# RIGATION WATER REQUIREMENT OF MAIZE CROP

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# RIGATION WATER REQUIREMENT OF MAIZE CROP

A Project Submitted

by

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**(Roll No. 100616018 F)**

In partial fulfillment of the requirements for the degree of

**Master of Engineering in Water Resources Engineering**

**DEPARTMENT OF WATER RESOURCES ENGINEERING**

**BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY (BUET)**

**Dhaka-1000, Bangladesh.**

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## RTIFICATE OF APPROVAL

We hereby recommended that the M. Engg. Project work submitted by Md. Golam Ambia Mahmud, Roll no. 100616018 F, Sesson- October, 2006 entitled ñAssesment of Irrigation Water Requirement of Maize cropò. has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Engineering in Water Resources on December 19, 2011.

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# DECLARATION

This is hereby certified that this project work entitled ñAssesment of Irrigation Water Requirement on Maize cropò has been done by me under supervision of Dr. Umme Kulsum Navera, Professor and Head of the Department of Water Resources Engineering (WRE), Bangladesh University of Engineering and Technology (BUET), Dhaka. I do declare that this project work or any part of it has not been accepted elsewhere for the award of any degree or dimloma from any other institutions.

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Signature of the candidate

## ABSTRACT

Water is one of the most important natural resources. The rationale use of this valuable resource is a dire need at present days because the useable water resource is diminishing very rapidly. Thousand of rivers are flowing through Bangladesh. The agriculture, transportation and economy of this country depends on these rivers. Irrigation for agriculture of this country mostly depends on surface and ground water. Bangladesh being a lower riparian country and the adverse effect of climate changes create less flow of these rivers. The less or no flow of these rivers resulting in shortage of irrigation water for agricultural production and these create a dire problem in agriculture sector for irrigation water in dry season of Bangladesh.

A study was conducted during the dry season (Rabi) in 2010-11 at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, to assess the irrigation water requirement of maize crop and to observe the impact of tillage methods on water use and maize yield. The effect of irrigation water on maize yield and to measure the impact of tillage practices on the surrounding environment was the other observatory object of this project work. The interactive effects of irrigation and tillage on the maize yield and yield contributing parameters of BARI Hybrid maize-6 were observed. The determination of suitable water requirement for maize crop with effective tillage method for maize cultivation and the saving of valuable water resources were the prime concern of this project study. Significant impact of irrigation water on maize yield was observed. Under $I_1$ irrigation treatment with zero ($T_1$), minimum ($T_2$) and traditional ($T_3$) tillage practices, the seasonal water requirements were 28.30 cm, 31.30 cm and 33.00 cm respectively. In $I_2$ irrigation treatment with zero, minimu and traditional tillage practices, the seasonal water requirements were 36.55 cm, 39.55 cm and 44.52 cm respectively and in $I_3$ irrigation treatment with zero, minimum and traditional tillage practices, the seasonal water requirements were 48.30 cm, 53.30 cm and 62.00 cm respectively.

Statistically no significant difference was found in $I_2$ and $I_3$ irrigation treatment for maize yield. In economical analysis, $I_3$ irrigation treatment was not suitable because a huge amount of water was required in this treatment and net returns was low in comparison to $I_1$ and $I_2$ irrigation treatments. The highest benefit cost ratio (BCR), yield and net returns were found in $T_2I_2$ treatment. In three tillage treatments, the maximum yields were found in $T_2$ (8.15 ton/ha) and $T_3$ (8.2 ton/ha) tillage treatments and lowest was found in $T_1$ (7.25 ton/ha) tillage treatment. The minor significant effects were found by differents tillage practices in yield and yield contributing characters of maize crop. From the economical analysis, the maximum net return was found in minimum tillage practices.

Therefore, $T_2I_2$ treatment combination is preferable for maize cultivation because maximum water resources can be saved in this treatments without compromising with yield of maize in dry season (Rabi) of Bangladesh. $T_2I_2$ is the environment friendly treatment combination for maize cultivation because this treatment combination consumes minimum amount of fuel for tilling purposes and required less water resources for irrigation purposes and produces minimum amount of carbon dioxide ($CO_2$) to the surrounding environment.

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## List of Abbreviation

| | |
|---|---|
| AFI | Alternative Furrow Irrigation |
| AEZ | Agro Ecological Zone |
| BARC | Bangladesh Agricultural Research Council |
| BARI | Bangladesh Agricultural Research Institute |
| BBS | Bangladesh Bureau of Statistics |
| BCR | Benefit Cost Ratio |
| BD | Bulk Density |
| BUET | Bangladesh University of Engineering University |
| CEGIS | Center for Environmental and Geographic Information Services |
| CPE | Cropping Pan Evaporation |
| CT | Conservation Tillage |
| CSO | Chief Scientific Ofiicer |
| DAE | Department of Agriculure Extension |
| DAS | Days After Sowing |
| EFI | Every Furrow Irrigation |
| EIA | Environmental Impact Assesment |
| ESCAP | Economic and Social Commission for Asia and the Pacific |
| ET | Evapotranspiration |
| $ET_C$ | Crop Evapotranspiration |
| $ET_0$ | Potential Evapotranspiration |
| FAO | Food and Agriculture Organization |
| FC | Field Capacity |
| FRG | Fertiliger Recommendation Gross |
| GDP | Gross Domestic Product |
| GIS | Geografic Information System |
| GPS | Global Positioning System |
| ha | Hactare |
| $I_1$ | One Irrigation 25 Days After Sowing |
| $I_2$ | Two Irrigation 25 and 50 Days After Sowing |
| $I_3$ | Three Irrigation 25, 50 and 85 Days After Sowing |
| IICT | Institute Of Information And Communication Technology |

| | |
|---|---|
| | nental Panel On Climate Change |
| | Requirement |
| IW | Irrigation Water |
| $K_C$ | Crop Coefficient |
| MC | Moisture Content |
| MPO | Master Planning Organization |
| MSS | Multi-spectral Scanner |
| MT | Metric Ton |
| NIR | Net Irrigation Reqirement |
| NPKSZB | Nitrogen Phosphorus Potasium Zink Boron |
| PD | Particle Density |
| SAFI | Semi- Alternative Furrow Irrigation |
| SOM | Soil Organic Matter |
| SPD | Split Plot Design |
| SRDI | Soil Resources Development Institute |
| $T_1$ | Zero Tyillage |
| $T_2$ | Minimum Tillage |
| $T_3$ | Farmer's Traditional Tillage |
| Tk. | Taka |
| t | Ton |
| UAO | Upazila Agricultural Office |
| UNDP | United Nation Development Program |
| UNEP | United Nation Environmental Program |
| UNRISD | United Nation Research Institute for Social Development |
| USA | United State Of America |
| WHO | World Health Organization |

# Chapter 1

# INTRODUCTION

## 1.1 General

Thousand of rivers are flowing through Bangladesh. The agriculture, transportation and economy of this country are largely depends on these river. Irrigation for agriculture of this country mostly depends on surface and ground water. The availability of surface and ground water directly depends on the sufficient flow of this river. The sources of these rivers are India, China and Myanmar. At present, Bangladesh being a lower riparian country and the diversion of river water by India and adverse effect of climate changes creates less flow of these rivers. The less or no flow of these rivers resulting in shortage of irrigation water for agricultural production and these create a dire problem in agriculture sector for irrigation water in dry season of Bangladesh.

Bangladesh is predominately an agricultural country. To feed her 143.32 million people from 8.2 million hectares of cultivable land is a difficult task (Hossain, 2009). Every year almost 0.20 million people are being added to the total population whereas the estimated annual shrinkage of agricultural land is about 0.10 million hectares due to various non-agricultural activities like constructions of houses, offices, roads, mills, factories etc. (BRRI, 2009). The contribution to national GDP by agriculture is about 19.95 percent.

The country lost a third of its agricultural land to accommodate more people as the population rose from 75 million in 1975 to 143.32 million at present (Karim et al., 2008). Therefore, to meet the demand of this fast growing population of this country from the limited land area, production per unit area must be increased with a faster rate of production. Since maize is a faster growing and high yielding cereal crop it can be cultivated to eliminate the shortage of cereal crop of our country. There was an insignificant amount of maize production in the early nineteenth decade in our country but in 1997-98, about 2,834 hectares of land were under maize cultivation with a production of 3,000 metric tons (BBS, 1999). The area is now expanded to 1,37,000 hectares and the corresponding production is 7, 83,640 metric ton (DAE, 2007).

Maize (*Zea Mays*) was originated in the Andean region of Central America. It is one of the most important cereals both for human and animal consumption and is grown for grain and forage. Maize has been found to be a very promising cereal crop. It can supply food, feed and fuel in relatively large quantity compared to other cereal crops. It can consume directly as green cob, roasted cob and popped grain. Maize can also be used for manufacturing starch, poultry feed, corn flakes, soap, varnishes, paints, printings and similar products (Ahmed, 1994). In addition, it has high nutritive values containing 66.2% starch, 11.1% protein, 7.12% oil and 1.5% minerals (Islam, et al., 2008). Pure 100 gm of dry weight of maize contains 90 gm carotene, 1.8 mg niacin 0.08 mg thiamin and 0.1 mg riboflavin (Thakur, 1980, Choudhury and Islam, 1993).

Maize grains have high nutritive values and it is used as food as well as fodder, feed and fuel. The demand of maize grains is increasing day by day. Maize is being cultivated all over the country but the yield of maize is low in Bangladesh as compared to other maize growing countries in the world. There are several constrains behind it, such as, lack of proper irrigation water application for maize cultivation. This factor plays an important role on production of hybrid maize (Sarif et al., 2009).

In Bangladesh, maize is the third most important cereal crop. Proper growth and development of maize needs favorable soil moisture up to its root zone depth. The moisture content of the soil gradually decreases with the passing of time during dry season in Bangladesh. Limited water supply during the growing season results in soil and plant water deficits and reduces maize yields (Gordon, et al., 1995; Patel et al., 2006). Irrigation scheduling is necessary for the most effective use of valuable water for optimizing maize production. Water deficit has little effect on timing of emergence of maize seedlings, number of leaves per plant but delayed tasseling initiation and silking, reduced plant height and vegetation growth of maize (Abrecht and Carberry, 1993; Singh et al., 2007). Improper scheduling of irrigation results not only in wastage of water but also decrease the crop growth and yield (Shaozong and Mingannang, 1992; Hussain et al., 2008). Among different agricultural elements of Bangladesh, irrigation is the key inputs for achieving higher yield of maize. Irrigation

; and made available to the crop for proper growth and ttempt has been made to evaluate the effect of irrigation water on the yield of maize.

Production of hybrid maize has been increased through optimum water application which was enhanced the root growth, nutrient availability and creates facility to uptake nutrient. Proper water application also reduces irrigation cost. So, for proper growth and development of hybrid maize, appropriate irrigation scheduling is needed (Lafound *et al*., 1992; Arshad *et al*., 1995). Despite evidences of benefit of irrigation management are available, a few works have been done in Bangladesh on irrigation management for maize cultivation.

Considering the manifold uses of maize, due attention is required to boost up the production of maize and to give more emphasis on improved cultivation practice for maize cultivation. Maize is a crop that harnesses soil nutrients and water at a higher rate. Irrigation is the most important for agricultural production and they have a prominent contribution to the cost of agricultural production. Now a days in Bangladesh for scarcity of irrigation water particularly in dry (Rabi) season (October-February) agricultural production cost has been increased. This increased production cost has been made the farmers reluctant to cultivate cereal crops (Rahman et al., 2008).

Irrigation water applied has been increased the agricultural production especially for maize crop, which was consumed a huge amount of water for its physiological activity resulting in acceleration of price of foods. For scarcity of irrigation water, the rationale use of irrigation water is more important. Therefore, for maize production, efficient and rationale use of water resources is a dire need. Winter maize (Rabi season) is grown in the driest period of the year when the rainfall does not occur frequently. So, for proper growth and development of the crop, irrigation becomes obvious. To ensure sustainable development in yield and soil health, appropriate irrigation scheduling and conservation tillage practices has no alternative. For a good potential yield, maize has to be grown under optimum water application. Over application of irrigation water for maize cultivation is not beneficial at all.

equires about 55.88 cm of water, with a range of 50.80 m-40.64 cm of water is enough to produce a low yield, but that depends on the season, weather and the availability of water. In general, higher yields need more water but factors like temperature affect this to some extent. One inch of water per acre is about 122850 liters per acre, so a corn crop uses about 50.80 x 122850 = 6240780 liters of water in every hectare of land (Luca, et al., 2003).

Tillage can be defined by the mechanical manipulation of the soil to improve its physical condition as a habitat for plants, to improve aeration and temperature conditions and to produce a firm seedbed. Tillage operations include the cultivation practices conducted by the various tillage implements such as mould board, chisel, duck foot chisel, harrow, etc. It is considered as the main cause of land degradation and desertification in hilly cultivated areas. There are several factors affecting tillage erosion such as type of tillage instrument, plough depth, wheel speed of the tractor, soil moisture content, slope gradient, direction of tillage operation, etc. Tillage erosion affects chemical and physical properties of soils such as organic matter content, available nutrients, soil structure stability, water holding capacity, etc. It exposes subsoil materials in the soil surface with low fertility and high content of rock fragments in many cases. Measurements have shown that the rate of soil loss from the upper steeper slopes can range from 0.2 to 1.4 cm, depending on slope gradient and surface characteristics (Source: European Union, http://www.websters-online-dictionary.org/definitions/Tillage+Operations).

Tillage aims to create a soil environment favorable to plant growth. Definitions of tillage vary; it is defined as physical, chemical or biological soil manipulation to optimize conditions for germination, seedling establishment and crop growth. Soil manipulation can change fertility status markedly and the changes may be manifested in good or poor performance of crops. In addition, tillage operations loosen, granulate, crush or compact soil structure, changing soil properties such as bulk density, pore size distribution and composition of the soil atmosphere that affect plant growth.

Tillage management can have a profound impact on soil properties. No tilled soils are generally wetted and can store more water compared with those that are tilled soil. However, in no tillage or minimum tillage system, yield becomes suppressed due to lage influences on aeration, root penetration but creates l activities. Therefore, the present study was under taken to study the effect of irrigation and tillage on the yield of hybrid maize. Conservation tillage (no tillage and reduced tillage) practices simultaneously conserve soil and water resources, reduce farm energy uses and increase or stabilize crop production. Conservation tillage leads to positive changes in the physical, chemical and biological properties of a soil (Gibbon, et al., 2007). Soil physical properties that are influenced by conservation tillage include bulk density, infiltration and water retention (Swmrg, 2004).

Conservation tillage practices improve the soil infiltration capacity. Improved infiltration of rainwater into the soil increases water availability to plants reduces surface runoff and improves groundwater recharge (Bredero et al., 1991). Minimum soil cultivation reduces farm energy requirements and overall farming costs because less soil pulverization has to be done for crop production (Madden et al., 2008). Infiltration and soil evaporation are the key processes that determine soil water availability to crops in arid agriculture. The presence of crop residue mulch (no tillage) at the soil interface has a direct influence on infiltration of rainwater into the soil and evaporation from the soil, resulting in less irrigation water requirement for maize and other crop cultivation. Mulch cover reduces surface runoff and holds rainwater at the soil surface thereby giving it more time to infiltrate into the soil. This conservation practices conducted in the higher potential areas of maize cultivation in Bangladesh for saving irrigation water is fruitful and mulching over soil surface significantly reduces surface runoff and hence soil loss (Alam et al., 2009).

Optimum irrigation water application and conservation tillage practice is done by putting previous crop residue in the field and that crop residue act as mulch for the land. Mulch cover shields the soil from solar radiation thereby reducing evaporation from the soil. Soil biota increase under mulched soil environment thereby improving nutrient cycling and organic matter build up over a period of several years (Holland, 2004).

Tillage practices provide a conditions for soil to intake water rapidly and temporary storage of water on the soil surface. At present, farmers are adopting the new tion agriculture that means optimum water uses and ultivation. This technology paved a way to save the irrigation water from excessive water uses for maize cultivation. It also saves the soil from erosion due to more soil pulverization. It is very important due to the shortage of labors at sowing period of crop in Bangladesh and has to be proven in agro-ecological zone in Bangladesh (Sarker, 2009).

The potential environmental benefits by changing soil management practices are now being recognized worldwide (Lal, 2000). In Bangladesh, however, soil degradation has only recently been identified as a widespread problem. This may include loss of structure leading to compaction, a decrease in soil organic matter and a reduction in soil organisms. Improper water application and soil management create a severe adverse condition for maize cultivation. Moisture is only retained in soil pore space so, mismanagement of soil develop the anaerobic conditions and that may negatively intense the process such as nutrient recycling of soil and will required more water (irrigated water) for crop production.

Optimum water should be utilized for maximum benefit and high yield. Modern high yielding crop practices system can be adopted only with good water management at the farm level. Optimum water availability to plants during their growth is essential for achieving the full yield production. Every year crop production is increasing due to more and more efficient utilization of water through better management practices. The optimum use of irrigation water should be an important strategy for increasing maize production (Sarker, 1987).

### 1.3 Scope of the study

Maize has been cultivated traditionally all over Bangladesh for two to three decades. Water is one of the most important factors in agricultural production. The studies relating to water saving with conservation agricultural practices for maize cultivation has not been conducted in Bangladesh. This project work has been focused on the saving of irrigation water and the yield of maize with the combination of three irrigation treatments and three tillage treatments during dry season (Rabi).

background and importance of maize production in
en taken which will provide an effective method of optimum water requirement and effective method for maize cultivation. Although a large number of experimental works on irrigation had done for various crop production but a little amount of experiment on irrigation for maize cultivation with tillage treatments had been done in Bangladesh. A little amount of work on application of irrigation water for maize cultivation with the combination of tillage practices for water saving purpose had done in Bangladesh. The present project work is to determine the optimum irrigation water requirement with suitable tillage practices for maize cultivation in the dry season (Rabi/ winter) of Bangladesh.

## 1.4 Objectives of the study

Considering above literature, giving emphasis on irrigation water saving with conservation agriculture the study has been undertaken to determine optimum water requirement and suitable tillage practices for maize cultivation. The experiment was set up for the following objectives.

### Objectives

1. To determine the optimum water requirement for maize cultivation under zero tillage, minimum tillage and traditional tillage method for maize cultivation.
2. To determine the effects of irrigation water on maize yields.
3. To determine the effects of soil tillage on water use.
4. To observe the effect of tillage practices on surrounding environment.

## 1.5 Structure of the report

This research work consists of six chapters. The contents of the chapters are as follows:

Chapter 1 includes general introduction, background and objectives of the study. Introductory information is written in this chapter as well.

review and review of previous similar studies. In this ind by different authors have been added and also a relevant idea of the new proposed technique has been discussed.

Chapter 3 contains the theory and methodology to describe about irrigation and tillage practices related term and the procedure to calculate water requirement for maize crop to reach the soil moisture at field capacity up to the root zone depth of maize crop and to discuss about various type of tillage practices for maize crop.

Chapter 4 contains the description of the study area, soil condition and climate related information of the study area.

Chapter 5 includes the results and discussions of this study which shows the preferable amount of water application and tillage practices for maize crop.

Chapter 6 includes the conclusions and recommendation of the study.

# Chapter-2

# LITERATURE REVIEW

## 2.1 General

The purpose of his chapter is to improve the knowledge by reviewing the previous research work that is relevant to the present project work. Here, this text deals with the water saving techniques and the land use pattern for agricultural production. Recent land use pattern changes due to saving the irrigation water and for resisting the environmental pollution from over pulverization of soil. In fact, this chapter gives the emphasis to review the most efficient use of water in maize cultivation. In Bangladesh for scarcity of irrigation water for maize crop cultivation especially in dry season (Rabi) is a common phenomenon. The purpose of this chapter is to increase the knowledge of irrigation and water saving method for maize cultivation.

## 2.2 Study on irrigation practices for maize cultivation

Igbadun et al., (2000) conducted an experiment on irrigation scheduling protocol which entails with irrigation at vegetative crop growth stage which gave the best productivity of water in terms of evapotranspiration and water application. They found crop yield based on the scheduling was not significantly different from the obtained result and control treatment, which was received regular irrigation at 7-day irrigation interval. A scheduling protocol which was entailed skipping every other irrigation at vegetative and at fruiting stage, but maintaining a regular 7-day irrigation frequency has been achieved the productivity of water in terms of evapotranspiration of 0.53 kg/m$^3$ and the productivity of water in terms of irrigation of 0.50 kg/m$^3$. Although the yield loss was as high as 19% with reference to the treatment under 7-day irrigation interval, the cost of water and labor were saved for large farms water users is a substantial amount. In period of serious water scarcity, this irrigation scheduling protocol can be practiced in the study area in order to release water for other users. They recommended that further research work might be carried out to evaluate the performance of the scheduling protocol across irrigation cropping seasons.

d an experiment on irrigation effect on maize yields in Greece. They used three treatment of irrigation with irrigation interval of 9 days, 12 days and 15 days (for investigation of plants waters stress) on four repetitions. They showed that the higher yield of maize was observed in the treatment with irrigation of 9 days interval which was followed by the yield of treatment with irrigation interval of 12 days and finally smaller was the yield in the treatment of irrigation every 15 days interval. They suggested that further research is necessary on using different irrigation interval and on different soil type and also on different season until more satisfactory and safer results are achieved.

Hasan et al., (2003) monitored the maize and wheat cultivation on raised bed with irrigation. They showed that maize on raised beds consumed less irrigation water in comparison to basins. The water savings of raised beds over basins was ranged from 16% to 83%, with an average value of 32%. There were seasonal variations in irrigation depths because of different rainfall amounts and distributions in each season. The least irrigation water was applied in 2002 and 555 mm rainfall was occurred. The number of irrigations applied was sometimes higher in raised beds but the amount of water applied in irrigation was always less than basins. The average amount of water per irrigation was 45 mm for beds and 70 mm for basins.  The seasonal differences in total irrigation amount were varied because of the rainfall occurrences and its distribution over each period. Lower overall irrigation water applied to raise beds is probably the result of reduced evaporation, less wetted area and soil configuration in the raised beds, and over-irrigation in the basins. The average amounts of water per irrigation for this crop were 46 mm for raised beds and 78 mm for basins. From the above experiment, it was found that in the raised bed irrigation for maize cultivation saved substantial amount of water in comparison to basin bed irrigation system for maize cultivation.

Tariq et al., (2003) monitored the total evapotranspiration of maize crop was 451 mm for the whole of the growing season and yield of the maize per unit water applied. The yield per unit volume of applied irrigation water was most significant measure for evaluating y found the average water use efficiency of maize ranged their experiment they concluded that optimum yield of maize can be obtained when crop is irrigated with a depth of 0.75 Epan (pan evapotranspiration).

Salam and Mazrooei (2006) conducted an experiment for irrigation water requirements of maize. They were estimated the water requirement by using the FAO CROPWAT model for the loamy sands of Kuwait. Agro-meteorological data of 43 years was used for that purpose. They reported that crop water requirement (ETc), irrigation requirement (IR) and net irrigation requirement (NIR) of maize vary with the planting date. Water use of grain maize was the lowest with planting date of 5 November. The period 25 October to 5 December is suitable for maize planting. The ETc of grain maize varied from 210 mm for a 90-day crop to 273 mm for a 110-day crop with planting date 5 November. The IR of grain maize varied from 126 mm for a 90-day crop to 179 mm for a 110-day crop with same planting date. The NIR varied from 1226 $m^3$ $ha^{-1}$ for a 90-day crop to 1898 $m^3$ $ha^{-1}$ for 110-day crop with planting date 5 November. Grain maize planting may not be advanced beyond 5 December, in order to economic water use. Water use of sweet corn (60 days) was the lowest with planting date of 5 December. The period 5 November to 15 December is suitable for sweet corn planting. ETc of sweet corn ranged from 125 mm (5th December planting) to 182 mm (15th October planting). The IR of sweet corn, ranged from 66mm (5 December planting) to 148 mm (15 October planting). The NIR (net irrigation requirement) of sweet corn was 532-$m^3$ $ha^{-1}$ with planting date on 5 December. Sweet corn planting may not be gone beyond 15 December, in order to economies the water use. An irrigation schedule was also developed for grain maize and sweet corn for the loamy sands.

