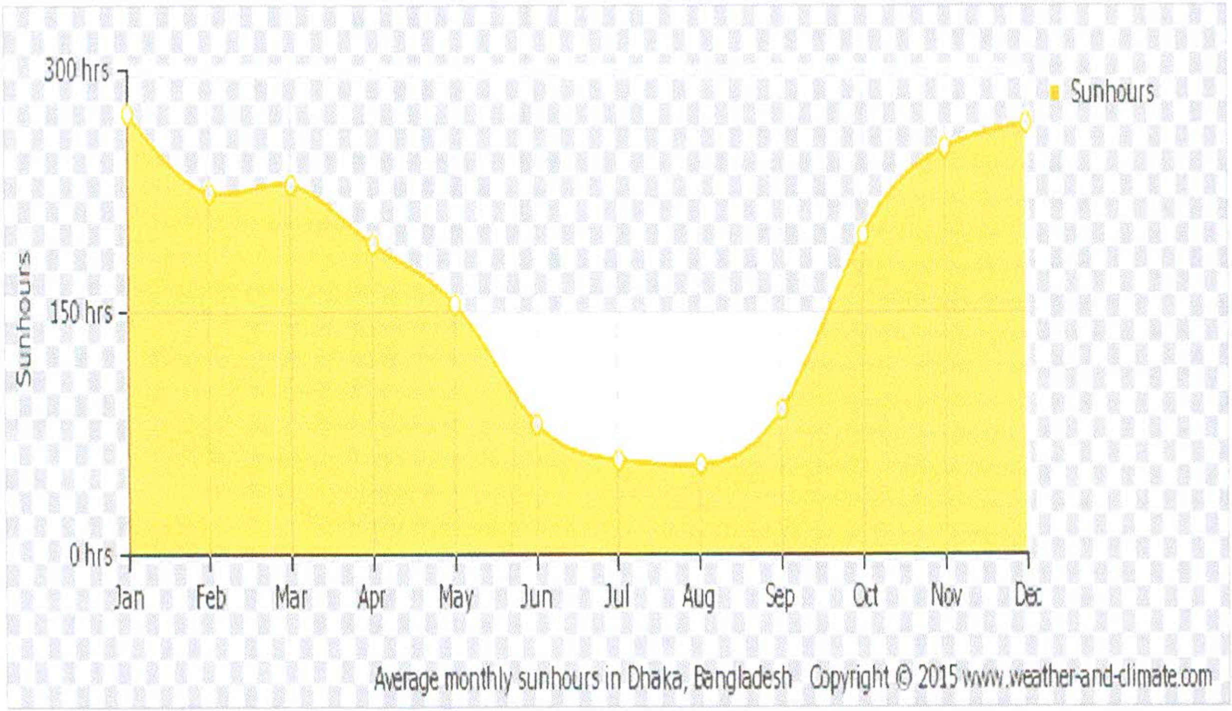
Plate. No. 02. Effect of irrigation on growth and growth performance of BARI hybrid maize-9

Plate. No. 03. Effect of irrigation on yield and yield performance of BARI hybrid maize-7

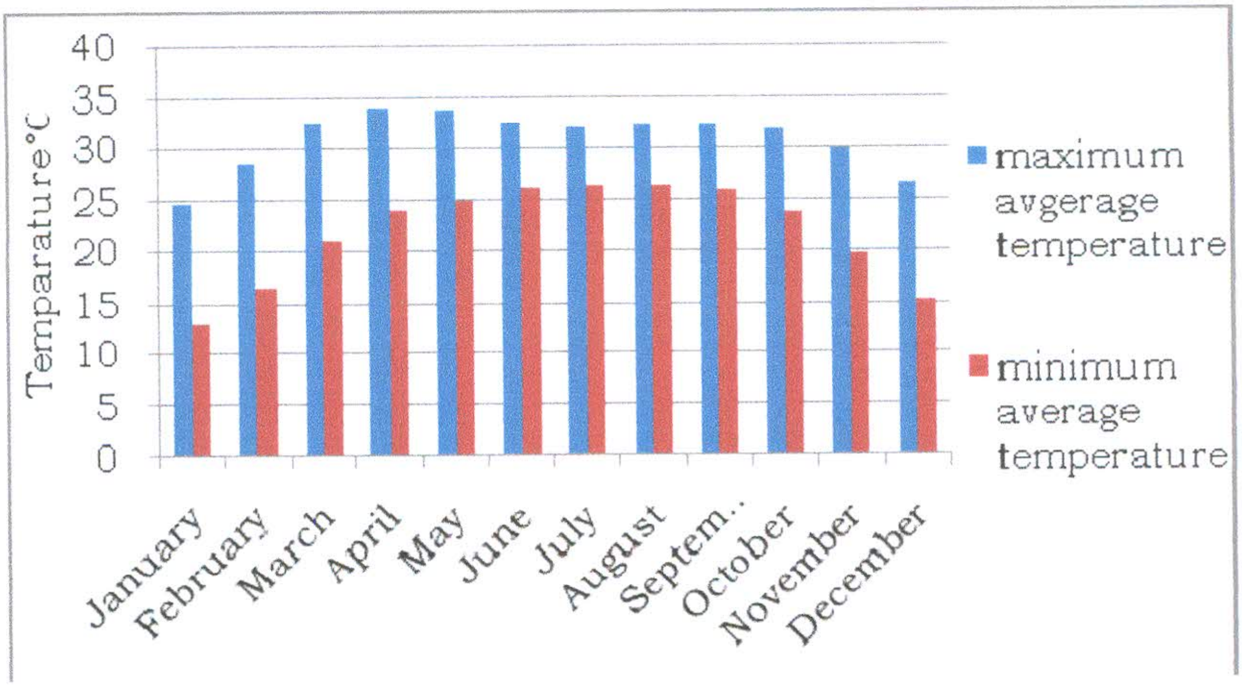
Plate. No. 04. Effect of irrigation on yield and yield performance of BARI hybrid maize-9