Yushuf et al., (2006) have done a research work on farm research station in several districts of Bangladesh on maize and others crop sowing time and supplement irrigation requirement. They recommended that there is an opportunity for planting maize after aman rice in the Rabi season is from early November to late February. Based on the simulations, the optimum period of planting for maximum yield would likely be from late hen maize could utilize the residual soil water after rice imize water logging during crop establishment and might be efficient use of soil water in dry conditions during maturity. Likewise, during the Kharif-1 season, though the window for planting maize would be from late February to late May, simulations showed that the optimum time for planting from a yield potential point of view would be from late March to early May, when maize could utilize rainfall during the early-to mid- aman season. They revealed if planted too late, the crop would mature during the rainy months in July and August, when rainfall might cause disease and post-harvest processing problems. During both the Rabi and Kharif-1 seasons, some supplemental irrigation for maize might be necessary. To illustrate the effect of maize planting date, 01 December and 01 January were chosen for planting maize during the Rabi season in Bogra district. These dates were chosen because, as mentioned earlier, even though planting maize in November would give the highest yield potential, it might not be practical and feasible to plant in November due to late harvest of rice and soil water logging problems. They worked on variability of yield potential of hybrid maize of Rabi and Kharif-1 seasons, collected the data of rainfall during the growing seasons, and determined the irrigation water requirements to achieve yield potential of that hybrid Maize in Bogra. They got yield potential for 01 December planting across 20 years of simulations ranged from 11.0 to 15.8 t/ha, while that for planting on 01 January ranged from 10.6 to 15.6 t/ ha. Yield potential across years was less variable for 01 December planting than for 01 January planting rainfall during the season for 01 December planting ranged from 1 to 10mm, while that for a 01 January planting ranged from 3 to 13mm. Irrigation water requirements to achieve yield potentials across years ranged from 130 to 227mm for the 01 December planting, or 97 to 22 mm for the 01 January planting. In all 20 years there was virtually no rainfall, so irrigation was needed. They recommended for the pre-rice season, 01 April and 01 May were chosen for calculating irrigation water requirements of maize. These dates or scheduling were choosing for maize cultivation because these scheduling would allow the use of most growing season effective rainfall and would also require less irrigation water. This scheduling creates an opportunity for saving irrigation water.

n commercial fodder production and taken an experiment quirement for sorghum and maize production. They recommended that irrigation at every seven days at 40 mm (light and frequent) is recommended for fodder production of maize. This amount of water is applied for kharief season sowing (July/August) and also for winter sowing (November/December.). They gave emphasis to determine the irrigation schedule for the year-round for maize cultivation as fodder production. They said that water requirement for fodder production depends on the soil moisture capacity of the soil. They suggested for determine the irrigation water requirement for different irrigated farms for the crops grown (with different effective rooting depths). This irrigation scheduling will help to determine the length of the irrigation and the interval of the irrigation.

Shirazi et al., (2008) had conducted a field experiment in Bangladesh that was carried out to find out the response on yield and yield contributing parameters of maize to water stress and nitrogenous fertilizer. The experiment was included two factors such as five irrigation regimes and four nitrogen levels. Texturally, the soil was clay loam. Yield and yield contributing characters were significantly affected due to the application of irrigation and nitrogen. The highest grain yield of 6.77 t/ha was obtained with IW/CPE ratio of 0.5 and 5.61 t/ha by the application of 70 kg N/ha. Interactions between IW/CPE ratio of 0.5 and 70 kg N/ha were the best combination for yield and yield contributing characters of maize. They revealed that nitrogenous fertilizer and irrigation regimes are the important factors to yield and yield contributing characters of maize. Grain yield significantly influenced by the irrigation regimes. IW/CRE ratio of 0.5 irrigation treatment is the best treatment in respect of yield and yield contributing characters. Based on the interaction effect of irrigation and nitrogen for silty loam soil combination of IW/CPE ratio of 0.5 and 70 kg N/ha is the best one for yield and yield contribution of maize.

Yenesew and Tilahun (2009) conducted an experiment to assess yield and the water use efficiency of deficit irrigated maize in semi arid region in Ethiopia. They found that maximum maize biomass yield, grain yield and stover yield were obtained by applying oughout the growing season. They observed that fifty and late season stages resulted in statistically similar average grain yield and biomass as that of applying full irrigation requirement throughout the whole season. They revealed that meeting full water requirement during the first two growth stages of maize is not advisable if water shortage cannot be avoided during the remainder of the season, especially during the mid season stage. This indicates that the most critical period for irrigation is the mid season stage. However, if water stress is unavoidable at the mid stage, it is better to stress the crop one-half deficit than by three-quarters. When water stress is imposed early in the growing season, high yield of maize could easily be sustained provided adequate watering conditions take place during the rest of the growing season. They recommended, maize water use efficiency is lowest when optimum or maximum irrigation water is applied throughout the growth season and highest when water is stressed by three quarter throughout the growing season. Higher water use efficiency can be obtained by stressing maize crop by three-quarter deficit at individual growth stages than stressing by one-half deficit. Overall, a strategy of stressing maize by one-half at the beginning and end of season, and using the water to irrigate a greater area, results in higher aggregate production than providing optimum irrigation throughout the season for a smaller area.

Islam and Hossain, (2010) taken a study in Bangladesh to determine the crop co-efficient at initial, development, mid-season, and late season stages of hybrid maize (variety: BARI Hybrid Maize-I). They found the crop co-efficient values as 0.38, 0.87, 1.36, and 0.75 respectively from the lysimeter study for the selected maize variety. These locally determined values of crop co-efficient for BARI Hybrid Maize-I differed to some extent from FAO recommended values. The corresponding FAO values are 0.4, 0.80, 1.15, and 0.70 respectively. They suggested that some reasons might be behind those values to be differed from the standard values to some extent. They said those $K_c$ values were determined by matching the local conditions of soil, plant, and environment. They recommended that to use the local value of $K_c$ are more accurate for local purpose than the world standard ones. Another reason may be the use of specific variety of hybrid maize in that experiment. They suggested locally determined values are preferred to o estimate location specific crop ET. They recommended water requirement of BARI Hybrid Maize-I, the values determined under that study was suitable for use in Bangladesh.

Pandey et al., (2011) initiated a field study to investigate sweet corn variety (maize) performance for yield and yield components under treatments of every furrow irrigation (EFI), semi-alternate furrow irrigation (SAFI) and alternate furrow irrigation (AFI), with different planting densities in shallow and deep groundwater regimes. Plots under SAFI were irrigated every other furrow from sowing till six weeks, followed by full irrigation on every furrow till the end of growing season. Plots under EFI were irrigated every furrow throughout the growth period, while those under AFI were irrigated every other furrow throughout growth period. Results showed significant effects of the three irrigation regimes for fresh ear yield, 1000-kernel weight, ear diameter, cob diameter, number of kernel rows per ear, number of kernels per row, number of kernels per ear, and fresh ear weight. However, there was no significant difference on the effects between EFI and SAFI for all the traits measured in the study. That indicates that yield and yield components of sweet corn under SAFI treatment were comparable with those under EFI. They found that the fresh ear yield and number of kernels per ear were significantly higher under SAFI at the density of eight plants per m2 than the other irrigation treatment combinations. The results also revealed significant effects of planting densities for all the traits measured except fresh ear weight. Plants at lower density produced ears with higher quality, however the overall performance was found to be higher while the number of plants per unit area was higher. This might be due to the level of competition among the individual plants for water, sunlight and nutrients at the different planting densities. In general, sweet corn yield under SAFI at the density of eight plants per square meter was found to be same as those under EFI, with 30% less water supplied. It can be concluded that SAFI is a way to save water in arid and semi-arid areas where corn production relies heavily on repeated irrigation. They recommended that semi-alternate furrow irrigation (SAFI) can be used as a simple and efficient method for corn production in arid and semi-arid areas where production is heavily dependent on irrigation. SAFI method allows planting on large land area with efficient use of available water. This method enables the orn yield as those offered by EFI method, while utilizing us the improved irrigation management in combination with the optimum planting density can increase the performance of deficit irrigation scheduling in semi-arid regions where water is the most limiting input to crop production.

**2.3 Study on tillage practices for maize cultivation**

Wilhelm et al., (1991) reported that the reduced-tillage cropping systems has been emphasized the maize *(Zea mays*) developed cultivation under conventional tillage systems (moldboard plow, disk, and harrow), it is readily adaptable to conservation production systems (greater than 30% residue cover after planting). Field experiments were conducted in 1982 and 1983 near Lincoln, Nebraska, U.S.A., on an Abrupt Argiaquo and in 1983 near Gothenburg, Nebraska, U.S.A. under dry land and irrigated conditions, respectively, to evaluate the response of eight hybrids to several tillage practices. Tillage practices studied were moldboard plow, tandem disk, and no-tillage. Tillage practice had a significant effect on only plant emergence at Lincoln during 1983 and dry matter production at Lincoln in 1982 and Gothenburg in 1983. A significant effect was found in tillage for hybrid maize for dry-matter production at the tasseling stage at Lincoln during 1983; however, no significant interactions were observed for grain-yield among the hybrids and tillage systems investigated. Results indicate that adapted hybrids maize taste is need for relative grain-yield with both conservation and conventional tillage.

Islam et al., (2006) conducted an experiment at Regional Agricultural Research Station (RARS), Rahamatpur, Barisal, during Rabi season at 2006-07 and 2007-08 to study the effect of different moisture regime and tillage on soil physical properties and its impact on the yield of wheat. Twenty treatments combination comprising four tillage practices namely (zero tillage, tillage by country plough (5 to 6 cm depth), tillage by power tiller (10 to 12 cm depth), tillage by chisel (20 to 25 cm depth) and five levels of irrigation on the basis of IW/CPE ratio of 0.4, 0.6, 0.8, 1.0 and rain fed condition were tested in a split plot design with three replications. Irrigation and tillage had significantly influenced the yield and yield contributing characters of wheat. The highest marketable yield 4.5 t $ha^{-1}$

tillage ($T_3$) and irrigation ($I_3$), respectively. In case of the ...d irrigation, the highest yield 4.8 and 4.85 t ha$^{-1}$ were recorded at 2006-07 and 2007-08, respectively from $T_3$ $I_3$. They observed that the influence of tillage and/or irrigation had no significant effect on soil physical parameters during two years of conducting the experiment.

Alam et al., (2007) carried out a field experiment at Joydebpur on Grey Terrace Soil (AEZ-28) during Rabi season of 2007-2008 at central research farm of BARI, Joydebpur to study the effect of tillage and crop rotation system on the changes of soil properties. Twelve treatment combinations comprising three tillage practices i.e. $T_1$: minimum tillage, $T_2$: tillage at 6-8 cm depth and $T_3$: tillage at 10-12 cm depth and four crop rotation systems i.e. $C_1$: Maize, $C_2$ : Wheat-Fallow-T. Aman, $C_3$: Wheat-G.M.,T. Aman and $C_4$: Wheatï Mungbean-T. Amans were examined in a split- plot design with three replications. Tillage had significant effect on the yield and yield contributing characters of wheat except 1000-grain weight. Crop rotation influenced insignificantly on the yield and yield-contributing characters of the beginning crop of rotations under study. Combined effect of tillage practices and crop rotation systems on yield and yield attributes were insignificant. Bulk density, particle density and field capacity were slightly affected by tillage and crop rotation systems. The lowest bulk density (1.46 g cm$^{-3}$) and particle density (2.49 g cm$^{-3}$) were found in $T_3$ and $T_2$ treatments respectively at 0-15 cm depth of soil tillage. However, the densities of the soil were found similar in all three tillage treatments at 15-30 cm depth of soil. At 0-15 cm depth of soil, the highest soil porosity (41.60 %) and field capacity (0.3839 cm3 cm$^{-3}$) were recorded from $T_3$ treatment. However, at 15-30 cm soil depth, the soil porosity and field capacity were also found identical through all tillage treatments.

Lamm et al., (2007) conducted an experiment on effect of tillage practices and deficit irrigation on corn in KSU Northwest Research-Extension Center, Colby Kansas. They had set up the experiment for corn production from the year 2004 to 2007 for three plant populations (26,800, 30,100 or 33,300 plants /acre) under conventional, strip and no tillage systems for irrigation capacities limited to 1 inch every 4, 6 or 8 days. Corn yield

)% from the lowest to highest irrigation capacity in these itation and crop evapotranspiration. Strip tillage and no tillage had approximately 8.1% and 6.4% greater grain yield than conventional tillage respectively. Their results suggest that strip tillage obtains the residue benefits of no tillage in reducing evaporation losses without the yield penalty sometimes occurring with high residue. The small increases in total seasonal water use (< 0.5 inch) for strip tillage and no tillage compared to conventional tillage can probably be explained by the greater grain yields for these tillage systems. They revealed the experimental results as corn grain yields were high all four years (2004 to 2007) with varying seasonal precipitation and crop evapotranspiration. Strip tillage and no tillage generally performed better than conventional tillage. They recommended that increasing the plant population from 26,800 to 33,300 plants /acre was beneficial at all three irrigation capacities.

Rahman et al., (2007) conducted an experiment at the Agricultural Research Station (ARS), On-Farm Research Division, Rangpur during 2005-06, 2006-07 and 2007-08 to study the effect of tillage practices on soil physical properties and moisture conservation under Maize ï Mungbean -T.aman cropping sequence. The experiment was laid out in a randomized complete block design with four replications. Five different tillage treatments viz. $T_0$: zero tillage, $T_1$: tillage at 6.0 to 8.0 cm depth, $T_2$: tillage at 10.0 to 12.0 cm depth, $T_3$: tillage at 14.0 to 16.0 cm depth and $T_4$: tillage at 18.0 to 20.0 cm depth was selected for different plots randomly. They observed for maize, the effect of different tillage treatments on the yield and yield contributing characters were not significant. The highest grain yield 8.29, 8.35 and 8.40 t $ha^{-1}$ of maize were obtained from treatment $T_4$ (tillage at 18-20 cm depth) during the year 2005-06, 2006-07 and 2007-08, respectively, which was statistically insignificant. For mungbean, the highest grain (0.98 and 0.97 t $ha^{-1}$) and biomass yield (8.18 & 8.20 t $ha^{-1}$) were found in $T_4$ treatment during 2006 and 2007, respectively, which was identical to $T_3$ treatment. The grain yield of T.aman showed increasing trend with increase of tillage depth during 2006 and 2007. The highest grain yield 4.08 and 4.0 t $ha^{-1}$ of T.aman was observed in $T_4$ treatment during 2006 & 2007, respectively. Bulk density values decreased due to different tillage treatments. Considerable influence on available water content of soil was observed due to tillage ntent (14.50cm) was recorded in plots with deep tillage 12.29 cm) was in the plots having $T_0$ tillage. Reverse trend was observed in the water infiltration of soil.

Mondol et al., (2008) they conducted an experiment at OFRD (on farm research division), Rangpur during Rabi season of 2007-08, to study the effect of irrigation and tillage on soil physical properties and yield of wheat. Fifteen treatment combinations comprising 3 tillage practices (zero tillage, tillage by power tiller 10-12 cm depth and deep tillage 20-25 cm depth) and 5 levels of irrigation (IW:CPE ratios of 0.6, 0.8, 1.0,1.2 and rain fed condition) were tested in a split plot design with three replications. They observed that bulk density, particle density, porosity, infiltration and field capacity were slightly affected by tillage and irrigation. They found highest bulk density, particle density and infiltration in zero tillage, and the lowest was recorded in deep tillage. On the other hand, porosity and field capacity were the highest in deep tillage. Physical parameters were almost similar in all irrigation levels. In their experiment yield and yield contributing characters of wheat were significantly influenced by irrigation levels. Deep tillage 20-25 cm depth treatment gave the highest grain yield. Interaction effect of tillage and irrigation on yield and yield contributing characters were insignificant.

Sarkar et al., (2008) have taken an experiment during the Rabi season of 2007-2008 at wheat research centre, Nashipur, Dinajpur to observe the impact of tillage methods and water use on the yield of wheat. Irrigation was applied at the three growth stages viz. 17-21 days after sowing (DAS), 45-50 DAS and 75-80 DAS. They observed no significant impact of tillage operation on yield but irrigation affected significantly on the yield. Under zero tillage operation and at IW: CPE of 0.85, the seasonal water use was 207 mm. The respective water use at IW: CPE of 1.10 was 201mm. Similarly under bed planting tillage operation and at IW: CPE of 0.85and 1.10, the second water uses were 224 mm and 209 mm respectively. They got highest yield of 4.096 t/ha from the treatment $I_2$ (irrigation at 17-21 DAS and 45-50 DAS).

Bangladesh is an agricultural prominent country and its economy depends on agriculture. This country is not self sufficient in food grains. Therefore, there is no alternative way to increase the cereals crop production in Bangladesh. At present in our country, maize is becoming one of the most important cereals crop because the manifolds uses of maize. Maize is used as direct food grains, major elements of some food items such as biscuit, cake, and others food, which is consumed by human being. It also used as main food for poultry, fish and diary animals. In our country, the production of maize is increasing but scientific research had not done on irrigation scheduling concerning water saving in maize cultivation with the combination of water application and tillage practices in Bangladesh.

In Bangladesh and around the world agricultural researchers suggested those irrigation and tillage operations are the most important inputs for agricultural production. Irrigation and tillage contribute to the maximum cost of agricultural production. Bangladesh has mainly two agricultural season, Rabi season and kharib season. Rabi season comprises of the driest period and Kharib season comprises of rainy months of the year. In our country, maximum maize crop is grown in the Rabi (driest period) season, so irrigation is inevitable for maize production in Rabi season. Very few scientific researches have been done to estimate the optimum water requirement for maize crop production at dry period in Bangladesh.

During Rabi season in our country the scarcity of water creates an acute problem particularly in agriculture sector irrigation water. Therefore, the assessment of optimum water requirement for maize crop is important for rationale use of valuable water. Agricultural scientist suggested that there is a strong correlation between soil tillage and irrigation water requirement because tillage practices have a contribution to soil physical properties (bulk density, particle density, porosity etc) which leads to the demand of irrigation water requirements.

Many researcher have been investigated the environmental impact due to air pollution, water pollution and sound pollution but the impact of soil pollution due to farmers been overlooked. Soil is one of the most important d it has a great contribution to environmental pollution. Farmers of our country are used to give emphasize on more tillage operation for more production but it has no scientific basis. Excessive pulverization of soil creates soil pollution and degrades soil fertility by disturbing the growth of soil microorganism. Now a days in our country farmers use power tiller and tractor for tilling purposes these machinery consume a huge amount of fossil fuel and exhaust a substantial amount of green house gases ($CO_2$, $CH_4$, $SO_2$, NO etc) to the air which has a contribution to the air pollution and soil pollution.

In Bangladesh no research had done concerning the impact of various tillage practices on irrigation water requirement for maize crop production at dry season. This is the gap has been found from the previous review. Therefore, the present experiment was taken to assess the impact of tillage practices on irrigation water requirement for maize crop production particularly at dry period in Bangladesh. The another purpose of this project work was to determine the cost effective method of irrigation water application and tillage practices that might be saved the valuable water in maize crop cultivation.

# Chapter 3

# THEORY AND METHODOLOGY

## 3.1 General

Bangladesh was not an irrigation predominant agricultural country. Nowadays in this country, irrigation in agriculture is increasing for augmentation of agricultural production. In dry season in this country, it is impossible to harvest sufficient yield without irrigation because sufficient rainfall is not available during dry season. Therefore, irrigation is now becoming one of the most important input elements for agricultural production. There are some major irrigation facilities in Bangladesh (Teesta, GK etc) but these major irrigation projects are not well active due to shortage of water. Irrigation of this country is mainly depends on the minor irrigation project which are mainly controlled by individual farmers. Therefore, the determination of irrigation water requirement for some high water demanded crop like maize is very important for rationale use of valuable water especially in dry season of this country.

For proper development of agriculture, it is very much important to conduct studies at various places in Bangladesh to determine the water supplies and water requirement for various crops. The determination of water requirement for various crops is important to assess whether supplied irrigation water is sufficient or not according to the demands of the crops. That is why the shifting from the traditional supply oriented system of irrigation operations to the demand based irrigation or to the crop-water requirements system has increased, this is the most challenging issues confronting the present Bangladesh irrigation system. In order to put more and more area under irrigation, water has to be conserved and water should be efficiently used. It is desirable to reduce water losses in the field by finding out the actual crop water requirement, and compare it with the water supplied to ensure an optimum supply of water to the entire crop in an irrigation unit throughout the year. This study was undertaken to determine the optimum water requirement for maize crop production and thereby save the valuable water.

ease yield in agricultural production has been done in s have been done to develop irrigation, agricultural mechanization and water saving techniques. Being an extremely dry environment with harsh climate and poor soils, agricultural production without irrigation is impossible. Maize is the most important crop which is grown under open field conditions under flood irrigation in Bangladesh. Water use efficiency in irrigated agriculture assumes greater significance particularly in arid environments with increasing pressure on water resources from competitive users (Hatfield et al., 1996). Information on scientific irrigation scheduling is meager for crops of Bangladesh. Indirect methods using evapotranspiration measurements are widely used to develop irrigation schedules in many countries. Reference crop evapotranspiration (ETo) is evapotranspiration rate from a reference surface, where no shortage of water. It expresses the evaporating power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. Reference crop evapotranspiration is also known as potential evapotranspiration (ETo).

The graph below depicts the cropping stages of maize, and summarizes the main crop coefficients used for water management.

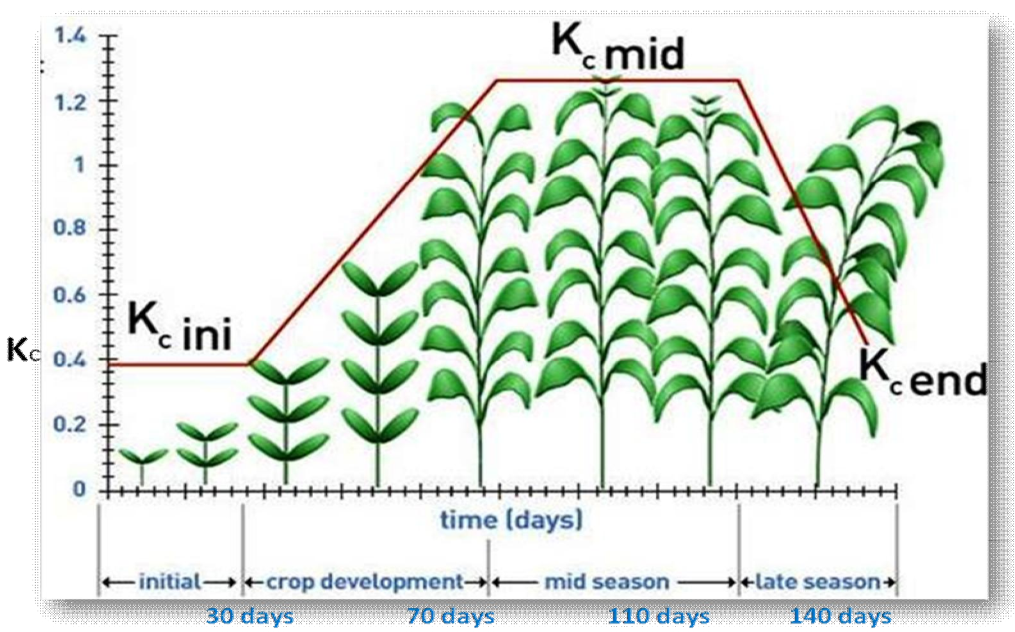



Figure 3.1.1: Crop coefficient ($K_c$) for maize crop at different growth stages.

of a crop can be related to the ETo of any area, as it is n climate. As such the information on ETo of an area will be a very useful guide for development of irrigation schedules for crops. There are different approaches in developing irrigation schedule. One method is the ñwater balanceò or ñsoil water budgetò approach which involves keeping an account of water input into the soil (rainfall and irrigation) and water output (evapotranspiration and drainage) on daily basis. Measurements of rainfall and irrigation may be easy but estimation of ET and drainage involves complex procedures. In many parts of the world, irrigation is scheduled by use of a class óAô evaporation pan (Doorenbos, 1976).

Penman model frequently overestimated ETo, while the other models showed variable adherence to grass reference. Further, the FAO-24 method assessed for a humid temperate environment in Tottori, Japan (Yano and Hayashi, 1977), using long-term weather data (1952-1974), indicated that Penman and Radiation balance models produced similar ETo estimates. Recent studies have raised few concerns about the FAO-24 methodology (Jensen et al., 1990). The ETo estimates obtained from six commonly used ETo estimation models indicates that Penman-Monteith method produced the most reliable estimates, compared to lysimeter data.

### 3.2 Estimation of water requirements

For maize cultivation, irrigation water was applied up to the field capacity of the soil for the optimum growth of the plant. Water logging condition in the soil creates an adverse environment for maize plant growth because maize plant does not tolerate water logging and it is susceptible to rotten in excessive water. The water requirement for maize cultivation was determined by measuring the soil moisture. Soil moisture was measured by gravimetric method.

was determined by the following equation-

Irrigation depth,

$$d = \frac{FC\% - MCi\%}{100} \times As \times D \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots 3.1$$

Where,

d= Depth of water to be applied, cm

FC= Field capacity of the soil, %

$MC_i$= Moisture content of the soil at the time of irrigation, %

As = Apparent specific gravity,

D= Root zone depth of maize crop, cm

Seasonal crop water requirement includes the applied water, the effective rainfall and the soil water contribution. Effective rainfall was estimated by using the USDA soil conservation method (Smith, 1992).

$P_{total}= P_{total}\,(125\text{-}0.2\ P_{total})\ /125$ for $P_{total} <250$ mmé é é é (3.2)

$P_{total}= 125+0.1\ P_{total}$ for $P_{total} >250$ mm. é é é .. (3.3)

Where, $P_{total}$ = Total rainfall (mm)

The soil moisture contribution was estimated from the difference of moisture content of the soil between the two irrigation and finally from the moisture content after harvesting the crop. The higher moisture content at plantation than that at harvest indicates the positive contribution of the soil to crop growth that means some losses of soil water which is used by the crop. On the other hand, lower moisture content of the soil at plantation than that of at harvest indicates irrigation water is stored in soil that means oisture to crop growth and excess or unused moisture in soil water contribution will be positive while in later situation, it will be negative. The following equation was used to estimate the seasonal water use of maize.

**Seasonal water requirement= Applied water+ Effective rainfall ± Soil water contribution.**

For calculating the seasonal water requirement the applied irrigation water (cm) was calculated by using the equation (3.1). To estimate the effective rainfall the rainfall data was collected from the metrological department of BARI then applying that data in the equation (3.2) and (3.3) and the effective rainfall was measured in cm. The soil sample of each plot was collected to measure the soil moisture before planting and after harvesting the maize to determine the soil water contribution.

Conservation tillage can improve soil structure and stability thereby facilitating better drainage and water holding capacity that reduces the extremes of water logging and drought. These improvements to soil structure also reduce the risk of runoff and pollution of surface waters with sediment, pesticides and nutrients. Reducing the intensity of soil cultivation lowers energy consumption and the emission of carbon dioxide, while carbon sequestration is raised though the increase in soil organic matter. Under conservation tillage, a richer soil biota develops that can improve nutrient recycling and this may also help combat crop pests and diseases. The greater availability of crop residues and weed seeds improves food supplies for insects, birds and small mammals (Holland, 2004).

Conventional irrigation practices in most of the world are designed to avoid crop stress in order to maximize yields. During the next few decades, as the inevitable expansion of irrigated lands for increased food production comes into conflict with accelerating economic competition for water and rising environmental concerns, this fundamental precept of irrigation management will probably be abandoned. The new operational rule that replaces it will be based on maximizing total benefits rather than yields (English, et al. 2002).

of tillage is predominantly one of the main consideration ageò is used throughout to encompass all of these non-inversion, soil cultivation techniques, but because with no-tillage or direct drilling the soil remains uncultivated this may create different soil conditions and is referred to separately where applicable. The term ñconventional tillageò defines a tillage system in which a deep primary cultivation, such as moldboard ploughing, is followed by a secondary cultivation to create a seedbed. Conservation tillage (CT) is now commonplace in areas where rainfall causes soil erosion or where preservation of soil moisture because of low rainfall is the objective. These were successful in reducing soil erosion; however, the social costs of erosion are still substantial. However, the potential environmental benefits of changing soil management practices are now being recognized worldwide. In Bangladesh, however, soil degradation has only recently been identified as a widespread problem. This may include loss of structure leading to compaction, a decrease in soil organic matter and a reduction in soil organisms.

### 3.3 Methodology

A field experiment was conducted in the central research station of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur during 2010-2011 to assess the water requirement for maize crop with various tillage practices mainly concerning to conservation agriculture for water resources saving. The soil belongs to the (Agro Ecological Zone) AEZ-28, namely, Modhupur Tract. Data on physical and chemical properties of initial and post harvest soils were collected from 0-30cm depth and are presented in Table 4.2.2 and Table 3.11.1. The experiment was set up in a Split Block Design (SBD) for tillage with a split plots arrangement with nine treatment combinations with three replications. The unit plot size was 3m x 4m. Since water resources saving are the main concern tillage practices have been assigned in the main plot and irrigation has been applied in the sub plots intensively.

Treatment combination comprises of three methods of tillage $T_1$ (zero tillage or no tillage), $T_2$ (minimum tillage) and $T_3$ (traditional tillage practices) and thee irrigation treatments have been applied based on growth stages. BARI butta -6 seed were planted on 08 November, 2010 with the spacing line to line distance 70 cm and plant to plant pplied at the rate of 250-100-40-5-1 kg $ha^{-1}$ of NPKSZnB ration except nitrogen. One third Nitrogen was applied during final land preparation and remaining nitrogen was applied in two equal splits at 30 and 55 days after sowing. The maize was harvested on 06 April, 2011. The yield contributing characters were collected after harvest. The yield contributing characters are plant height, cob diameter, grain per cob, cob length, 100 grains weight, plant dry weight, numbers of plant per plot, line of grain per cob and number of cob per plant etc. The yield of maize per hectare was determined after threshing the maize. After harvest, the soil physical parameters such as bulk density, particle density and porosity were determined to assess the change of soil parameters for different tillage and irrigation practices. Finally the collected data were analyzed with MSTATC software.

### 3.4 Experiment setup

The split plot design with three replications which is considered to be the most suitable for experiments involving less than 10 treatments and any number of replications, has been used in this experiment. Using the principle of órandomizationö, each experiment plot was allocated a treatment such that a particular treatment did appear not more than once in a particular block considered in any direction. The layout plan of the experimental plots is shown in Figure. 3.4.1. Since irrigation was the main concerns in the experiment, irrigation was applied in the sub-plot and the tillage was assigned in the main plot.

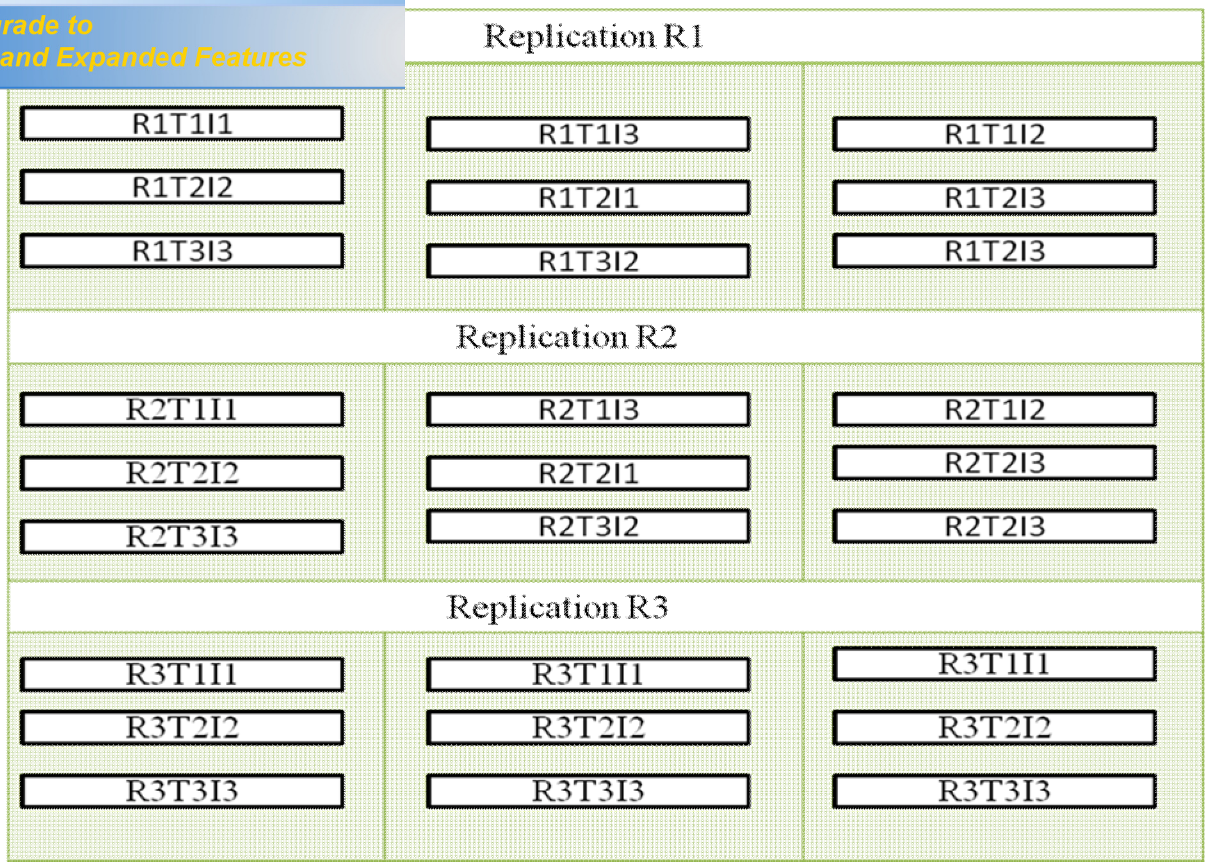



Figure 3.4.1: Layout of experiment

| | | | |
|---|---|---|---|
| Design | SPD | No. of Treatments | 09 |
| No. of Replication | 03 | No. of Plots | 27 |
| Size of Each Plot | 3m × 4m | Drawings are not done in scale | |

### 3.4.1 Land preparation

The land preparation was started one week prior to maize seeds sowing. At first, the selected land was flooded (02 cm) by applying water in sufficient amount to soften the soil and to facilitate tilling by use of the power tiller. When the soil was dry but still soft, the land was tilled according to the experimental requirement. Weeds exposed to the surface were removed. The entire land was then flooded by applying enough water. For conservation purposes the previous crop (rice) residue was kept up to 30 cm length on the field. The basal doze of fertilizer was applied before tillage. When the field was tilled and zer was mixed properly. A sufficient amount of water (02 ys of sowing uniformly over the whole experimental field for maize seedling surviving and establishing.

### 3.4.2 Application of fertilizer

Fertilizer was applied to reach the soil in optimum condition for maize cultivation. Fertilizer was applied at the rate of 250-100-40-5-1 kg $ha^{-1}$ of NPKSZnB at the time of final land preparation except nitrogen. One-third Nitrogen was applied during final land preparation and remaining nitrogen was applied in two equal splits at 30 and 55 days after sowing. The dosages of fertilizer were applied according to (Fertilizer Recommendation Guide) FRG-2005, Bangladesh Agricultural Research Council (BARC) recommendation.

Table 3.4.1: Amount of fertilizer applied

| Name of fertilizer | Urea | TSP | MP | Gypsum | $ZnSO_4$ | Boric Acid |
|---|---|---|---|---|---|---|
| Amount kg/ha | 512 | 275 | 200 | 222 | 14 | 5.88/6 |

**Source:** FRG-2005, BARC recommendation

### 3.5 Irrigation water application

Irrigation water was applied in a control and measuring system. Irrigation was applied by volumetric methods to maintain the accurate amount of water. Three type of irrigation treatment were applied based on growth stages depending on the root zone depth at different stages. Three level of irrigation were

$I_1$ = only one irrigation was applied at 25 days after sowing.

$I_2$ = Two time were applied at 25days after sowing and 50 days after sowing respectively.

$I_3$ = Three time were applied at 25 days after sowing, 50 days after sowing and 85 days after sowing, respectively. (Irrigation water were applied according to BARI agriculture technology hand book-2005, pp- 47) ording to the requirement of the soil to reach the soil field th of maize crop based on the growth stages. The depth of irrigation water required for soil to reach the field capacity was determined by the equation (3.1). Then water was applied with bucket (water measuring device) by measuring the water in volume. Irrigation channel and reservoir of Bangladesh Agricultural Research Institute (BARI) was used as the source of water resources for irrigation purposes. Soil moisture was measured before and after application of irrigation water by gravimetric method in each replication to ensure the moisture to reach the field capacity of the soil. Irrigation water was applied uniformly in every experimental plot. Since irrigation was applied to reach the soil moisture in field capacity no percolation and seepage was considered. Potential evapotranspiration was calculated by CROPWAT software by giving necessary parameters in the software. The necessary parameters for determining the potential evapotranspiration were the daily maximum and minimum temperature, daily humidity, wind speed, rainfall and sunshine. Then the crop evapotranspiration was determined by multiplying potential evapotranspiration with crop coefficient. Crop coefficient (Ks) were taken for same experiment plot for maize at initial stage is 0.38, for development stage is 0.47, for mid season is 1.36 and late season is 0.75 for local purposes and more accuracy (Islam and Hossain, 2010).

Table 3.5.1: Root depth at various growth stages of maize crop.

| Days after sowing of maize crop | Root depth of maize crop |
|---|---|
| 25-30 days (vegetative stage) | 95-100 cm |
| 50-60 days (crop development stage) | 105-110 cm |
| 80-85 days ( mid season matured stage) | 125-130 cm |
| 115-120 days (late season full matured stage) | 140-150 cm |

(Source: A manual based on Small-scale pumped irrigation: energy and cost, FAO land and water development, ROM, pp-79 by Kay. M and N. Hatcho, 1992).

ore applied water at first irrigation and depth of applied

| Treatment | Initial soil moisture % | Depth of applied irrigation water to reach the field capacity ( cm) | Irrigation water requirement for every plot (liter) |
|---|---|---|---|
| $R_1T_1I_1$ | 23.0 | 9.00 | 1080 |
| $R_1T_1I_2$ | 23.0 | 9.00 | 1080 |
| $R_1T_1I_3$ | 23.0 | 9.00 | 1080 |
| $R_1T_2I_1$ | 21.0 | 12.00 | 1440 |
| $R_1T_2I_2$ | 21.0 | 12.00 | 1440 |
| $R_1T_2I_3$ | 21.0 | 12.00 | 1440 |
| $R_1T_3I_1$ | 19.0 | 15.00 | 1782 |
| $R_1T_3I_2$ | 19.0 | 15.00 | 1782 |
| $R_1T_3I_3$ | 19.0 | 15.00 | 1782 |
| $R_2T_1I_1$ | 23.0 | 9.00 | 1080 |
| $R_2T_1I_2$ | 23.0 | 9.00 | 1080 |
| $R_2T_1I_3$ | 23.0 | 9.00 | 1080 |
| $R_2T_2I_1$ | 21.0 | 12.00 | 1440 |
| $R_2T_2I_2$ | 21.0 | 12.00 | 1440 |
| $R_2T_2I_3$ | 21.0 | 12.00 | 1440 |
| $R_2T_3I_1$ | 20.0 | 13.50 | 1620 |
| $R_2T_3I_2$ | 20.0 | 13.50 | 1620 |
| $R_2T_3I_3$ | 20.0 | 13.50 | 1620 |
| $R_3T_1I_1$ | 23.0 | 9.00 | 1080 |
| $R_3T_1I_2$ | 23.0 | 9.00 | 1080 |
| $R_3T_1I_3$ | 23.0 | 9.00 | 1080 |
| $R_3T_2I_1$ | 21.0 | 12.00 | 1440 |
| $R_3T_2I_2$ | 21.0 | 12.00 | 1440 |
| $R_3T_2I_3$ | 21.0 | 12.00 | 1440 |
| $R_3T_3I_1$ | 20.0 | 13.50 | 1620 |
| $R_3T_3I_2$ | 20.0 | 13.50 | 1620 |
| $R_3T_3I_3$ | 20.0 | 13.50 | 1620 |

Root zone depth, D= 100 cm and apparent specific gravity, $A_s$ = 1.5

re applied water at second irrigation and depth of applied

| Treatment | Initial soil moisture % | Depth of applied irrigation water ( cm) | Irrigation water requirement for every plot (liter) |
|---|---|---|---|
| $R_1T_1I_2$ | 24.0 | 8.25 | 990 |
| $R_1T_1I_3$ | 24.0 | 8.25 | 990 |
| $R_1T_2I_2$ | 24.0 | 8.25 | 990 |
| $R_1T_2I_3$ | 24.0 | 8.25 | 990 |
| $R_1T_3I_2$ | 22.0 | 11.55 | 1386 |
| $R_1T_3I_3$ | 22.0 | 11.55 | 1386 |
| $R_2T_1I_2$ | 24.0 | 8.25 | 990 |
| $R_2T_1I_3$ | 24.0 | 8.25 | 990 |
| $R_2T_2I_2$ | 24.0 | 8.25 | 990 |
| $R_2T_2I_3$ | 24.0 | 8.25 | 990 |
| $R_2T_3I_2$ | 22.0 | 11.55 | 1386 |
| $R_2T_3I_3$ | 22.0 | 11.55 | 1386 |
| $R_3T_1I_2$ | 24.0 | 8.25 | 990 |
| $R_3T_1I_3$ | 24.0 | 8.25 | 990 |
| $R_3T_2I_2$ | 24.0 | 8.25 | 990 |
| $R_3T_2I_3$ | 24.0 | 8.25 | 990 |
| $R_3T_3I_2$ | 22.0 | 11.55 | 1386 |
| $R_3T_3I_3$ | 22.0 | 11.55 | 1386 |

Root zone depth, D= 110 cm and apparent specific gravity, $A_s$ = 1.5

Table 3.5.4: Soil moisture before applied water at third irrigation and depth of applied water in each plot (only $I_3$ irrigation)

| Treatment | Initial soil moisture % | Depth of applied irrigation water ( cm) | Irrigation water requirement for every plot (liter) |
|---|---|---|---|
| $R_1$ $T_1$ $I_3$ | 23.0 | 11.70 | 1404 |
| $R_1$ $T_2$ $I_3$ | 22.0 | 13.65 | 1638 |
| $R_1$ $T_3$ $I_3$ | 20.0 | 17.55 | 2106 |
| $R_2$ $T_1$ $I_3$ | 23.0 | 11.70 | 1404 |
| $R_2$ $T_2$ $I_3$ | 2.02 | 13.65 | 1638 |
| $R_2$ $T_3$ $I_3$ | 20.0 | 17.55 | 2106 |
| $R_3$ $T_1$ $I_3$ | 23.0 | 11.70 | 1404 |
| $R_3$ $T_2$ $I_3$ | 22.0 | 13.65 | 1638 |
| $R_3$ $T_3$ $I_3$ | 20.0 | 17.55 | 2106 |

Root zone depth, D= 130 cm and apparent specific gravity, $A_s$ = 1.5

Soil tillage is the manipulation of soil, which is generally considered as necessary to obtain optimum growth conditions for all crops including maize. The growing concerns about agricultural sustainability, environmental pollution and soil erosion, conservation tillage with proper management strategies and proper selection can protect water movement and runoff losses. Excessive tillage result in increases cost and reduces benefit cost ratio of yields of maize production. Tillage operation vary according to water availability, soil texture, topography, level of resources available to the farmer, and farmers preference for particular type of culture (Datta et. al. 1981).

Three methods of tillage were used in the experiment. They were-

$T_1$= Zero tillage/ no tillage (strip tillage), that means no disturbances of soil, only sowing operation was done by power tiller operated inclined plate planter.

$T_2$= Minimum tillage, only minimum tillage and sowing operation was done simultaneously by power tiller operated inclined plate planter.

$T_3$= Traditional tillage operation (farmers practices), that means three to four times tillage with power tiller and sowing operation was done by hands.

**(a) Zero tillage (strip tillage $T_1$) operation**

Power tiller was used for zero tillage operation. In this type of tillage operation only sowing was done by power tiller operated inclined plate planter. In zero tillage practices soil was pulverized in the form of strip (6-7cm) to put the maize seed and the rest of the field was undisturbed. For this purpose, the number of tines of power tiller was changed. Six tines were used in zero tillage; in each travel, sowing was done in two rows, for each row only three tins were used. Sowing line to line distance was maintained 75 cm and plant to plant distance was 25 cm. inclined plate planter was adjust to maintain the distance between line to line and plant to plant. In zero tillage practices power tiller with inclined plate planter was used which was a new mechanism invented by BARI for maize planting. In this practice, only two labors and one inclined plate planter mounted power tiller was required. Two labors and only one power tiller in six hours operation were of each acre of land. This practice was time and fuel traditional method.


Figure 3.6.1: Zero tillage practices only sowing with crop residue remaining in the plot


Figure 3.6.2: Establishment of maize seedlings in zero tillage practice plot

**ractices**

Minimum tillage means minimum soil disturbances. Soil was pulverized at a minimum stage. Soil pulverization and maize sowing were done at simultaneously. Minimum tillage operation was done by keeping the prior crop residue and removing the weed exposed on the upper soil of the land. In minimum tillage operation, power tiller has been passed over the soil only one time to manipulate the soil and for sowing the maize seeds. In minimum tillage operation, two labors and one power tiller was requires for six hours in operation for tilling and sowing of maize seeds. Minimum tillage operation can save a substantial amount of labors hours and fuel so; the cost of production can be minimized. It is more time and fuel saving methods in comparison to traditional method.


Figure 3.6.3: Minimum tillage operation and sowing were done simultaneously


Figure 3.6.4: Establishment of maize seedlings in minimum tillage practice plot

**es**

Another treatment was traditional tillage practices that mean the farmerÓs tillage culture in our country. In this tillage practices was done three lengthwise and two crosswise. Five times tillage were done in these practices. The exposed weeds were removed. In traditional tillage practices maximum soil pulverization was occurred. This treatment covered maximum soil tillage and sowing was done manually like farmerÓs culture. Traditional tillage practices consumed fossil fuel for maximum soil pulverization and power tiller in operation for more time. In traditional culture, eight labors were required for sowing and soil tillage. One power tiller was required for fifteen hours in operation for tilling one acre of land. The more tilling operation creates an adverse environment for growth of beneficial soil microorganisms.


Figure 3.6.5: Labors are sowing maize manually in traditional tillage practice plot


Figure 3.6.6: Establishment of maize seedlings in traditional tillage practice plot

**ces**

Various type of data were collected for experimental work, the data including field survey data, different thematic data and other relevant published information. Metrological data have been used for completing the experimental deeds. Metrological data such as rainfall, humidity, temperature and sunshine have been collected from BARI metrological department. These data have been used for determination of crop evapotranspiration ($ET_c$) particularly for potential evapotranspiration ($ET_0$).

### (a) Metrological data

Metrological data were collected from metrological department of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Metrological data which were related to crop physiological activities, they were the daily maximum and minimum temperature, daily humidity, wind speed, rainfall and sunshine. BARI Metrological Department collects the daily data under the supervision of experienced scientist and that data are used in various scientific and sensitive experimental works. The metrological data were collected only for growing season of maize crop from November, 2010 to April, 2011.

Table 3.7.1: Monthly rainfall and monthly average maximum and minimum temperature

| Month | Weekly Rainfall (mm) | | | | Monthly Rainfall (mm) | Temperature ($^0$C) Monthly average | |
|---|---|---|---|---|---|---|---|
| | 1$^{st}$ week | 2$^{nd}$ week | 3$^{rd}$ week | 4$^{th}$ week | | Max. | Min. |
| November | 02 | 00 | 00 | 00 | 02 | 29.3 | 20.4 |
| December | 00 | 53 | 00 | 00 | 53 | 24.53 | 13.3 |
| January | 00 | 00 | 00 | 00 | 00 | 21.45 | 10.95 |
| February | 00 | 00 | 00 | 00 | 00 | 28.25 | 14.34 |
| March | 00 | 22 | 00 | 48 | 70 | 29.4 | 19.13 |
| April | 30 | 01 | 58 | 65 | 154 | 31.3 | 22.6 |

(Source: BARI metrological department, Gazipur) umidity and sunshine

| Month | Relative humidity (%) | | Average daily sunshine (hour) |
|---|---|---|---|
| | Maximum | Minimum | |
| November | 90.20 | 68.30 | 6.65 |
| December | 91.00 | 67.61 | 5.99 |
| January | 93.00 | 65.70 | 4.55 |
| February | 94.50 | 68.40 | 6.53 |
| March | 86.70 | 63.48 | 8.54 |
| April | 90.20 | 65.26 | 8.74 |

(Source: BARI metrological department, Gazipur)

### 3. 8 Software used

The methodology adopted for this experiment involves field experiment, collection of experimental data and analysis the data. Mainly, the following softwareôs were used for this experiment work.