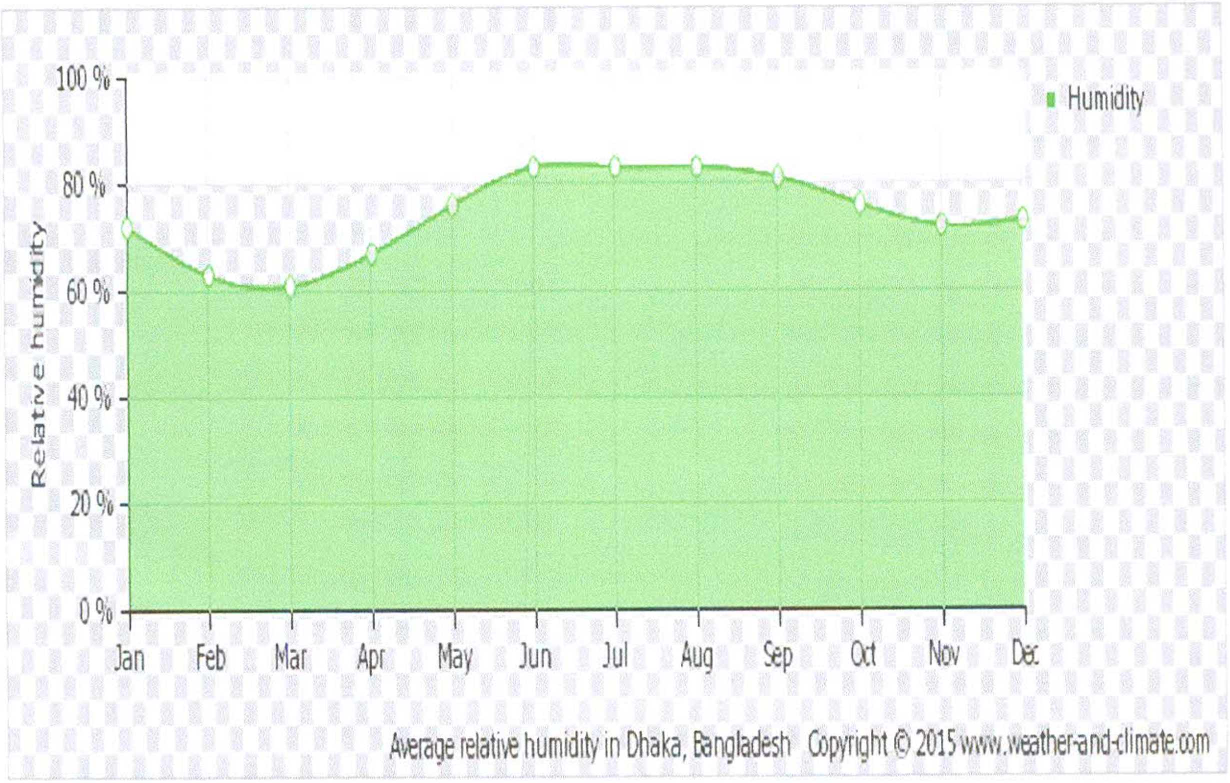
Appendix. Fig. 1: Average rainy days in Bangladesh during the experimental year, 2014 (BBS, 2015).



Appendix. Fig.2: Average monthly sun hours in Bangladesh during the experimental year, 2014 (BBS, 2015).



Appendix. Fig. 3: Average monthly temperature (^{0}C) in Bangladesh during the experimental year, 2014 (BBS, 2015).



Appendix. Fig. 4: Average related humidify in Bangladesh during the experimental year, 2014 (BBS, 2015).