(a) MSTATC was used for analysis the yield related parameter and data.

(b) PC based GIS used for map making.

(c) Microsoft words used basically for report writing and presentation of the research.

(d) Microsoft Excel used for the presentation of data.

(e) ETo calculator (CROPWAT software)

### 3.9 Potential Evapotranspiration

For the calculation of potential evapotranspiration, the daily maximum and minimum temperatures, daily humidity, wind speed and sunshine hours during experiment were collected from BARI Metrological Department. The reference evapotranspiration (ETo) for the maize was computed by using CROPWAT software (Smith, 1992). Crop evapotranspiration (ETc) is the product of reference evapotranspiration (ETo) and crop coefficient ($K_c$). Crop co-efficient ($K_c$) is a value of crop specific and the value of $K_c$ vary for a particular crop with the growth stages. The value is highest during mid season (i.e. reproductive stage) when the maize crop develops maximum canopy and root system.

itial stage is 0.38, for development stage is 0.47, for mid s 0.75 (Islam and Hossain, 2010). The daily ETo during the experiment was determined by CROPWAT software and shown in Figure: 3.9.1 and actual crop evapotranspiration ($ET_C$) are shown in Table: 3.9.1.

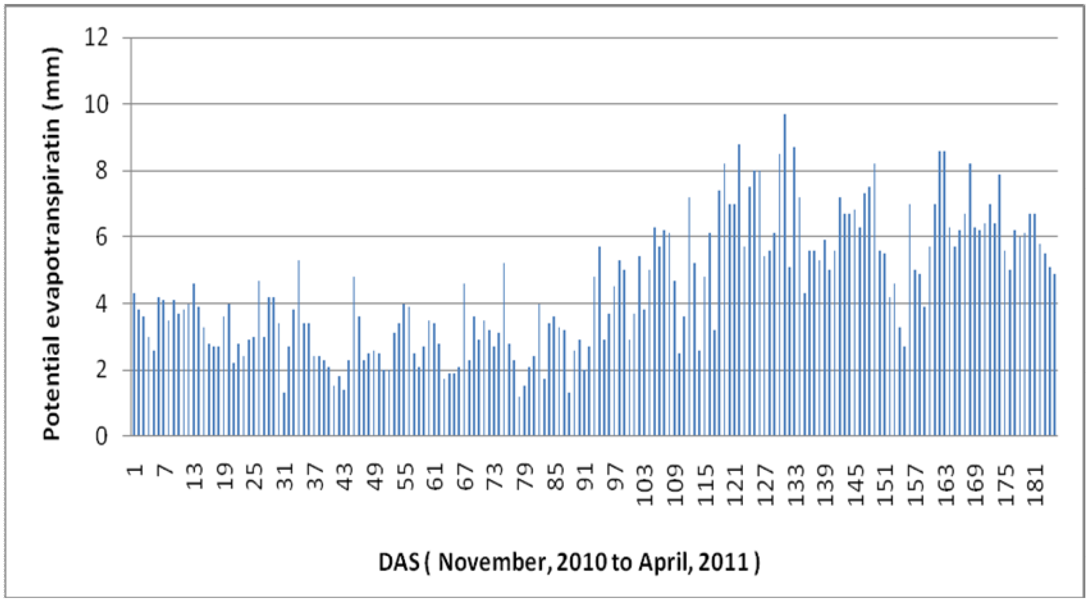



Figure 3.9.1: Daily potential evapotranspiration (ETo) during experiment season

…potranspiration ($ET_C$) of maize (mm) during experiment time

| [illegible] | [illegible] | …ember | January | February | March | April |
|---|---|---|---|---|---|---|
| 1 | 0.988 | 1.292 | 0.987 | 1.739 | 2.7 | 1.998 |
| 2 | 1.596 | 1.292 | 2.162 | 2.115 | 2.88 | 5.18 |
| 3 | 1.558 | 0.912 | 1.081 | 2.491 | 2.88 | 3.7 |
| 4 | 1.33 | 0.912 | 1.692 | 2.35 | 1.944 | 3.626 |
| 5 | 1.558 | 0.874 | 1.363 | 1.363 | 2.016 | 2.886 |
| 6 | 1.406 | 0.798 | 1.645 | 1.739 | 2.196 | 4.218 |
| 7 | 1.444 | 0.57 | 1.504 | 2.538 | 3.06 | 5.18 |
| 8 | 1.52 | 0.684 | 1.269 | 1.786 | 3.492 | 6.364 |
| 9 | 1.748 | 0.532 | 1.457 | 2.35 | 1.836 | 6.364 |
| 10 | 1.482 | 0.874 | 2.444 | 2.961 | 3.132 | 4.662 |
| 11 | 1.254 | 1.824 | 1.316 | 2.679 | 2.592 | 4.218 |
| 12 | 1.064 | 1.368 | 1.081 | 2.914 | 1.548 | 4.588 |
| 13 | 1.026 | 0.874 | 0.564 | 2.867 | 2.016 | 4.958 |
| 14 | 1.026 | 0.95 | 0.705 | 2.209 | 2.016 | 6.068 |
| 15 | 1.368 | 0.988 | 0.987 | 1.175 | 1.908 | 4.662 |
| 16 | 1.52 | 0.95 | 1.128 | 1.692 | 2.124 | 4.588 |
| 17 | 0.836 | 0.76 | 1.88 | 3.384 | 1.8 | 4.736 |
| 18 | 1.064 | 0.76 | 0.799 | 2.444 | 2.016 | 5.18 |
| 19 | 0.912 | 1.178 | 1.598 | 1.222 | 2.592 | 4.736 |
| 20 | 1.102 | 1.292 | 1.692 | 2.256 | 2.412 | 5.846 |
| 21 | 1.14 | 1.52 | 1.551 | 2.867 | 2.412 | 4.144 |
| 22 | 1.786 | 1.482 | 1.504 | 1.504 | 2.448 | 3.7 |
| 23 | 1.14 | 0.95 | 0.611 | 3.478 | 2.268 | 4.588 |
| 24 | 1.596 | 0.798 | 1.222 | 3.854 | 2.628 | 4.44 |
| 25 | 1.596 | 1.026 | 1.363 | 3.29 | 2.7 | 4.514 |
| 26 | 1.292 | 1.33 | 0.94 | 3.29 | 2.952 | 4.958 |
| 27 | 0.494 | 1.292 | 1.269 | 4.136 | 2.016 | 4.958 |
| 28 | 1.026 | 1.064 | 2.256 | 2.679 | 1.98 | 4.292 |
| 29 | 1.444 | 0.646 | 2.679 |  | 1.512 | 4.07 |
| 30 | 2.014 | 0.722 | 1.363 |  | 1.656 | 3.774 |
| 31 |  | 0.722 | 0.987 |  | 1.188 |  |

Crop coefficient ($K_c$) at initial stage 0.38, development stage 0.47, midseason 0.36 and late season 0.75

**loss**

The seepage and percolations loss was not consider because irrigation was applied only to reach the soil moisture up to the field capacity. During the experimental work no substantial rainfall was occurred so there was no scope to deep percolation. Irrigation water was applied based on the physiological growth stage of maize crop considering the root zone depth of different growth stages.

### 3. 11 Physical and chemical properties of experimental soil

Soil samples were collected from the experiment field of every plot at the depth of 0-30 cm and 31-60 cm. Soil analysis was done in BARI soil science department. Soil moisture was also measured by gravimetric method. The data of soil analyses of experiment field are shown in the Tables (3.11.1 and 3.11.2)

Table 3.11.1: Physical properties of soil of experiment field

| Soil depth (cm) | Bulk density (g cm$^{-3}$) | Particle density (g cm$^{-3}$) | Porosity (%) | Infiltration (mm hr$^{-1}$) | Field capacity (%) | Textural class |
|---|---|---|---|---|---|---|
| 0-30 | 1.50 | 2.68 | 44 | 8.50 | 29 | Clay loam |

Table 3.11.2: Chemical properties of soil of experiment field

| pH | OM (%) | Ca | Mg | K | Total N % | P | S | B | Cu | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | meq /100 ml | | | | µg g-1 | | | | | | |
| 6.3 | 0.69 | 4.5 | 4.0 | 0.12 | 0.41 | 12 | 25 | 0.10 | 2.2 | 112 | 15 | 2.0 |
| Critical level | | 2.0 | 0.8 | 0.2 | - | 14 | 14 | 0.2 | 1.0 | 10 | 5 | 2.0 |

Source: Soil analysis has been done in the laboratory of BARI soil science department.

### 3.12 Summary

Irrigation water was applied to reach the soil moisture up to field capacity. The soil moisture was measured by digital meter in each replication before every irrigation water application. Since irrigation water was applied to reach the soil moisture up to field

...ep percolation were happened. Weed was controlled by ... weeder from each plot for two times during experiment. The application of irrigation water was done with bucket by measuring the water in volume (liter). First the water requirement was estimated in depth (cm) by the help of equation (3.1) then the depth of water was converted into in liter (volume) by calculation. A close observation was kept during water application so, water was not wastage. Plot to plot distance have been maintained 1.5 m to avoid the impact of seepage effect of water from one plot to another plot.

# Chapter 4

# DESCRIPTION OF THE STUDY AREA

## 4.1 General description of location

The experiment was conducted during the robi season (November, 2010 to April, 2011) in Gazipur. The study was conducted in Bangladesh Agricultural Research Institute (BARI), Gazipur. The site is situated at 23°50´N - 24°20N´latitude and 90°10´E- 90°40´E longitude and bounded by mymensingh district on the north, Tangail district on the west, Dhaka district on the south and Narayangong, Narsingdi and kishorgonj on the east. The topography of the study areais moderately high land and well drained. The location map of the study area is shown in (Figure4.1.1)

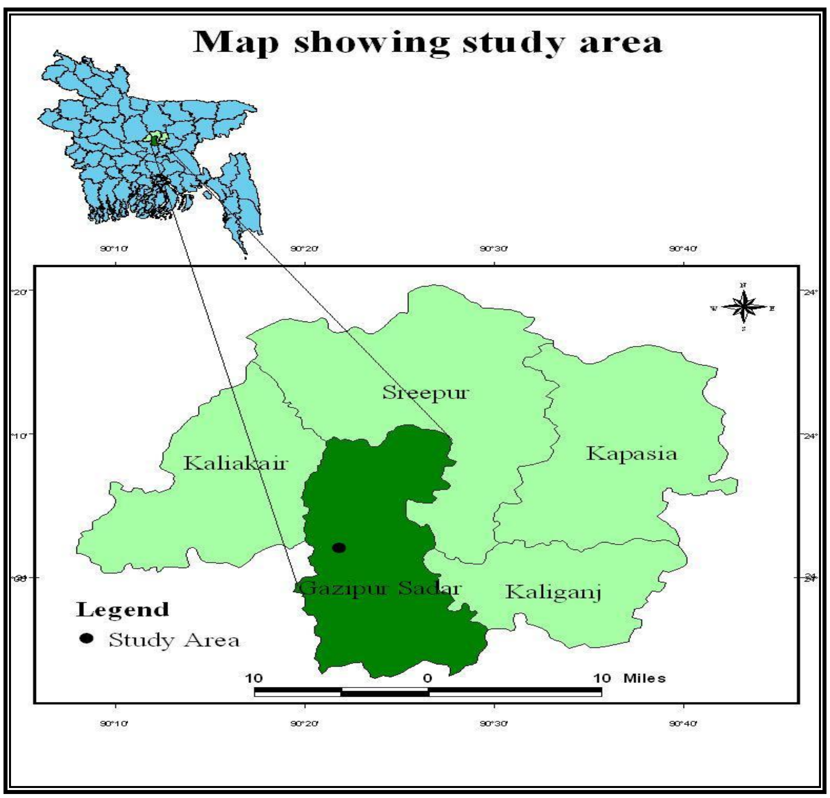



Figure 4.1.1: Location map of the study area (BARI, Gazipur).

Figure 4.1.2: Photograph of experimental field of BARI farm Gazipur

## 4.2 Soil condition

The farm area of BARI, Gazipur is mainly leveled with solely permeable soils. A part of farm area is low land and clay loam to loam soil. The others part of farm is high land and soil dominate with clay to silty- clay textures all over the area. The amount of potassium and phosphorus in the soil is below the critical limit (critical limit of potassium and phosphorus is 0.2 meq /100 ml and 14 g g-1 respectively) for maize cultivation and the soil is low in organic matter (0.69%) and slightly acidic to neutral (ph 6.3).

Table 4.2.1: Chemical properties of soil

| pH | OM (%) | Ca | Mg | K | Total N % | P | S | B | Cu | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | meq /100 ml | | | | g g-1 | | | | | | |
| 6.3 | 0.69 | 4.5 | 4.0 | 0.12 | 0.41 | 12 | 25 | 0.10 | 2.2 | 112 | 15 | 2.0 |
| Critical level | | 2.0 | 0.8 | 0.2 | - | 14 | 14 | 0.2 | 1.0 | 10 | 5 | 2.0 |

(Source: Soil analysis has been done in the laboratory of BARI soil science department) rties of experimental field

| Soil Type | values | Method/Apparatus used |
|---|---|---|
| Sand (%) | 30.56 | Hydrometer method |
| Silt (%) | 34.00 | |
| Clay (%) | 35.44 | |
| Textural Class | Clay Loam | |
| Bulk density (g $cm^{-3}$) | 1.50 | Core sampling method |
| 0-30 cm depth | 1.53 | |
| Particle density (g $cm^{-3}$) | 2.68 | |
| Porosity (%) | 44% | Laboratory method |
| 0-30 cm depth | 43.94% | Digital meter |
| Field capacity (%) | 29% | |
| 0-150 cm depth | 29% | |
| Wilting point ($cm^3$ $cm^{-3}$) 0-15 cm depth | 0.153 | Pressure plate apparatus |
| Soil moisture at various stages | | Gravimetric mehods |

Source: Soil analysis has been done in the laboratory of BARI soil science department.

### 4.3 Climate

Gazipur district bears a sub-tropical typical monsoon climate with high temperature, considerable high humidity and moderate rainfall. The minimum and maximum average monthly temperature varies between $10^0$C to $30.5^0$C. The monthly humidity level ranges from 64 % in May to 90% in April and annual average rainfall is 1875 mm and rainfall during the Rabi season (dry period of the year) is only 310 mm. During the growing season of maize, the mean monthly weather data has collected from the BARI weather station. Soil samples were collected from 0-75 cm depth of the experimental plots randomly to determine soil moisture, bulk density, and field capacity. The data on other s nutrients properties, soil type determined by BARI soil

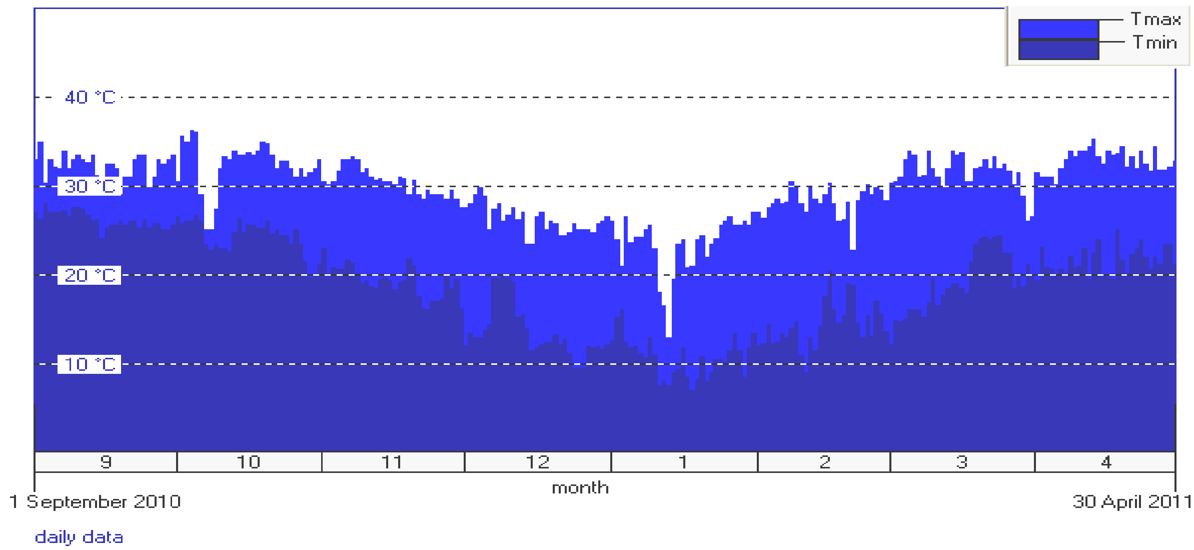



Figure 4.3.1: Daily average maximum and minimum temperature at BARI experimental field. (Source: BARI metrological department, Gazipur)

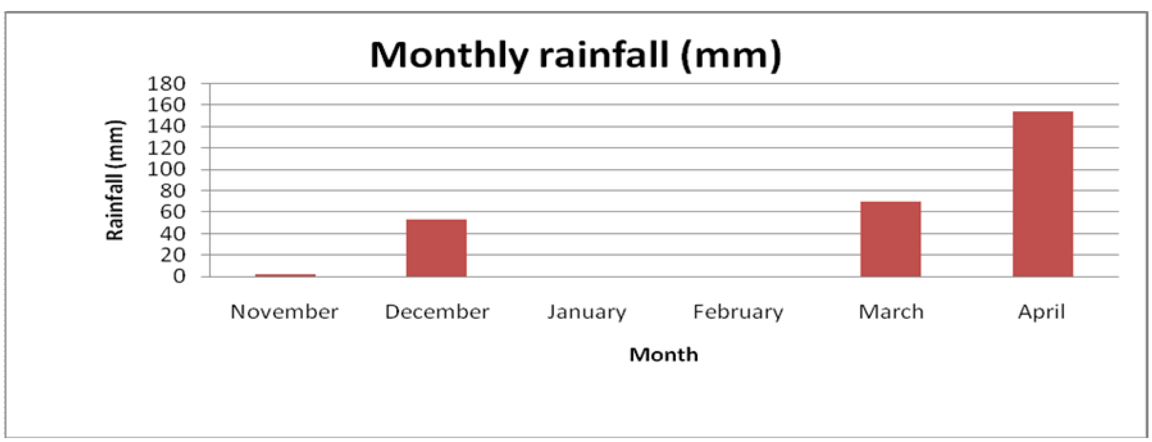



Figure 4.3.2: Monthly total rainfalls from November to April (Source: BARI metrological department, Gazipur)

# Chapter 5

# RESULTS AND DISCUSSIONS

## 5. 1 General

This Chapter deals with the minimum amount of water application practices for maize cultivation and observation the impact of water application on the yield influential parameters due to different level of water application and different tillage practices for water saving. The project work was conducted in dry season (Rabi) of the Bangladesh. The climate of Bangladesh is characterized by high temperature (30°C-34°C) during summer, short mild winters, medium sunshine hours, high humidity and general dry conditions. The mean monthly data of weather parameters during growing season were collected. The average daily temperature was varying from 13.2$^{o}$C to 29.5$^{o}$C during the experimental time of the project work. The total rainfall of the study area was 164 mm of which 133 mm was effective rainfall during the experiment and it was estimated by the equations (3.2) and (3.3).  Practically, due to insufficient rainfall occurs during the dry season (Rabi) in Bangladesh, the rain-fed agriculture (precipitated agriculture) is not possible in Bangladesh. The daily mean ETo of the study area was varied from 2.75 mm $d^{-1}$ to 7.5 mm $d^{-1}$ during the experiment period. The mean sunshine hours were varied from 6.2 h $day^{-1}$ to 11.1 h $day^{-1}$ during project work (Metrological Department, BARI, Gazipur).

## 5.2 Effects of water application on maize yield contributing characters

The effects of water on the yield and yield contributing characters of maize have been shown in the Table 5.2.1. The yield contributing characters of maize were significantly affected with the variations of water application. The lowest yield (7.133 ton/ha) was found in lowest amount of water application $I_1$ treatment. The maximum yield of maize was found 8.31 t $ha^{-1}$ in maximum amount of water application $I_3$ treatment. In $I_2$ treatment, the maize yield was recorded as 8.2 t $ha^{-1}$  that was the nearest value of $I_3$ irrigation treatment. The yield was increased rapidly with the increase of water application up to a certain level then the yield was not sufficiently increased with the

The highest yield were obtained in $I_2$ and $I_3$ treatment
e applied on the dated of 25 and 50 days after sowing (DAS) and 25, 50 and 85 days after sowing.

The highest level of significant was found in plant height, maximum plant height 214.7 cm, 207.3 cm were found for $I_3$, and $I_2$ irrigation treatment respectively and lowest plant height 193.7 cm was found in $I_1$ irrigation treatment (Figure 5.2.1). Number of plant per plot varies with the variation of water application up to a certain level then it does not depend on water application. The minimum number of plant was found (66) in one water application treatment and maximum number of plants (75.33) and (75.00) were found in two and three times of water application respectively. Maximum number of plant depends only on the availability of water, not on maximum number of water application. The maximum number of cob per plot were found in $I_2$ and $I_3$ treatments as 75.33 pieces and 77.67 pieces respectively and the lowest number of cobs 62.33 pieces was found in $I_1$ irrigation treatment shown in Table 5.2.1. Number of cobs were increased with the increased of water application. Maximum number of cobs does not indicate the higher yield because more than one cob in a single plant becomes unhealthy and decreases yield. So, maximum water application does not give the maximum yield. Therefore, the optimum water application is required for maximum yield.

Table 5.2.1: Effect of water application on the yield and yield contributing characters of maize

| Treatment | Plant height (cm) | Plant/ plot | Cob/ plot | Grain/cob | 100-grain weight (gm) | Yield (ton $ha^{-1}$) |
|---|---|---|---|---|---|---|
| $I_1$ | 193.7 | 66.33 | 62.33 | 358.0 | 14.93 | 7.133 |
| $I_2$ | 207.3 | 75.33 | 75.33 | 416.7 | 15.23 | 8.190 |
| $I_3$ | 214.7 | 75.00 | 77.67 | 426.0 | 15.73 | 8.310 |
| Level of significance | HS | ** | ** | ** | ** | ** |
| CV (%) | 3.02 | 5.26 | 6.90 | 3.13 | 2.50 | 5.03 |

** indicate significant difference, HS- high level of significant

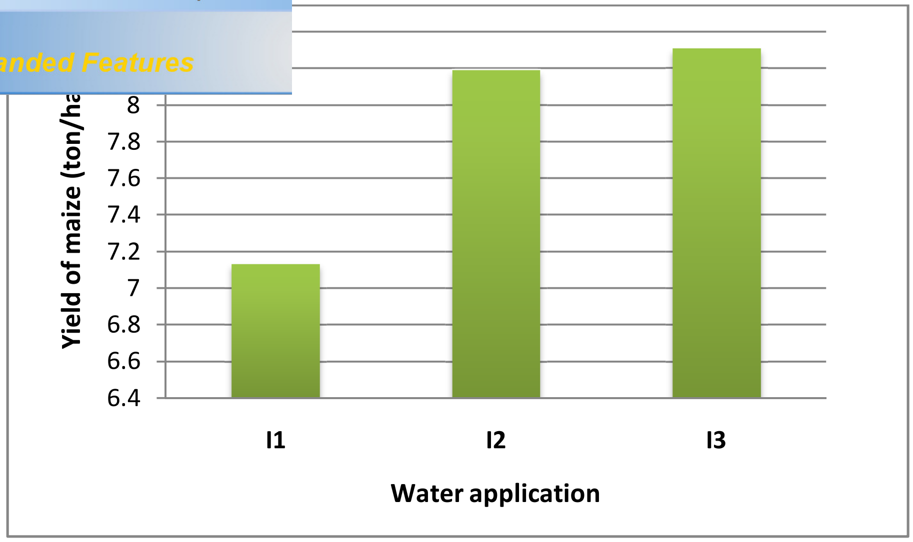



Figure 5.2.1: Effect of water on maize yield in the experiment

Maximum numbers of grains were found in maximum water application that indicates little size of grains. The grains weight is similar in two and three times of water application. So for greater yield maximum benefit the optimum water application is essential.

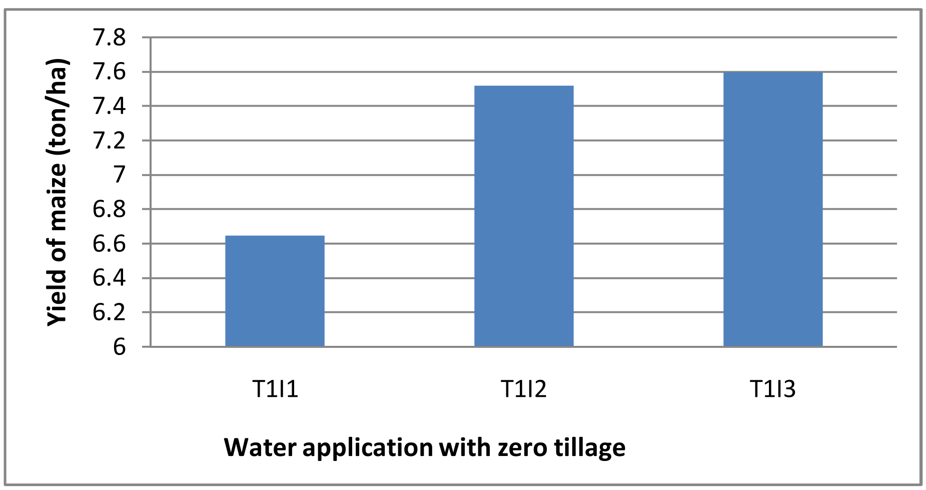



Figure 5.2.2: Effect of water with zero tillage on maize yield in the experiment

In zero tillage practice three type of water were applied. The three types of water application were i) $I_1$ = one irrigation, ii) $I_2$ = two irrigation and iii) $I_3$ = three irrigation. The effects of irrigation on maize yields with zero tillage are presented in Figure 5.2.2. The maize yield were 6.65 t ha-1, 7.52 t ha-1 and 7.6 t ha-1 for $I_1$, $I_2$ and $I_3$ irrigation yield of $I_2$ irrigation was statistically similar with $I_3$ . Yield was increased with the increased of water application. One irrigation treatment practice with zero tillage is not suitable because the yield is the lowest in this treatment combination. Two and three- times water application with zero tillage has nearly the similar effects on the maize yield.

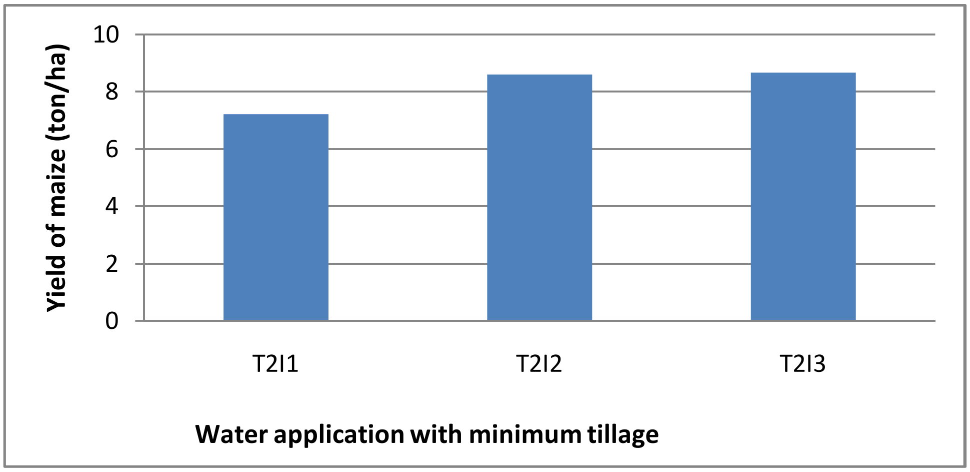



Figure 5.2.3: Effect of water with minimum tillage on maize yield in the experiment

In minimum tillage practices the three level of irrigation water applied. The maize yield were 7.20 t ha-1, 8.60 t ha-1 and 8.65 t ha-1 for $I_1$, $I_2$ and $I_3$ irrigation treatments respectively. Maize yield of $I_2$ irrigation was statistically very similar with $I_3$ irrigation except $I_1$ irrigation. A minor yield variation was found in two and three times water application. Minimum tillage with two times and three times water application gave the same results in yields and yields contributing characters of maize. The lowest amount of maize yield was recorded in minimum tillage with one time water application.

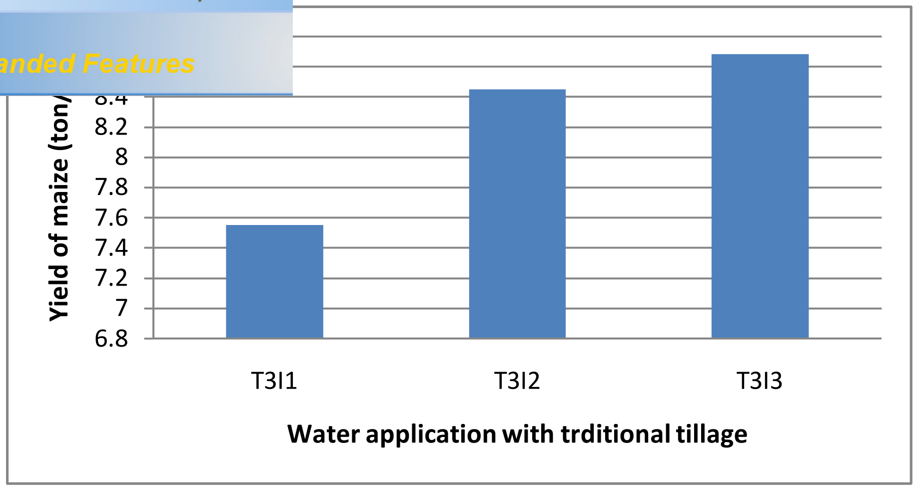



Figure 5.2.4: Effect of water with traditional tillage on maize yield in the experiment

Traditional tillage means five times tillage of soil then the sowing by hand is a general practice, which is done by the farmer of this country. The effects of traditional tillage with one, two and three times water application for maize cultivation was observed. Traditional tillage with one time water application gave the lowest yield and the maximum yield was found in two and three times water application with traditional tillage. Two ($I_2$) and three ($I_3$) times water application with traditional tillage have given the very similar results in yield and yield contributing characters. The yield was increased rapidly from one time water application to two times water application. The yield did not increase substantially from two times ($I_2$) water application to three times ($I_3$) water application. This result indicates the more water application is not beneficial for maize cultivation. One time ($I_1$) water application is also not sufficient water application for maize production because the yield is not substantial in one time water application. Two times ($I_2$) water application with zero, minimum and traditional tillage practices gave a substantial amount of yield with minimum water application (Figure 5.2.5).

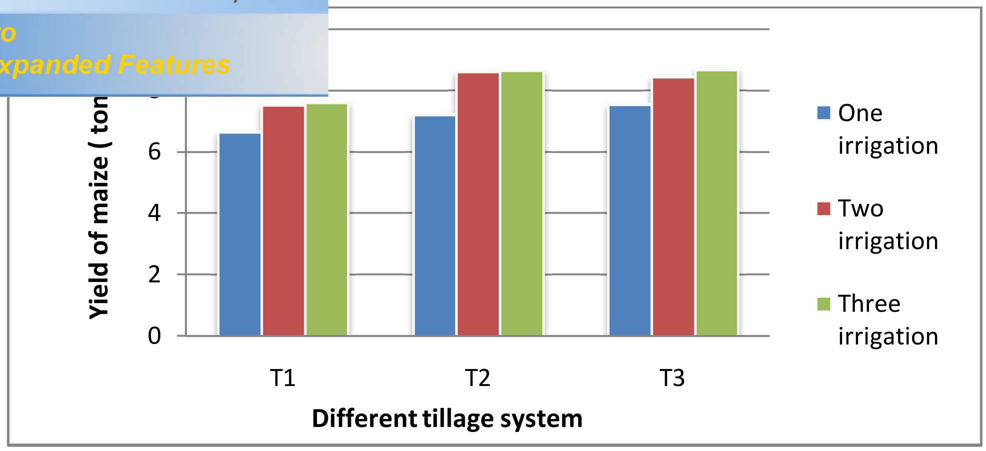
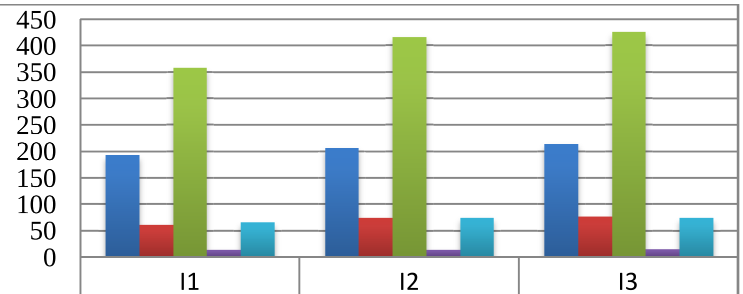



Figure 5.2.5: Effect of irrigation on maize yields with different tillage practices

The effects of tillage system with three level of water application on maize yield were observed. The three type of tillage system were zero tillage ($T_1$), minimum tillage ($T_2$) and Traditional tillage ($T_3$) and three level of water application were one time ($I_1$) water application, two times ($I_2$) water application and three times ($I_3$) water application. In every tillage system, the lowest yield was found in one time water application and the height yield was found in three times water application. The yield for two times water applications was very much similar with three time water applications in each type of tillage system. The very much similar results were found in zero, minimum and traditional tillage with same level of water application. The yield of maize was varied with the of different amount of water application (Figure 5.2.5).

The maize yields contributing characters such as plant height, cob number, grains per cob, 100-grains weight and plant population per plot were affected by different levels of irrigation (Figure 5.2.6). Statistically significant different was found in each yield contributing characters of maize. Highly significant variation observed in plant height and grains per cob parameters. Similar impact was recorded in plant height, cob per plot and grains per cob in $I_2$ and $I_3$ irrigation treatments. Maximum number of plant per plot was found in $I_2$ irrigation practices, which was followed by $I_3$ irrigation practices. The lowest number of plant was found in $I_1$ irrigation practices. The another yield contributing character of 100-grain weight was found high in $I_3$ irrigation practices (15.73

...ilar with $I_2$ irrigation practices (15.23 gm) and lowest was ...gm).




| | I1 | I2 | I3 |
|---|---|---|---|
| Plant height (cm) | 193.7 | 207.3 | 214.7 |
| No. of cobs per plot | 62.33 | 75.33 | 77.67 |
| grains per cob | 358 | 416.7 | 426 |
| 100-grains weight (gm) | 14.93 | 15.23 | 15.73 |
| Plant population per plot | 66.33 | 75.33 | 75 |

Figure 5.2.6: Effect of different amount of irrigation water on maize yields parameters

The effects of three irrigations on maize yield contributing characters were recorded. Unsatisfactory and poor results of maize yield contributing characters were found for one time water application. The higher values of maize yield contributing characters were found for three times water application. Satisfactory results of maize yield contributing characters were also found for two times water application. $I_3$ (three times water application) irrigation was sufficient for higher yield maize cultivation but a huge amount of water was required in this practices. Statistically same significance for maize yield contributing characters were found in two times and three times water application. Among the three irrigations practices ($I_1$, $I_2$ and $I_3$) $I_2$ irrigation practice (irrigation applied two times, after 25 days after sowing and 50 days after sowing) was found as preferable water application practices for maize cultivation in dry season of Bangladesh.

**d and yield contributing characters of maize**

Effect of different tillage on yield and yield contributing characters are presented in (Table 5.3.1). Significant change among the different tillage practices was observed except plant populations, grains per cob and 100-grains weight. The highest plant height (207.7 cm) was observed in $T_2$ treatment, which was statistically identical to $T_3$ treatment (207.3 cm) and the lowest plant height (200.7 cm) observed in $T_1$ treatment. In case of plant population, statistically no significant difference was observed, statistically all plot was contained same plant. Statistically significant difference was found in yield of maize in different type of tillage practices. Maximum yield (8.25 t $ha^{-1}$) was found in $T_3$ treatment and the lowest yield (7.257 t $ha^{-1}$) was found in $T_1$ treatment. In $T_2$ treatment, the yield was found (8.15t $ha^{-1}$) which was very similar to $T_3$ treatments yield (8.25 t $ha^{1}$). In case of 100-grains weight and grain per cob, no statistical different were obtained among $T_1$, $T_2$ and $T_3$ tillage practices. Statistically minor different was found in cob per plot. The average number of cobs per plot 69.00 pieces, 72.67 pieces and 73.67 pieces were found in $T_1$, $T_2$ and $T_3$ tillage practice respectively.

Table 5.3.1: Effect of tillage on the yield and yield contributing characters of maize

| Treatment | Plant height (cm) | Plant /plot | Cob/ plot | Grain/cob | 100-grain weight (gm) | Yield t $ha^{-1}$ |
|---|---|---|---|---|---|---|
| $T_1$ | 200.7 | 70.33 | 69.00 | 392.3 | 14.43 | 7.257 |
| $T_2$ | 207.7 | 73.33 | 72.67 | 399.3 | 15.53 | 8.150 |
| $T_3$ | 207.3 | 73.00 | 73.67 | 409.0 | 15.93 | 8.227 |
| Level of significance | * | NS | * | NS | NS | * |
| CV (%) | 3.02 | 5.26 | 6.90 | 3.13 | 2.50 | 5.03 |

N.B. CV- Coefficient of variance NS- Not significance * statistically significant

It was observed that maximum yield of maize was found in traditional tillage practice ($T_3$) and it was very much similar to that of the minimum tillage practice ($T_2$) but different from that of the no tillage ($T_1$) practice (Figure 5.3.1). Zero tillage practice was not statistically approved for maize cultivation in dry season of Bangladesh.

e practice has no adverse contribution to environment illage practices were required more fossil fuel, more time and more labor than minimum tillage practices. Green house gases emission from traditional practices were more than five times than that of the minimum tillage practices ($T_2$) for more power tiller in operation was required for more tilling purposes which has a contribution to increase of global warming.

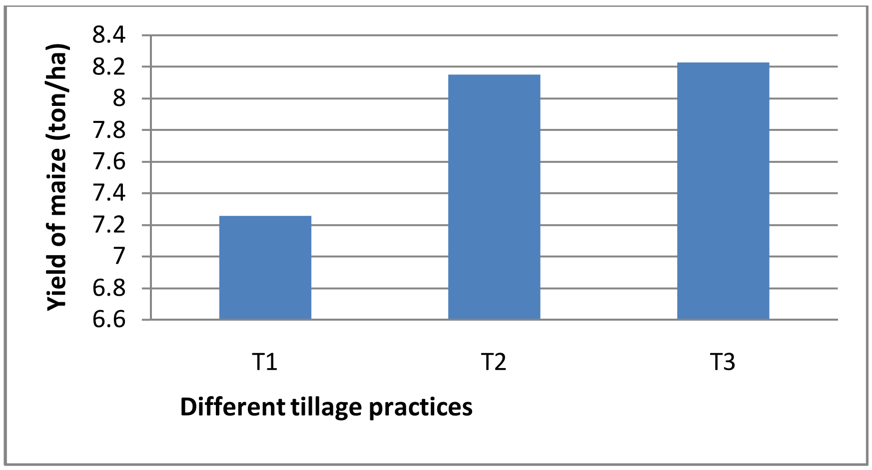



Figure 5.3.1: Influence of tillage practices on maize yields

In traditional tillage ($T_3$) practices have a great contribution to environmental pollution specially by air pollution. Therefore, it can be said that minimum tillage practice ($T_2$) was better than traditional practice ($T_3$) and zero tillage ($T_1$) in regards of production cost, environment pollution and maize yield.

Every irrigation practices ($I_1$, $I_2$ and $I_3$) have been contained three types of tillage practices the zero tillage ($T_1$), the minimum tillage ($T_2$) and the traditional tillage ($T_3$) practices. The lowest maize yield was found in zero tillage practices ($T_1$) and the highest yield was fond in traditional tillage practices ($T_3$) (Figure 5.3.2). The highest yield was found in minimum tillage ($T_2$) practices with $I_2$ irrigation. The yields of maize of $T_2$ tillage practices with $I_2$ and $I_3$ irrigation treatment were very much similar with $T_3$ tillage practices with $I_2$ and $I_3$ water application. In every irrigation treatment the lowest yield es so, this tillage practices is not suitable for maize gladesh.

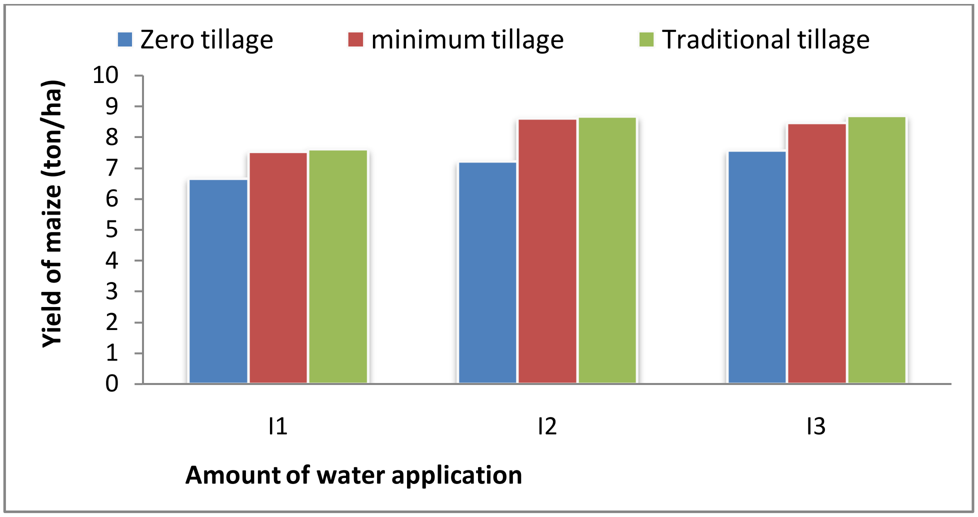



Figure 5.3.2: Effect of tillage practices on maize yield with different level of irrigation.

Statistically no significance different was found between $T_2$ and $T_3$ tillage practices in regards of yield and yield contributing parameters of maize (Figure 5.3.2). Statistically insignificant different was found among the tillage treatments in plant height, cob per plot and maize yield. The maximum plant height was observed in $T_2$ tillage treatment that was followed by $T_3$ tillage treatment and the lowest plant height was observed in $T_1$ tillage practices. Maximum number of cob per plot was found in $T_3$ tillage practices which was very similar to $T_2$ tillage practices and minimum number of cob were found in $T_1$ tillage treatment. Statistically no significant different were found among others maize yields parameters such as grains per cob, 100-grains weight and plant population per plot. Statistically tillage treatments ($T_2$ and $T_3$) had the similar effect on maize yields and yield contributing characters except $T_1$ (zero tillage) treatment. In zero tillage treatment, maize yields, plant height and cob per plant were lower than $T_2$ and $T_3$ tillage treatment. Minimum tillage and traditional tillage practices had the similar effect on the yields and yields contributing characters of maize.

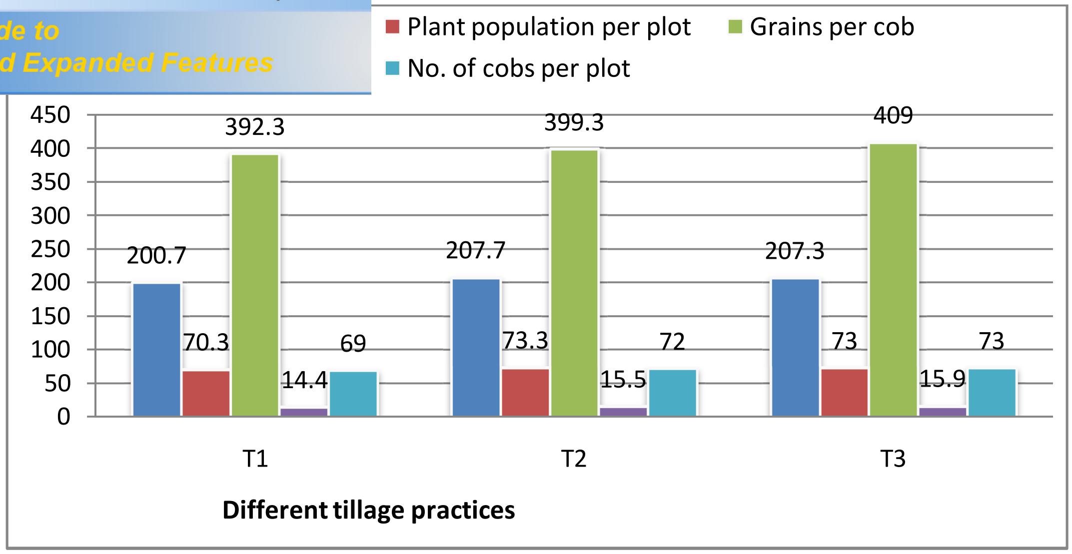



Figure 5.3.3: Effect of different tillage practices on various maize yields parameters

Minimum tillage ($T_2$) practice is less costly and has less contribution to environment pollution than traditional tillage ($T_3$) practices; therefore minimum tillage ($T_2$) practices is suitable for maize production in Bangladesh.

## 5. 4 Effect of tillage on the soil physical properties

Soil physical properties change very slowly. Bulk density (BD) of surface soil was decreased insignificantly due to depth and different types of tillage practices and it was varied from 1.50g/cm$^3$ to 1.47g/cm$^3$. Bulk density was observed highest in zero tillage and lowest in farmerôs traditional practices treatment. The field capacity (FC) was lowest in zero tillage and highest in deep tillage due to compaction of soil (Table 5.4.1) whereas BD and FC of initial soil was 1.50 g cm$^{-3}$ and 29.26 percentages in volume. The physical properties of soil were not significantly changed in the short-term experiment due to tillage and irrigation application among three treatments (Table 5.4.1). Statistically no significant difference was found in particle density of the soil. Particle density was decreased slightly with tillage practices.

tillage on physical properties of post harvest soil

| Treatment | Depth (cm) | Bulk Density (g/cm$^3$) | Particle Density (g/cm$^3$) | Porosity (%) | Field capacity (Volume %) |
|---|---|---|---|---|---|
| $T_1$ | 0-30 | 1.50 | 2.663 | 43.93 | 29.00 |
| $T_2$ | 0-30 | 1.483 | 2.662 | 44.24 | 29.56 |
| $T_3$ | 0-30 | 1.474 | 2.658 | 44.84 | 29.96 |
| CV (%) | - | 2.34 | 1.38 | 1.64 | - |
| Level of significant | - | NS | NS | NS | NS |
| Initial soil | 0-30 | 1.50 | 2.67 | 43.93 | 29.36 |
| | | | | | |

N.B. CV- Coefficient of variance NS- Not significance * statistically significant

### 5.5 Bulk density, particle density, porosity and field capacity

The bulk density, particle density, porosity and field capacity were not significantly affected by the tillage practices presented in table 5.4.1. Statistically no significant variation was observed in bulk density and particle density due to variation of tillage practices. The minimum bulk and particle density indicates the greater amount of irrigation water requirement. Bulk density and particle density slightly decreased in $T_2$ and $T_3$ tillage treatments. Bulk density and particle density were low in traditional tillage practice than minimum and zero tillage practices. This was might be due to improvement of soil health.

Bulk density and particle density were generally lower in clay soil because of higher organic matter content and soil microorganism organisms. Porosity and field capacity were not significantly affected due to different tillage treatments (Figure 5.5.1). The porosity and field capacity were slightly increased due to the application of increased tillage practices. The highest field capacity (29.96 %) was observed in $T_3$ tillage treatment and the lowest field capacity was (29 %) found in $T_1$ tillage treatment. The highest field capacity and porosity was observed in the farmerǿs traditional tillage practices ($T_3$). The higher field capacity and porosity indicates higher irrigation water requirement, which causes the excessive water uses and creates higher crop production cost. The soil physical properties were not significantly affected due to various tillage soil physical properties were not affected by the tillage ad no contribution to maize yield and yield contributing characters.

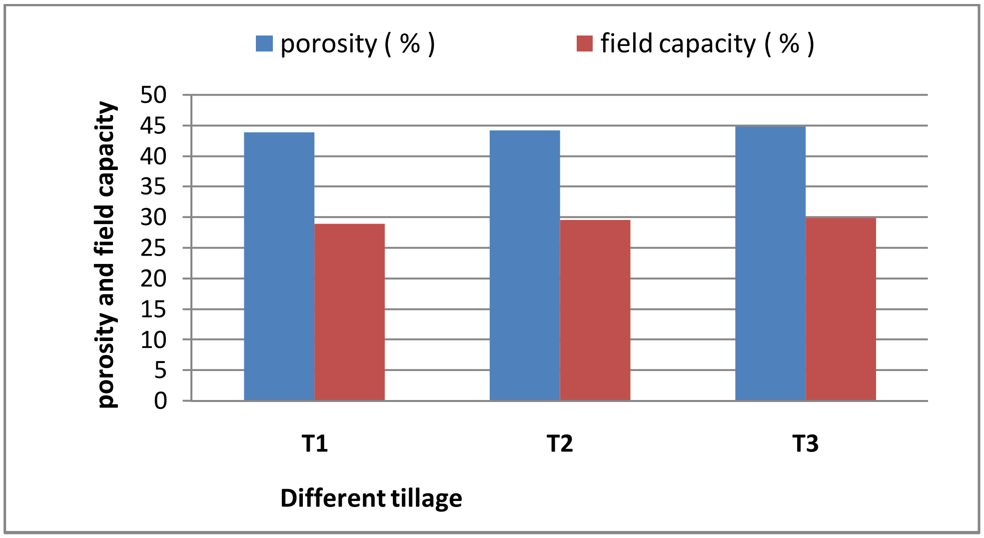



Figure 5.5.1: Changes of soil physical property due to tillage practices

**5. 6 Influence of excessive tillage to increase air pollution**

There were three types of tillage practices in this project work they were i) zero tillage ($T_1$), ii) minimum tillage ($T_2$) and iii) farmerôs traditional tillage ($T_3$) practices. In $T_1$ tillage operation no tillage had been done, only sowing operation was completed by power tiller mounted inclined plate planter. Fifteen hours power tiller in operation was required for one hectare of land for maize sowing in zero tillage practices. The second treatment was minimum tillage operation that means a little amount of soil pulverization had been done. In minimum tillage treatment, tilling and sowing had been done simultaneously. Minimum tillage treatment had been also required fifteen hours of power tiller mounted inclined plate planter in operation for one hectare of land for sowing and tilling simultaneously. Power tiller mounted inclined plate planter was required in operation for sixty hours for tilling the soil, then twenty five labors were required for manually maize sowing for one hectare of land. The power tiller was consumed 1.25 liter of diesel fuel for one hour in operation.

bors required for one hectare of land with three-tillage

| Treatments | Time required for power tiller in operation (hours) | Fuel required for one hour power tiller in operation (liter) | Fuel required (liter) | Labors required (Number person) |
|---|---|---|---|---|
| $T_1$ | 14.82 | 1.25 | 1.25×14.82= 18.52 | 5 |
| $T_2$ | 14.82 | 1.25 | 1.25×14.82= 18.52 | 5 |
| $T_3$ | 59.28 | 1.25 | 1.25×59.28= 74.00 | 25 |

**5.7 Calculating the carbon dioxide ($CO_2$) emissions**

The Intergovernmental Panel on Climate Change (IPCC) guidelines for calculating emissions inventories require that an oxidation factor be applied to the carbon content to account for a small portion of the fuel that is not oxidized into $CO_2$. For all oil and oil products, the oxidation factor used is 0.99 (99 percent of the carbon in the fuel is eventually oxidized, while 01 percent remains un-oxidized). Finally, to calculate the $CO_2$ emissions from a gallon of fuel, the carbon emissions are multiplied by the ratio of the molecular weight (m.w) of $CO_2$ to the molecular weight of carbon. $CO_2$ emissions from a liter of diesel = 611.9 grams x 0.99 x (44/12) =2221.2 grams = 2.22 kg/ liter of fuel (www.epa.gov/otaq/greenhousegases.htm).

Table 5.7.1: Carbon dioxide ($CO_2$) emissions from various type of fuel

| Name of fuel | 1 liter fuel emits $CO_2$ (Kg) | 1 tone of $CO_2$ means |
|---|---|---|
| Petrol | 2.33 | 429 liters of petrol |
| Diesel | 2.77 | 360.75 liters of diesel |
| Crude oil | - | 3.15 barrels of crude oil |

(Source: http://numero57.net/2008/03/20/carbon-dioxide-emission)

The amount of carbon dioxide ($CO_2$) emission from three type of tillage treatment that had been used in this project can be calculated. Among the green house gases, $CO_2$ has the most severe effect on increasing the global warming. Power tiller consumes diesel

$NO_2$, SO, $SO_2$ and others green house gases. One liter of $CO_2$, which has a great contribution to increase the air temperature. Among the green house gases, $CO_2$ is the major portion so, the amount of $CO_2$ emission in one hectare of land for cultivation of maize by different tillage treatments are shown in (Table 5.7.2).

Table 5.7.2: Carbon dioxide emission by different type of tillage treatment

| Treatments | Time required for power tiller in operation (hours/ha) | Fuel required for one hour power tiller in operation (liter) | Fuel required (liter/ha) | Amount of carbon dioxide($CO_2$) emission (kg/ha) |
|---|---|---|---|---|
| $T_1$ | 14.82 | 1.25 | 18.52 | 18.52×2.77= 51.30 |
| $T_2$ | 14.82 | 1.25 | 18.52 | 18.52×2.77= 51.30 |
| $T_3$ | 59.28 | 1.25 | 74.00 | 74.00×2.77= 205.0 |

In $T_1$ and $T_2$ tillage practices same amount of fuel and labors were required for tilling and sowing operation (Table 5.6.1). For tilling and sowing of one-hectare land by $T_1$ and $T_2$ tillage treatments, 18.52-liter fuel had been required. In $T_3$ tillage treatment 74 liters fuel had been required for one hectare of land for tilling purpose and 25 labors were required for sowing manually.

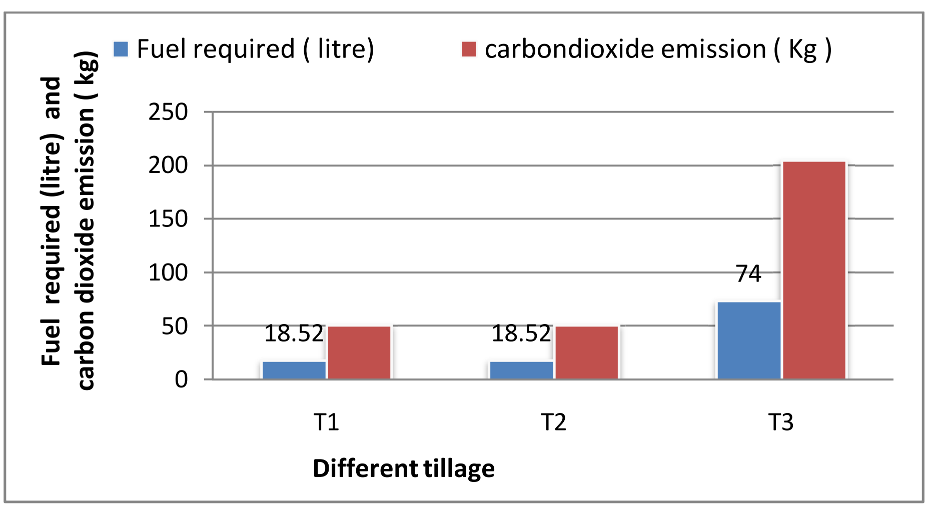



Figure 5.7.1: Carbon dioxide produces in various tillage treatments

l 51.30 kg of carbon dioxide in zero ($T_1$) and minimum in farmerꞌs traditional tillage treatment power tiller had been produced about 205 kg of carbon dioxide for maize cultivation of one hectare of land (Figure 5.7.1). Fuel cost for tilling of land in traditional tillage ($T_3$) treatment (74×60 = Tk. 4440) for one hectare of land is four times more than that of the zero ($T_1$) and minimum ($T_2$) tillage treatment (18.52×60 = Tk. 1111). Carbon dioxide and others green house gases that had been produced in $T_3$ tillage treatment were also four times more than that of the $T_1$ and $T_2$ tillage treatment (Figure 5.7.1). Since $T_2$ and $T_3$ tillage treatment had the same effects on yields and yields contributing characters but $T_3$ tillage treatment was consumed more than four times fuel and labors. In $T_3$ tillage treatment, $CO_2$ was emitted more than four times than that of the $T_1$ and $T_2$ tillage treatments.

### 5.8 Interaction effects of irrigation and tillage on yield contributing characters

The interaction effects between tillage practices and irrigation on some yield contributing characters such as plant population per plot, 100-grains weight and yields had been significantly changed. Only cob per plot did not significantly change. The highest maize yield (8.680 t $ha^{-1}$) was found from $T_3I_3$ treatment combination and the lowest yield (6.650 t $ha^{-1}$) was observed at $T_1I_1$ combination. The yield had been significantly different among treatments shown at (Table 5.8.1). There was a significant effect on plant height with treatment combination of tillage and irrigation. The highest plant height (218.0 cm) found from $T_3I_3$ treatment combination and the lowest plant height (180.0 cm) found from $T_1I_1$ treatment combination. Statistically significant difference observed in grain per cob of combined treatment (Table 5.8.1). The maximum grains per cob (427) was found from $T_1I_3$ which was followed by $T_2I_2$, $T_3I_3$, $T_3I_2$, $T_1I_2$ and $T_2I_2$ treatment combination and lowest number of grains (330) was observed for $T_1I_1$ treatment combination.

Combined effects of tillage and irrigation on the yield and yield contributing characters of maize were significant. The effects of combined treatments were found on the plant height and grains per cob. Plant height was increased with maximum number of irrigation sign in higher plant height because the higher plant height lsing of plant. The yield of any kind of crop drastically decreases due to the lodging of plant so; higher plant height is discouraged. Maximum grain number per cob did not put contribution to higher yield of maize that indicates the smaller grain size of maize. The others yield contributing parameters such as plant per plot, Cob per plot and 100-grain weights were statistically same with interaction effect of irrigation and tillage treatment.

Table 5.8.1: Interaction effects of tillage and irrigation on the yield and yield contributing characters of maize

| Treatment | Plant height (cm) | Plant/ plot | Cob/ plot | Grain/cob | 100- grain weight (gm) | Yield (t $ha^{-1}$) |
|---|---|---|---|---|---|---|
| $T_1I_1$ | 180.0 | 63.00 | 58.00 | 330.0 | 14.00 | 6.650 |
| $T_1I_2$ | 208.0 | 73.00 | 74.00 | 416.0 | 14.50 | 7.520 |
| $T_1I_3$ | 214.0 | 75.00 | 75.00 | 431.0 | 14.80 | 7.600 |
| $T_2I_1$ | 201.0 | 68.00 | 64.00 | 364.0 | 15.00 | 7.200 |
| $T_2I_2$ | 210.0 | 78.00 | 76.00 | 414.0 | 15.60 | 8.600 |
| $T_2I_3$ | 212.0 | 74.00 | 78.00 | 420.0 | 16.00 | 8.650 |
| $T_3I_1$ | 200.0 | 68.00 | 65.00 | 380.0 | 15.80 | 7.550 |
| $T_3I_2$ | 204.0 | 75.00 | 76.00 | 420.0 | 15.60 | 8.450 |
| $T_3I_3$ | 218.0 | 76.00 | 80.00 | 427.0 | 16.40 | 8.680 |
| Level of significance | * | * | NS | * | * | * |
| CV (%) | 3.02 | 5.26 | 6.90 | 3.13 | 2.50 | 5.03 |

N.B. CV- Coefficient of variance NS- Not significance * statistically significant

The maximum tillage that means the farmerôs traditional practices with minimum water application ($T_3I_1$) treatments did not give the substantial amount of maize yields. On the other hand, substantial amount of maize yield has been found in zero and minimum water application in ($T_1I_2$) and ($T_1I_3$) treatments (Figure ield has been found in minimum tillage with maximum water application in ($T_2I_2$) and ($T_2I_3$) treatments combination. In the analysis, statistically minor significant difference has been found in the tillage treatments. The yield of maize was substantially varying with the variation of the water application. Three times water application with zero tillage did not give the substantial amount of maize yield. The highest maize yield was found in three times water application with traditional tillage practices, it was very much similar with the yield of two times water application, and minimum tillage practices.

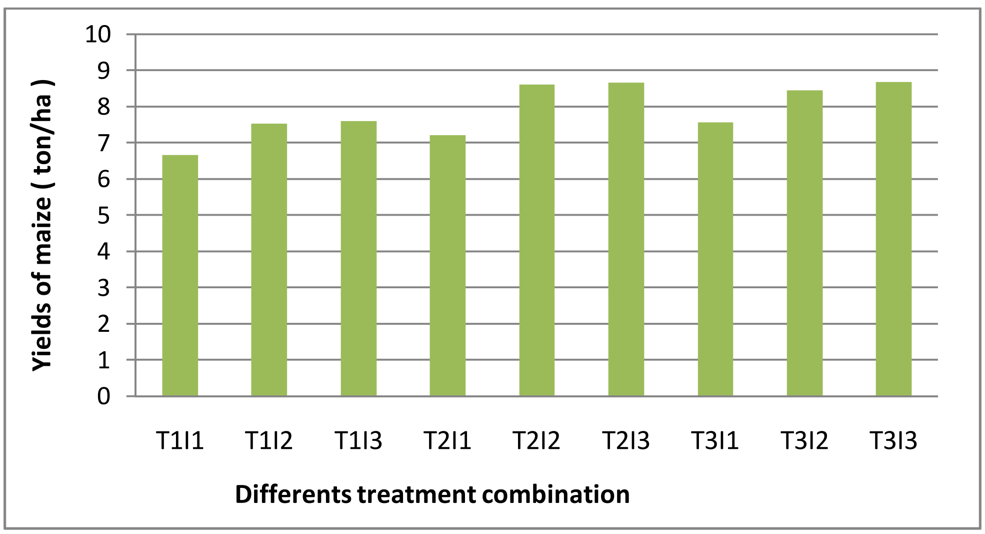



Figure 5.8.1: Interaction effects of irrigation and tillage on maize yield

The maize yield was rapidly increased from one time water application to two times water application. The yield of maize did not increase rapidly from two times water application to three times water application. In economic analysis, three times water application with traditional tillage practices was not preferable treatment combination for maize cultivation. In economic analysis, two-time water application with minimum tillage practices were the best treatment combination for maize cultivation. The highest net return has been found in minimum tillage with two-time water application ($T_2I_2$) treatment.

hat to give the maximum number of tillage and over are imprudent activities. The excessive application of irrigation water increases the agricultural production cost. The prudent and rationale use of water is most important because in dry season (Rabi) of Bangladesh the acute scarcity of water is a frequent occurrence.

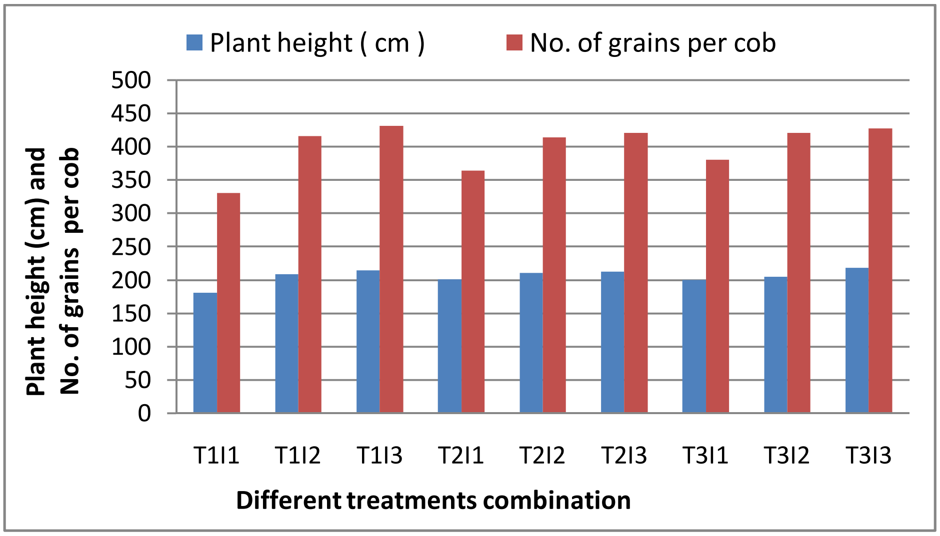



Figure 5.8.2: Interaction effect of irrigation and tillage on maize plant height and number of grains per cob.

Plant height was increased with increase the increased number of water application (Figure 5.8.2). Plant height depends on the application of water. It was not depend on the tillage practices. The plant height was increased by over application of water but yield did not increase with plant height. The yield of maize was increased by the over application of water but the excessive water application was not economically preferable method for maize cultivation. Number of grains per cob is another yield contributing character of maize. Number of grains per cob increased with the number of application of irrigation water (Figure 5.8.2). Tillage treatments have no significant effect on number of grains per cob. Grains per cob have no significant effect on maize yields. $I_2$ and $I_3$ irrigation treatment have the same effect on grains per cob. Therefore, ($I_3$) three times water application is not rationale water application for maize cultivation.

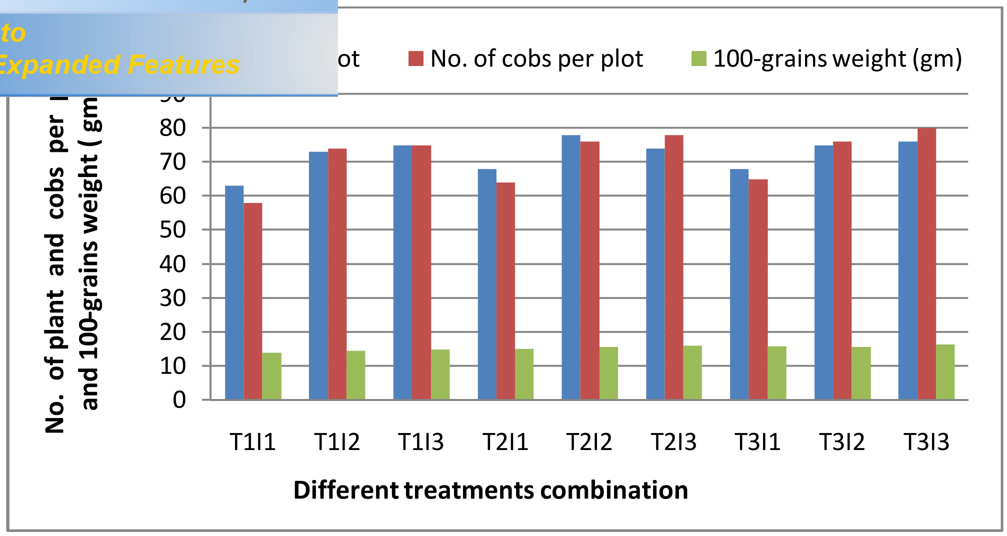



Figure 5.8.3: Interaction effect of irrigation and tillage on plant population, cobs per plot and 100-grains weight

Statistically significant difference was found in 100-grains weight of maize. It is another contributing character of maize. 100-grains weight increase with the number of application of irrigation water. Minimum tillage and traditional tillage have the same effect on 100-grains weight but a minor different was found with zero tillage. The highest grains weight found in $T_2I_3$ and $T_3I_3$ treatment combination so, grains weight is independent of tillage treatment but irrigation water has minor effect on grains weight. Therefore, excessive tillage practices and water application are not rationale practices for maize cultivation. Statistically insignificant difference was found in cob per plot with the treatment combination of water application and tillage. Number of cobs increase with the application of water (Figure 5.8.3). In tillage treatment with the maximum number of cobs found with $I_2$ and $I_3$ water application. The number of cobs in $I_2$ water application was very much similar with that of the $I_3$ water application. Tillage has no effect on number of cob per plot.

From the above discussion, it can be concluded that the irrigation water application plays a vital role for increasing the maize yield. From this project work, it has been found that at a certain level of water application was better than three time water application for maize cultivation based on statistical analysis. Two-time water application ($I_2$) irrigation treatment with minimum tillage ($T_2I_2$) was the preferable treatment combination for s and yields contributing characters of maize were very cation treatment with traditional tillage practices.

**5.9 Water use efficiency with different water application and tillage practices**

The water use efficiency has been depended on crop variety, tillage type, intensity of tillage practices, rainfall, humidity etc. The total water application was varied from 28.30 cm to 62.00 cm (Table: 5.9.1). The lowest amount of water was applied in $T_1I_1$, $T_2I_1$ and $T_3I_1$ treatments combination and the highest total water were used in $T_1I_3$, $T_2I_3$ and $T_3I_3$ treatments combination (Table 5.9.1). Total water use was increased with maximum number of irrigation treatment. Minimum number of irrigation with zero tillage has been produced lowest yields. The highest maize yields was found in $T_3I_3$ (8.68 ton/ha) and $T_2I_2$ (8.60 ton/ha) treatments combination. Yield of maize were increased with the maximum number of water application. Maize yield were dependent on tillage and water application. Statistically high significant difference was found in water application for maize yield. A significant difference was found in combined treatment of tillage and water on maize yield. In zero tillage treatment with three level of water were applied but yield did not significantly increase. Maize yield was increased significantly in minimum and traditional tillage treatment with three times of water application (Figure 5.8.1). Significant difference was not found among $T_2I_2$, $T_2I_3$, $T_3I_2$ and $T_3I_3$ treatments combinations for maize yield and yield contributing characters.

Water use efficiency is an important factor for maize cultivation in dry season of Bangladesh. The highest water use efficiency (0.235 ton/ ha-cm) was found in $T_1I_1$ treatment combination and lowest water use efficiency (0.145 ton/ ha-cm) was found in $T_3I_3$ treatment combination (Table: 5.9.1). The higher water use efficiency were found in $T_2I_{1,}$ $T_2I_2$ and $T_3I_1$ treatment combination. Though higher water use efficiency was found in $T_2I_1$ and $T_3I_1$ treatment combination but these treatment combination were not preferable because the yield of maize of these treatments were lower (7.20 ton/ha.) and (7.55 ton/ha.) respectively that are lower than standard yield of maize of Bangladesh 8.00 ton/ha. (Islam et al., 2008)

Table 5.9.1: Water used for maize cultivation under different levels of irrigation and tillage treatment combinations.

| Treatment combination | Average applied water (cm) | Average soil water contribution (cm) | Effective rainfall + water applied at land preparation+ water required for seedling establishment (cm) | Total average water used (cm) | Maize yields (t $ha^{-1}$) | Water use efficiency (t $ha^{-1}cm^{-1}$) |
|---|---|---|---|---|---|---|
| $T_1I_1$ | 9.00 | 3.3 | 15.3+2+2=19.3 | 28.30 | 6.650 | 0.235 |
| $T_1I_2$ | 17.25 | 3.3 | 19.3 | 36.55 | 7.520 | 0.206 |
| $T_1I_3$ | 29.00 | 3.3 | 19.3 | 48.30 | 7.600 | 0.157 |
| $T_2I_1$ | 12.00 | 1.0 | 19.3 | 31.30 | 7.200 | 0.230 |
| $T_2I_2$ | 20.25 | 1.0 | 19.3 | 39.55 | 8.600 | 0.217 |
| $T_2I_3$ | 34.00 | 1.0 | 19.3 | 53.30 | 8.650 | 0.162 |
| $T_3I_1$ | 13.67 | -1.0 | 19.3 | 33.00 | 7.550 | 0.228 |
| $T_3I_2$ | 25.22 | -1.0 | 19.3 | 44.52 | 8.450 | 0.190 |
| $T_3I_3$ | 42.77 | -1.0 | 19.3 | 62.00 | 8.680 | 0.140 |

The higher yield has been found in traditional tillage practices with three times water application ($T_3I_3$) treatment combination but the water use efficiency was lower. This treatment combination was not preferable for maize cultivation. $T_3$ tillage treatment has a contribution to increase air temperature because a huge amount of $CO_2$ has been produced in this treatment. Traditional tillage practice treatment creates an opportunity for soil erosion so this treatment has a negative effect on environment pollution. Three times water application treatment has been consumed more power for motor and engine operation (fuel or electricity).

…tion in different treatment contribution

| Treatment combination | Initial moisture content (%) | Moisture content at first irrigation (%) | Moisture content at second irrigation (%) | Moisture content at third irrigation (%) | Average moisture content at different irrigation (%) | Average soil moisture contribution in different treatment (cm) |
|---|---|---|---|---|---|---|
| $T_1I_1$ | 21 | 23 | 24 | 23 | 23.3 | 3.3 |
| $T_1I_2$ | 21 | 23 | 24 | 23 | 23.3 | 3.3 |
| $T_1I_3$ | 21 | 23 | 24 | 23 | 23.3 | 3.3 |
| $T_2I_1$ | 21 | 21 | 22 | 22 | 21.6 | 1.0 |
| $T_2I_2$ | 21 | 21 | 22 | 22 | 21.6 | 1.0 |
| $T_2I_3$ | 21 | 21 | 22 | 22 | 21.6 | 1.0 |
| $T_3I_1$ | 21 | 19 | 22 | 20 | 20.3 | -1.0 |
| $T_3I_2$ | 21 | 19 | 22 | 20 | 20.3 | -1.0 |
| $T_3I_3$ | 21 | 19 | 22 | 20 | 20.3 | -1.0 |

Soil water contribution has been observed highest in zero tillage treatment and lowest in traditional tillage treatment. In $T_1$, $T_2$ and $T_3$ tillage with different water application treatments the average soil water contribution were (3.3 cm), (1.0 cm) and (-1.0 cm) respectively. The soil water contributions were positive in zero ($T_1$) and minimum tillage ($T_2$) practice treatments. The negative soil water contribution has been found in traditional tillage ($T_3$) treatment that means soil has been consumed water from irrigation water to reach the previous soil moisture Table: 5.9.2). The positive soil water contribution means soil supply water to crop from itself and negative soil water contribution means soil consumes water from applied irrigation water.

Zero and minimum tillage treatments have been developed the soil physical properties that has been influenced on the water requirement for maize cultivation. The highest water holding capacity has been observed in $T_1$ tillage treatment and lowest water holding capacity has been found in $T_3$ tillage treatment. It has been observed that in traditional tillage treatment the soil moisture was decreased rapidly. More tillage practices have been created the soil more aeration to more evaporation of soil water. The s been found in zero tillage treatment and maximum was ment. This phenomenon has been indicated that the more tillage the more water requirement for maize cultivation (Figure 5.9.1).

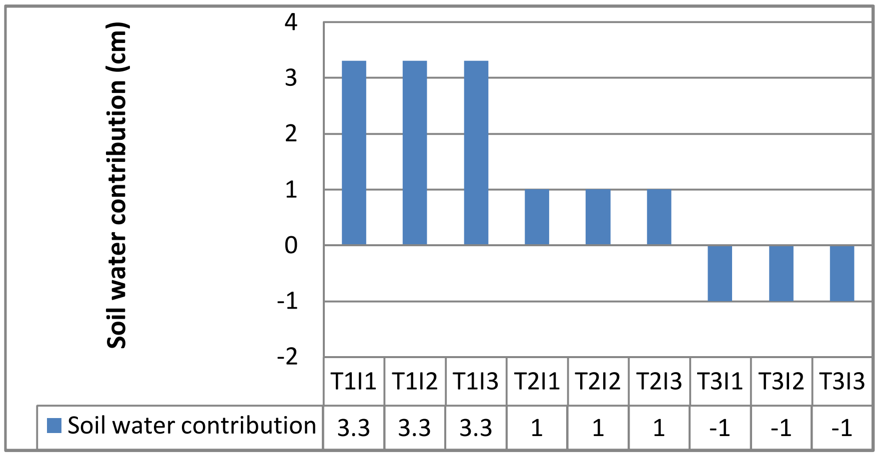



Figure 5.9.1: Soil water contribution on different irrigation and tillage treatments.

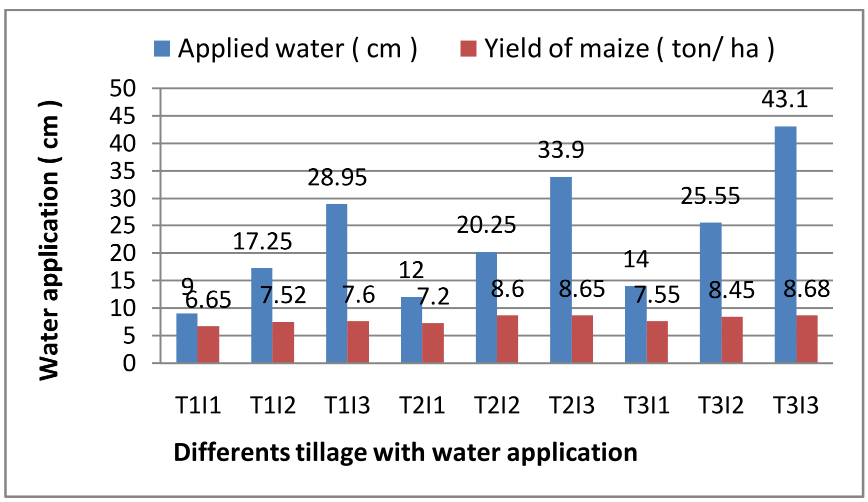



Figure 5.9.2: Total average water application and maize yield with different treatment combination

The maize yield has been varied with the variation of water application and tillage treatment combinations. The maximum water was applied (62.00 cm) in traditional tillage practices ($T_3$) and the lowest amount of water was applied (28.30 cm) in zero tillage treatments. The maximum maize yield (8.68 ton/ha) was found in traditional tillage practices with three times water application. The lowest maize yield (6.65 ton/ha) ne time water application. In this experiment it was found endend on the water application and tillage treatment. A satisfiable maize yield were not found in $T_1I_1$ and $T_1I_2$ treatment combination that means zero tillage with minimum water application was also not preferable treatments combination for maize cultivation. Minimum tillage with two time water application ($T_2I_2$) has been given a substantial amount of maize yield. Therefore, maximum tillage and zero tillage practices are not suitable practices for maize cultivation, the suitable tillage practice for maize cultivation is minimum tillage practices. Maximumm water application is also not preferable for maize cultivation. Two times water application with minimum tillage practices are better treatment combination for maize cultivation.

Table 5.9.3: Water use efficiency in different irrigation treatments

| Irrigation treatment | No. of irrigation | Irrigation applied days after sowing | Water requirement for land preparation and seedling establishment (cm) | Average Irrigation water applied (cm) | Effective rainfall (cm) | Total water used (cm) | Maize yields (t $ha^{-1}$) | Water use efficiency (t $ha^{-1}cm^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| $I_1$ | 1 | 25 | 2+2= 4.00 | 35.00 | 15.30 | 54.30 | 7.33 | 0.135 |
| $I_2$ | 2 | 25, 50 | 4.00 | 62.70 | 15.30 | 82.00 | 8.20 | 0.102 |
| $I_3$ | 3 | 25, 50, 85 | 4.00 | 105.00 | 15.30 | 124.3 | 8.31 | 0.067 |

The total applied irrigation water in three irrigation treatments were 54.30 cm, 82.00 cm and 124.30 cm in $I_1$, $I_2$ and $I_3$ irrigation treatment respectively. Water use efficiency varied from (0.140 t / ha-cm) in $I_1$ irrigation treatment to (0.068 t /ha-cm) in $I_3$ irrigation practices. Water use efficiency was decreased drastically from $I_1$ irrigation treatment to $I_3$ irrigation treatment but maize yield was increased slightly from $I_1$ treatment to $I_3$ treatment (Table 5.9.3). The highest water use efficiency was found in one time water maize yield was found in this treatment combination. A s been found among three level of water application. Statistically no significant variation has been found in regards of the maize yield between two-time water application ($I_2$) and three times water application ($I_3$). In two times water application treatment ($I_2$) the higher water use efficiency (0.102) has been found and the yield of maize in two-time water application was also very much similar with the yield of three time water application. Two-time water application is the preferable for maize cultivation considering water use efficiency and maize yield.

### 5.9.1 Total irrigation water used in different irrigation treatment

A high-yields maize crop requires average 50 cm of water, with a range of 45.0 cm to 80.0cm for acceptable yield of maize. About 35-41 cm of water is enough to produce a low yield, but that depends on the season and on the water is availability or unavailable. In general, higher yield need more water but factors like temperature affect this to some extent. One centimeter of water per hectare is about 120.47 $m^3$ (120469 liter) of water per hectare of land, so maize crop uses average 50 x 120.47 = 6023.5 $m^3$of water per hectare (source: Australian Journal of Agricultural Engineering, 1(4): pp-119-125, 2010).

Table 5.9.4: Total average irrigation water applied different irrigation treatment

| Irrigation treatment | Water used in zero tillage ($T_1$) | Water used in minimum tillage ($T_2$) | Water used in traditional tillage ($T_3$) | Total water applied (cm) | Total irrigation water applied ($m^3$/hactare) |
|---|---|---|---|---|---|
| $I_1$ | 9.00 | 12.00 | 14.00 | 35.00 | 4216.42 |
| $I_2$ | 17.25 | 20.25 | 25.22 | 62.70 | 7553.40 |
| $I_3$ | 29.00 | 34.00 | 42.00 | 105.00 | 12645.00 |

...er was applied in $I_3$ irrigation treatment and minimum ...s applied in $I_1$ irrigation treatment (Table 5.9.4). In $I_2$ irrigation treatment a moderate amount of water was applied. However, substantial difference of applied water was found in $I_1$, $I_2$ and $I_3$ irrigation treatment but a little amount of yields difference was observed in $I_1$, $I_2$ and $I_3$ irrigation treatment.

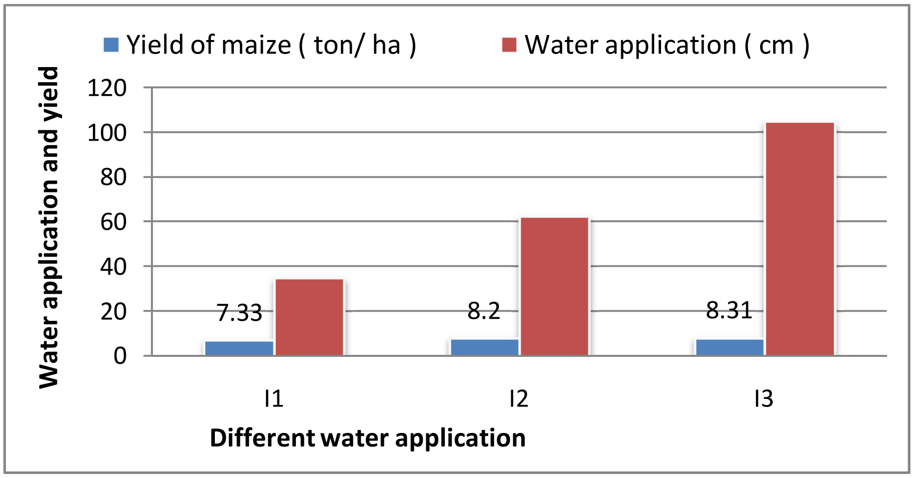



Figure 5.9.3: Different amount of water applied and yield of maize

From the above results and discussions, it can be said that $T_2I_2$ treatment combination is the rationale methods for maize cultivation in dry season (Rabi) of Bangladesh. That means $I_2$ irrigation practices is most suitable for maize cultivation in regarding the yield, water use efficiency and economic analysis (Table 5.11.1). In $I_1$ irrigation treatment satisfactory yield was not found. In $I_3$ irrigation treatment a huge amount of valuable water was used but yields was not statistically significant different from $I_2$ irrigation treatment.

Table 5.9.5: Comparison between $I_2$ and $I_3$ irrigation treatment

| Variables | Irrigation treatment ($I_2$) | Irrigation treatment ($I_3$) |
|---|---|---|
| No. of irrigation | 2 | 3 |
| Total applied water ($m^3$/ha.) | 7553.40 | 12645.00 |
| Yields (ton/ha) | 8.20 | 8.31 |
| Water use efficiency (t /ha-cm) | 0.102 | 0.067 |

of land from maize cultivation by adopting $I_2$ irrigation treatment over $I_3$ irrigation treatment is

$$12645.00 \text{ m}^3 - 7553.40 \text{ m}^3 = 5092.00 \text{ m}^3/\text{ha}.$$

$I_2$ irrigation treatment (irrigation water applied after 25 days of sowing and after 50 days of sowing) saves 5092.00 $m^3$ of water per hectare of land for maize cultivation than $I_3$ irrigation treatment (irrigation water applied after 25 days of sowing, after 50 days of sowing and after 85 days of sowing).

**5.10 Total water uses in different tillage practices**

It has been seen that the amount of irrigation water requirement was increased with the increase of tillage treatment (Table: 5.10.1). The maximum amount of water was required in $T_3$ tillage treatment (farmerôs traditional practices). Minimum amount of water was applied in zero ($T_1$) and minimum ($T_2$) tillage practices. The highest amount of water (82.65 cm) was applied in $T_3$ tillage treatment because over tilled soil loses its moisture more rapidly than minimum and zero tillage practices.

Another reason for consuming higher amount of water were maximum number tillage practices inspire the crop more rooting development that harnesses more soil moisture, so maximum amount of water was required in $T_3$ tillage treatment than $T_2$ and $T_1$ tillage treatment. The treatment $T_2$ (minimum tillage practices) tillage practices were consumed 66.15 cm of water. . Field capacity of soil was increased with the increased number of tillage practices. Field capacity of soil governs the more water requirement to reach the soil moisture up to field capacity. Therefore, the demand of irrigation water was increased with the increase of tillage practices.

different tillage methods

| Treatment combination | First average irrigation $I_1$ (cm) | Second average irrigation $I_2$ (cm) | Third average irrigation $I_3$ (cm) | Average soil moisture contribution in different treatment (cm) | Total applied water (cm) | Yields ( t/ha) |
|---|---|---|---|---|---|---|
| $T_1I_1$ | 9.00 | | | 3.3 | 9.00 | 6.650 |
| $T_1I_2$ | 9.00 | 8.25 | | 3.3 | 17.25 | 7.520 |
| $T_1I_3$ | 9.00 | 8.25 | 11.70 | 3.3 | 28.95 | 7.600 |
| Total average water application in $T_1$ tillage treatment | | | | | 55.20 | |
| $T_2I_1$ | 12.00 | | | 1.0 | 12.00 | 7.200 |
| $T_2I_2$ | 12.00 | 8.25 | | 1.0 | 20.25 | 8.600 |
| $T_2I_3$ | 12.00 | 8.25 | 13.65 | 1.0 | 33.90 | 8.650 |
| Total average water application in $T_2$ tillage treatment | | | | | 66.15 | |
| $T_3I_1$ | 14.00 | | | -1.0 | 14.00 | 7.550 |
| $T_3I_2$ | 14.00 | 11.55 | | -1.0 | 25.55 | 8.450 |
| $T_3I_3$ | 14.00 | 11.55 | 17.55 | -1.0 | 43.10 | 8.680 |
| Total average water application in $T_3$ tillage treatment | | | | | 82.65 | |

At first irrigation, the demand of water was 9 cm, 12 cm and 14 cm for $T_1$, $T_2$ and $T_3$ tillage treatment respectively. The water demand was 8.25 cm, 8.25 cm and 11.55 cm at second irrigation treatment for $T_1$, $T_2$ and $T_3$ tillage treatment respectively. At third irrigation, the water requirement were 11.70 cm, 13.65 cm and 17.55 cm for $T_1$, $T_2$ and $T_3$ tillage treatment respectively. Statistically insignificant difference was found in maize yield with different tillage treatment. In $T_1$ tillage treatment maize yield was lower than $T_2$ and $T_3$ tillage treatment. No significant difference were found in $T_2$ and $T_3$ tillage treatment. Statistically $T_2$ and $T_3$ tillage treatment were similar in yield and yield contributing characters so, $T_2$ tillage treatment was considered as the suitable tillage for ove discussion $T_2$ tillage practices can be choose as most n in regarding water saving and maize yield.

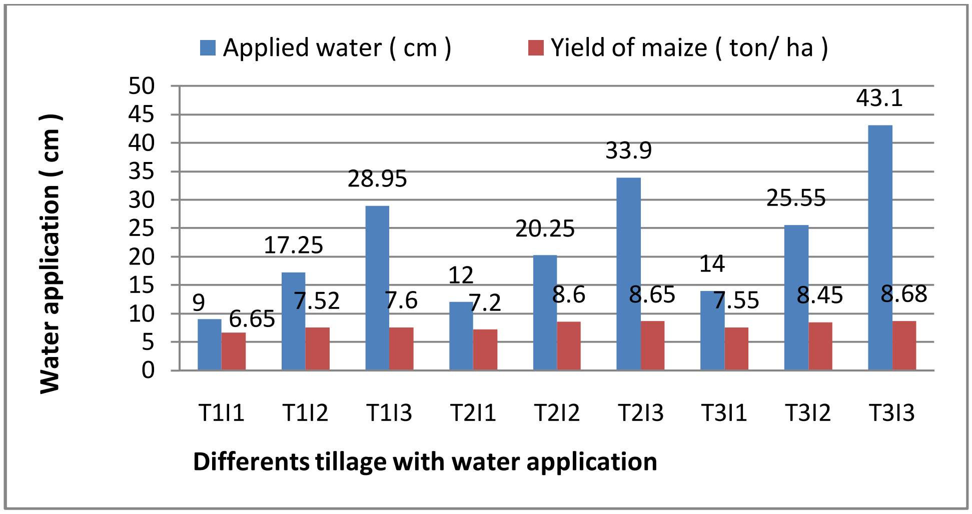



Figure 5.10.1: Irrigation water applied in different tillage treatment

Therefore, there is a scope to save a huge amount of water resources by using $T_2$ tillage practices over $T_3$ tillage practices. Minimum tillage treatment is also an environmentally friendly practices because this treatment consumed minimum amount of fuel and no soil tillage was done so it emitted minimum amount of carbon dioxide ($CO_2$). Minimum and zero tillage treatments have been given an opportunity of soil microorganisms to increase their progeny and physiological activity. Although zero tillage was environment friendly and less costly it was not acceptable due to lowest maize yield in this treatment. $T_2$ tillage treatment was scientifically preferable for greater maize yield and minimum cost for maize production in this treatment.

Table 5.10.2: Amount of water saving by using optimum tillage practices

| Treatments | No. of tillage | Total applied water (cm) | Water requirement ( $m^3$/ ha) | Yield (ton /ha) |
|---|---|---|---|---|
| $T_1$ | No tillage | 55.20 | 6650.00 | 7.257 |
| $T_2$ | Minimum tillage | 66.15 | 7970.00 | 8.150 |
| $T_3$ | 4 times tillage, farmer's traditional tillage practices | 82.65 | 9956.80 | 8.227 |

treatment means $T_2$ tillage practices was the best suit for the yield, water use efficiency and economic analysis Table 5.11.1. Calculation can be done to measure the amount of water can be saved by using $T_2$ tillage treatment over $T_3$ tillage treatment. $T_2$ tillage practices were statistically potential for maize cultivation in Bangladesh at dry season. Water saving in one hectare of land for maize cultivation by adopting $T_2$ tillage treatment over $T_3$ tillage treatment is

9,956.80 $m^3$ ï 7,970.00 $m^3$ = 1,986.8 $m^3$/ha.

From the above discussion it was measured that 1,986.8 $m^3$ of water per hectare of land for maize cultivation was saved by adopting $T_2$ tillage practices over $T_3$ tillage practices. Yield of maize in treatment $T_2$ and $T_3$ was very much similar. Three times water application ($I_3$) with traditional tillage practices ($T_3$) was more productive cost than $T_2$ tillage practice with two-time water application ($I_2$). Since $T_2I_2$ treatment was suitable for maize cultivation, the total water can be saved in one hectare of land are

5092.00 $m^3$ + 1,986.8 $m^3$ = 7078.8 $m^3$/ hectare.

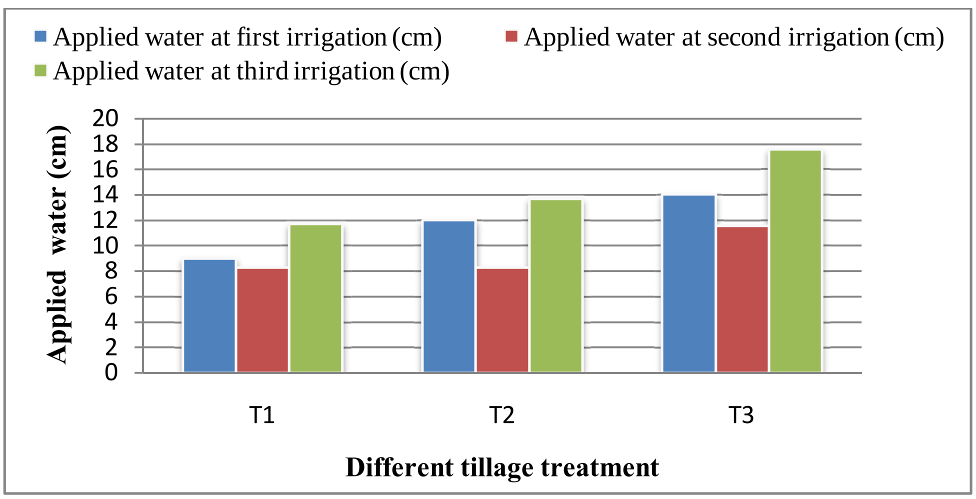



Figure 5.10.2: Water requirement at different irrigation and tillage treatment

Yield or benefit cost ratio and net economical return per unit water consumed or irrigation depth or marginal productivity are good indicators for assessing or evaluating the performance of irrigation strategies (Ali et al. 2008). High productivity values with high yields have important implications for the crop management for achieving efficient use of water resources in water scarcity areas. Parallel increase in yield and productivity indices, however, does not continue always. Attaining higher yield with increased productivity is only economical when the increase yield is not affected by increased costs of other inputs (Oweis and Hachum, 2004).

Table 5.11.1: Economic effect of tillage and irrigation on the yield and yield contributing characters of maize.

| Cost items | Treatment combination | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $T_1I_1$ (Tk./ha) | $T_1I_2$ (Tk./ha) | $T_1I_3$ (Tk./ha) | $T_2I_1$ (Tk./ha) | $T_2I_2$ (Tk./ha) | $T_2I_3$ (Tk./ha) | $T_3I_1$ (Tk./ha) | $T_3I_2$ (Tk./ha) | $T_3I_3$ (Tk./ha) |
| Human labors | 8680 | 9500 | 10000 | 8680 | 9500 | 10000 | 26500 | 27500 | 28500 |
| Fuel | 3000 | 3000 | 3000 | 3000 | 3000 | 3000 | 15000 | 15000 | 15000 |
| Manure | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 |
| Urea | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 |
| TSP | 9612 | 9612 | 9612 | 9612 | 9612 | 9612 | 9612 | 9612 | 9612 |
| MP | 10656 | 10656 | 10656 | 10656 | 10656 | 10656 | 10656 | 10656 | 10656 |
| Gypsum | 660 | 660 | 660 | 660 | 660 | 660 | 660 | 660 | 660 |
| Irrigation | 4000 | 10000 | 13000 | 4000 | 10000 | 13000 | 4000 | 10000 | 13000 |
| Total variable cost | 48608 | 55428 | 58928 | 48608 | 55428 | 58928 | 69777 | 85428 | 89428 |
| Gross return | 133000 | 150400 | 152000 | 144000 | 172000 | 173000 | 151000 | 169000 | 173600 |
| Net return | 84392 | 94972 | 93072 | 95392 | 116572 | 114072 | 81223 | 83572 | 84172 |
| Benefit cost ratio | 2.74 | 2.71 | 2.58 | 2.96 | 3.10 | 2.93 | 2.16 | 1.98 | 1.94 |

Considering, price of maize = 20.00 Tk. /kg, Labor wages/ day-person = Tk. 250
(Sources: Annual Research Report-2009-2010, pp-46-48. Agricultural Economics Division, BARI, Gazipur)

BCR) was observed (3.10) in $T_2I_2$ treatment combination, with minimum tillage treatment are the best suit for maize cultivation. The second and third highest BCR (2.96) and (2.93) were found in $T_2I_1$ and $T_2I_3$ treatment combination. In maximum BCR the most common treatment was $T_2$ tillage treatment with $I_1$, $I_2$ and $I_3$ irrigation treatment (Table 5.11.1). The lowest BCR was observed in $T_3I_3$ treatment combination (1.94) which was followed by $T_3I_2$ (1.98) and $T_3I_1$ (2.16) treatment combination. In minimum BCR the most common treatment was $T_3$ tillage treatment with $I_1$, $I_2$ and $I_3$ irrigation treatment. Yield was increased with the increase of water application but BCR was not increased with the increase of water application. The highest gross return (Tk. / ha 173600) was found in $T_3I_3$ treatment combination which was very much similar to $T_2I_2$ (Tk. /ha.173000) treatment combination and the lowest gross return (Tk. /ha. 1330000) was found in $T_1I_1$ treatment combination.

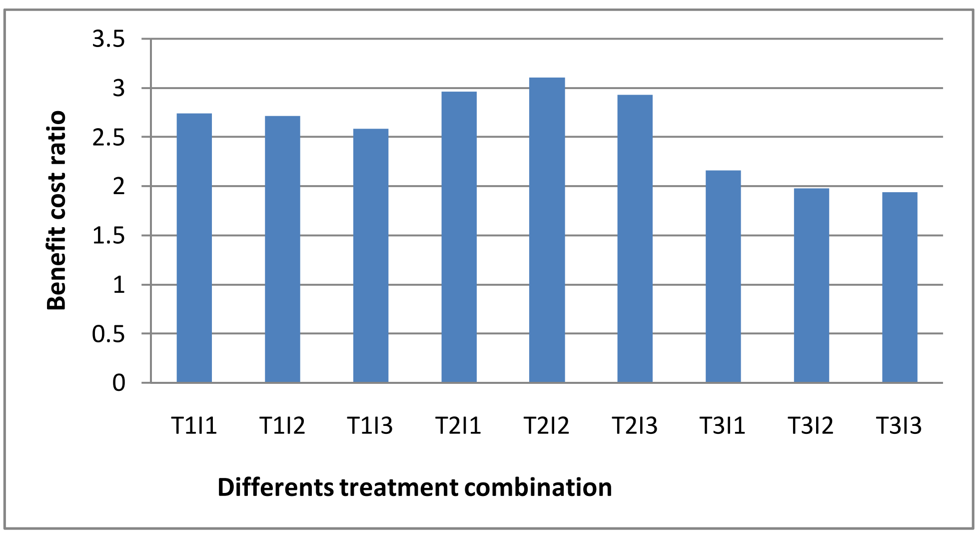



Figure 5.11.1: Benefit cost ratio of maize cultivation with different treatments combination

In this project work, it has been observed that the value of BCR was decreased with the increase of tillage intensity and water application. The poor BCR were found in both zero tillage and traditional tillage practices with three times water application. Therefore, zero tillage and traditional tillage practices with three times water application are not a suitable tillage and water application method for maize cultivation. The high value of tillage with two times water application. This result with two times water applications is the optimum tillage and water application methods for maize cultivation in Bangladesh.

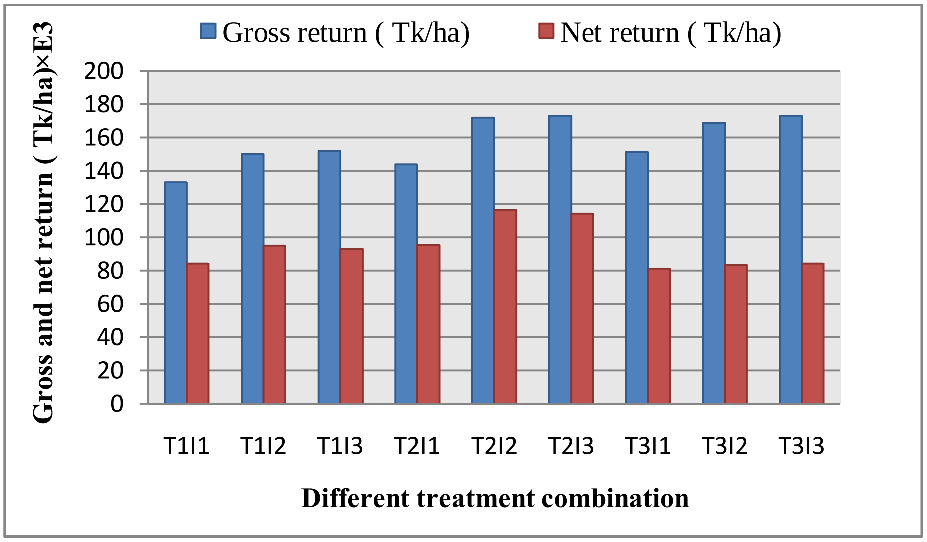



Figure 5.11.2 : Gross and net return with different treatment combination

The highest net return (Tk. /ha. 1165720) was found in $T_2I_2$ treatment combination which was nearest to $T_2I_1$ (Tk. /ha. 95392) and $T_1I_3$ (Tk. / ha. 93072) treatment combination. The lowest BCR was found in $T_3I_2$ (Tk. /ha. 83572) treatment combination which was very much similar to $T_3I_3$ (Tk. / ha. 84172) and $T_1I_1$ (Tk. /ha. 84392) treatment combination. The reason are the uses of fertilizer and manure are same the variable costs are tillage and irrigation . The gross and net return have been followed the same trends in all the treatment combinations. The gross and net return were increased with the increase of water application in every tillage treatments up to a certain level beyond that level gross and net return were not substantially increased (Figure 5.11.2). The lower gross and net returns were found in zero and traditional tillage practices that means zero and traditional tillage practices are not beneficial tillage method for maize cultivation. The gross and net returns were poor in one time water application with all tillage practices that means one time water application is not optimum water application for maize cultivation at dry season in Bangladesh. The higher gross returns were found in minimum and traditional tillage practices with two and three times water application. Gross return does not give the real scenario whether the method is beneficial or not, the nario. The poor net returns were found in one time water ments. Zero and traditional tillage with all level of water application have been given poor net returns. The minimum tillage practice with two times water application has been given the satisfiable net and gross returns. This means minimum tillage with two-time water application is the preferable treatment combination for maize cultivation in dry season of Bangladesh.

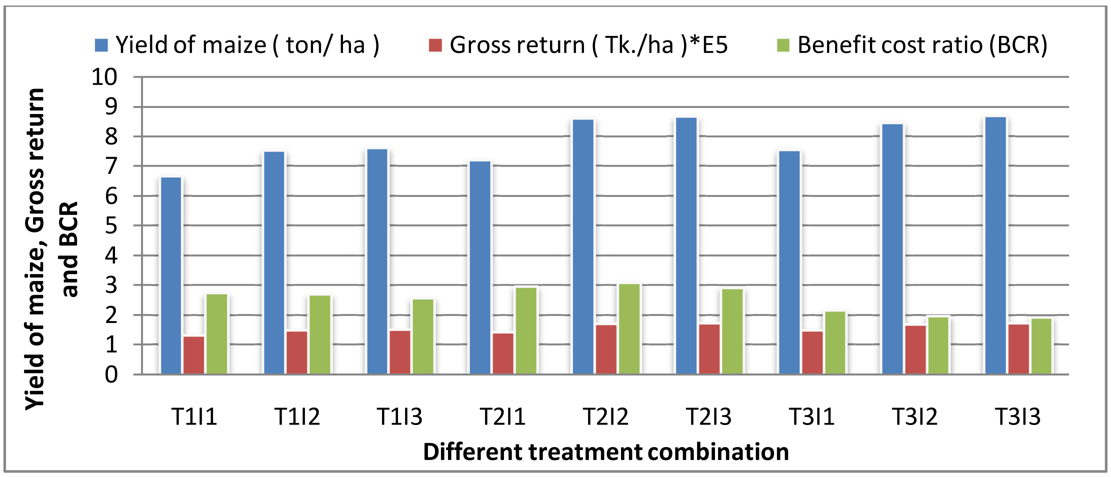



Figure 5.11.3: BCR, maize yields and gross returns with different treatment combination

The highest benefit cost ratio and higher yields were found in $T_2I_2$ treatment combination (Figure 5.11.3). Although the highest yields was found in $T_3I_3$ treatment combination the lowest BCR and net returns were found in this treatment combination. This treatment is not preferable treatment combination for maize cultivation in Bangladesh. $T_3$ tillage treatment with $I_1$, $I_2$ and $I_3$ irrigation treatment combination are not economically beneficial because the BCR and benefit percentage are very much lower than $T_2$ and $T_1$ tillage treatments (Figure 5.11.4 and 5.11.5). Zero tillage treatment ($T_1$) tillage treatment with $I_1$, $I_2$ and $I_3$ irrigation treatment combination are also not preferable treatment combination because the BCR and benefit in percentage are lower than $T_2$ tillage treatment but higher than $T_3$ tillage treatment. Therefore, $T_1$ tillasge treatment is not suitable for maize cultivation in regarding maize yield (Figure 5.11.3 and 5.11.5).

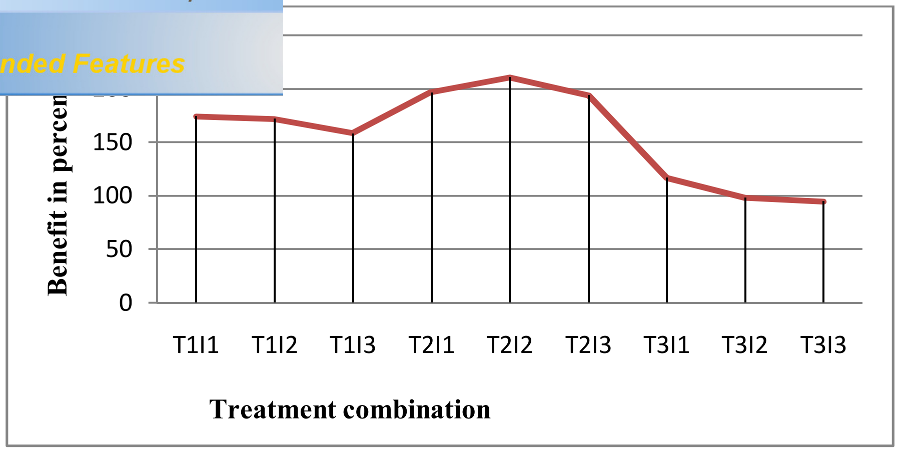



Figure 5.11.4: Benefit in percentage with different treatment combination

The highest average maize yields, net return, BCR and higher benefit in percentage were found in $T_2$ tillage treatment with $I_2$ and $I_3$ irrigation treatments combination. $T_2I_1$ and $T_2I_3$ treatment combinations have been given the higher BCR and percentage of benefit but yields were slightly lower than $T_3I_2$ and $T_3I_3$ treatment combinations. In agricultural production the most important factors are the net return and BCR because these two factors governs the farmers attitude towards cultivation for any specific crop. $T_2$ tillage treatment has been contained the higher BCR and net returns values for maize cultivation at dry season in Bangladesh. From the above disscussion it can be said that $T_2$ ( minimum tillage) treatment can be economically the most preferable treatment among others three tillage treatment for maize cultivation.

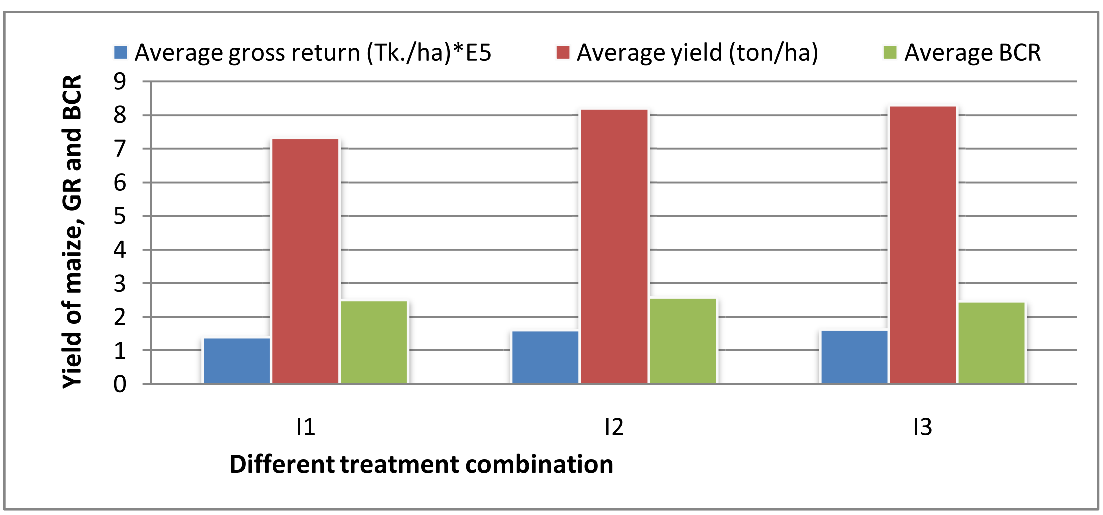



Figure 5.11.5: Average gross returns, yield and BCR with different irrigation treatments.

s found in $I_2$ (8.2 ton/ha.) and $I_3$ (8.3 ton/ha.) water vest in $I_3$ (7.13 ton/ha.) three times water application treatment. Maximum average gross returns were found in $I_2$ (Tk. /ha. 164000) and $I_3$ (Tk. /ha. 166000) and lowest was found $I_1$ (Tk. /ha. 143000) irrigation treatment. Average highest benefit cost ratio was observed in $I_2$ (2.6) two-time water application which was followed by $I_1$ (2.53) one time water application treatment and the lowest was in $I_3$ (2.48) three time water application treatment. Among three irrigation treatments ($I_1$, $I_2$ and $I_3$), two time water application treatment is an optimum irrigation treatments for maize cultivation. Therefore, $T_2I_2$ (minimum tillage with two-time water application) treatments are the most preferable treatments combination for maize cultivation in dry season (Rabi) of Bangladesh.

## 5.12 Summary

Irrigation and tillage are the two most important practices for agricultural production. The cost of agricultural production largely depends on the supply of water for irrigation and tillage practices. Now a days the production area of maize is expanding very rapidly in this country. The cost of maize production is also influenced by the irrigation water application and tillage practices for maize cultivation. A dire shortage of supply of irrigation water occurs in dry season (Rabi) of Bangladesh. Therefore, the optimum application of valuable water and rationale use of water is the most important in agricultural sector for saving the valuable water. Maximum tillage has a great effect on excessive water consumption , environment pollution and cost of maize production.

From this project work, it can be revealed that irrigation water has a significant effect on maize yield and yield contributing characters. Plant heights, plant population, cob per plant, grain per cob, 100-grain weight and yield have been affected significantly by the variation of water application. Statistically same effect was found on maize yield for two-time irrigation ($I_2$) water application and three-time irrigation ($I_3$) water application. Maximum yields was found in three-time water application ($I_3$) treatment but the lowest BCR and minimum net return were found in this treatment. Maximum water was required in $I_3$ irrigation treatment but yields was not increased as per increase of water application.

as been found in one time water application ($I_1$) in ($I_3$) three-time water application treatment. The results of water application on yield and yield contributing characters of maize indicates one time water application ($I_1$) treatment is not suitable water application for maize cultivation. The higher yields, higher BCR, higher net returns and higher gross returns were found in two-time ( $I_2$) water application treatment. Among three irrigation treatments ($I_{1,}$ $I_2$ and $I_3$), two-time irrigation ($I_2$) treatment is scientifically appropriate for maize cultivation.

In $T_1$ and $T_2$ tillage treatment, the lowest amounts of fuel were required for tilling the soil and sowing maize seed but $T_1$ (zero) tillage is not scientifically preferable because lowest amount of yield has been found in zero tillage treatment. The maximum amount of yield was found in traditional tillage practices. $T_3$ tillage treatment was consumed maximum amount of fuel and irrigation water. The maximum amount of carbon dioxide ($CO_2$) was emitted from this tillage treatment. The lowest BCR and the lowest net return were found in $T_3$ tillage treatment. Scientifically traditional tillage treatment ($T_3$) was not a suitable method for maize cultivation. The higher yield, higher BCR, and higher net return were found in $T_2$ (minimum tillage) tillage treatment. $T_2$ tillage treatment was consumed minimum amount of fuel resulting in minimum amount of carbon dioxide ($CO_2$) was emitted from this treatment. The production cost was less in this tillage treatment in comparison to others tillage treatments. Therefore, minimum tillage ($T_2$) treatment is the most rationale method for saving of valuable water and the most preferable tillage practices for maize cultivation.

# Chapter 6

# CONCLUSIONS AND RECOMMENDATIONS

## 6.1 General

Water is one of the most important natural resources. The rationale use of this valuable resource is a dire need at present days because the useable water resource is diminishing very rapidly. The highest amount of water is required for agriculture sector in Bangladesh. In Bangladesh at dry season, the scarce of irrigation water in agriculture sectors is a frequent occurrence. Therefore, the scientific application of water in agriculture sector is important for saving the water resources and for minimizing of cost of agricultural production is a dire need. Bangladesh is a small country of 1, 47,570 square kilometer but it has about 150 millions of population. Food crisis especially the cereal food grains is a common phenomenon in this country. To meet the need of the population of cereal grains the cultivation of high yielding grains crops like maize and scientific application of water resources for maize cultivation is the most important.

## 6.2 Conclusion of the study

i. From this project work, it can be revealed that irrigation water has a significant effect on maize yield and yield contributing characters. Plant population, cob per plant, grain per cob, 100-grain weight and yield have been affected significantly by the variation of water application.

ii. Statistically same effect was found on maize yield for two-time irrigation ($I_2$) water application and three-time irrigation ($I_3$) water application. Maximum yields was found in ($I_3$) treatment but the lowest BCR and minimum net return were found in ($I_3$) irrigation treatment.

iii. Maximum water was required in ($I_3$) irrigation treatment but yields were not increased rapidly as per increase of water application. Therefore, three-time water application ($I_3$) treatment is not a preferable water application treatment for maize cultivation.

ze has been found in one time water application ($I_1$) in
$_3$) water application treatments.

v. The higher yields, higher BCR, higher net returns and higher gross returns were found in two-time ($I_2$) water application treatment. Among three type of irrigation treatment ($I_1$, $I_2$ and $I_3$), two-time irrigation ($I_2$) treatment is statistically preferable for maize cultivation.

vi. Tillage has significant effects on maize yield and maize yield contributing characters. In ($T_1$) and ($T_2$) tillage treatments, the lowest amounts of fuel were required for tilling the soil and sowing the maize seed but $T_1$ (zero) tillage is not preferable because lowest amount of yield has been found in zero tillage treatment.

vii. The maximum amount of yield was found in traditional tillage ($T_3$) practices. Traditional tillage ($T_3$) practices treatment was consumed maximum amount of fuel and irrigation water. The maximum amount of carbon dioxide ($CO_2$) was emitted from this tillage treatment.

viii. The lowest BCR and the lowest net return were found in $T_3$ tillage treatment. Statistically traditional tillage treatment ($T_3$) was not a preferable tillage practices for maize cultivation.

ix. The higher yield, higher BCR, and higher net return were found in $T_2$ (minimum tillage) tillage treatment. $T_2$ tillage treatment was consumed minimum amount of fuel resulting in minimum amount of carbon dioxide ($CO_2$) was emitted from this treatment to the surrounding environment.

x. The production cost was less in minimum tillage ($T_2$) practices in comparison to others tillage treatments. Therefore, minimum tillage ($T_2$) treatment is the most preferable tillage practices for saving of valuable water and in maize cultivation.

**tudy**

Based on experiment results, some prospective suggestion can be recommended as follows.

i. To save the irrigation water from maize cultivation only two-time ($I_2$) water application is the preferable water application for maize cultivation without hampering the maize yield.

ii. Statistically, only one time water applicationn ($I_1$) is not suitable because in this treatment maize yield was the lowest in comparison to others water application treatments and three-time water application ($T_3$) is also not preferable water application for maize cultivation in Bangladesh.

iii. Similar significant effects have been found between minimum tillage practices ($T_2$) and traditional tillage practices ($T_3$) for maize cultivation. Therefore, maximum tillage practices are not a preferable tillage practices for maize cultivation. Minimum tillage practices ($T_2$) is the most preferable tillage practices in regarding water saving and yield of maize.

iv. In combination of minimum tillage practice and two-times water applications ($T_2I_2$) treatments is the most preferable treatments combination for maize cultivation considering economic returns and maize yields.

v. Continuous efforts are necessary to continue the experiment for long terms experimental results because this project work duration was only for six months.

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# *APPENDICES*

# Appendix-A

d different growth stages of maize

Land preparation for sowing

Zero tillage only for sowing

Minimum tillage sowing and tilling

Traditional tillage

Sowing in traditional tillage

Hand sowing in traditional tillage

Figure: A.1 Land preparation, tillage, sowing and growth stages of maize with different tillage and irrigation treatments.

aize in various tillage treatments

Zero tillage

Minimum tillage

Traditional tillage

Vegetative sage at zero tillage

Vegetative sage at minimum tillage

Vegetative sage at traditional tillage

Figure: A.2 : Germination and vegetative stages of maize in various tillage and irrigation treatments


Minimum tillage


Minimum tillage


Zero tillage


Zero tillage


Traditional tillage


Traditional tillage

Figure: A.3 : Vegetative stages of maize in various tillage and irrigation treatments roject supervisor

Flowering stage of maize in the treatment $T_1I_1$


Flowering stage of maze in the treatment $T_1I_2$

Figure: A.4 : A Field Visit in experimental field by project supervisor


Flowering stage of maize in the treatment $T_1I_3$

Flowering stage of maize in the treatment $T_2I_1$


Flowering stage of maize in the treatment $T_2I_2$


Flowering stage of maize in the treatment $T_2I_3$


Flowering stage of maize in the treatment $T_3I_1$


Flowering stage of maize in the treatment $T_3I_2$

Figure: A.5 :Flowering stages of maize in different tillage and irrigations treatment


Flowering stage of maize in the treatment $T_3I_3$

Maize cobs of $I_1$ Irrigation treatment

Maize cobs of $I_2$ Irrigation treatment

Maize cobs of $I_3$ Irrigation treatment

Figure: A.6 Storing of maize after harvesting

## Appendix-B

Determination of Irrigation water requirement for each plot (sample Calculation):

Irrigation depth, $d = \frac{FC\%-MCi\%}{100} \times As \times D$

Where, d = Irrigation Depth (cm)

FC = Field Capacity (%)

MCi = Moisture Content (%)

As = Apparent specific gravity,

D = Maize average root zone depth (cm)

Here, FC = 29%

MCi = 23%

As = 1.5 unit less

D = 110 cm

We have, $d = \frac{FC\%-MCi\%}{100} \times As \times D$

$= \frac{29-23}{100} \times 1.5 \times 110$

= 9.9cm

So, Irrigation Water Requirement was 9.9 cm

Area of each plot = 300 cm × 400 cm

= 120000 $cm^2$

Now, Volume of water required was = 120000 $cm^2$ × 9.9 cm

= 1188000 $cm^3$

= 1188 Liters/plot

## Appendix-C

Table B. 1: Daily potential evapotranspiration $ET_0$ (mm) during experiment period.

| Days | November | December | January | February | March | April |
|---|---|---|---|---|---|---|
| 1 | 2.6 | 3.4 | 2.1 | 3.7 | 7.5 | 2.7 |
| 2 | 4.2 | 3.4 | 4.6 | 4.5 | 8.0 | 7.0 |
| 3 | 4.1 | 2.4 | 2.3 | 5.3 | 8.0 | 5.0 |
| 4 | 3.5 | 2.4 | 3.6 | 5.0 | 5.4 | 4.9 |
| 5 | 4.1 | 2.3 | 2.9 | 2.9 | 5.6 | 3.9 |
| 6 | 3.7 | 2.1 | 3.5 | 3.7 | 6.1 | 5.7 |
| 7 | 3.8 | 1.5 | 3.2 | 5.4 | 8.5 | 7.0 |
| 8 | 4.0 | 1.8 | 2.7 | 3.8 | 9.7 | 8.6 |
| 9 | 4.6 | 1.4 | 3.1 | 5.0 | 5.1 | 8.6 |
| 10 | 3.9 | 2.3 | 5.2 | 6.3 | 8.7 | 6.3 |
| 11 | 3.3 | 4.8 | 2.8 | 5.7 | 7.2 | 5.7 |
| 12 | 2.8 | 3.6 | 2.3 | 6.2 | 4.3 | 6.2 |
| 13 | 2.7 | 2.3 | 1.2 | 6.1 | 5.6 | 6.7 |
| 14 | 2.7 | 2.5 | 1.5 | 4.7 | 5.6 | 8.2 |
| 15 | 3.6 | 2.6 | 2.1 | 2.5 | 5.3 | 6.3 |
| 16 | 4.0 | 2.5 | 2.4 | 3.6 | 5.9 | 6.2 |
| 17 | 2.2 | 2.0 | 4.0 | 7.2 | 5.0 | 6.4 |
| 18 | 2.8 | 2.0 | 1.7 | 5.2 | 5.6 | 7.0 |
| 19 | 2.4 | 3.1 | 3.4 | 2.6 | 7.2 | 6.4 |
| 20 | 2.9 | 3.4 | 3.6 | 4.8 | 6.7 | 7.9 |
| 21 | 3.0 | 4.0 | 3.3 | 6.1 | 6.7 | 5.6 |
| 22 | 4.7 | 3.9 | 3.2 | 3.2 | 6.8 | 5.0 |
| 23 | 3.0 | 2.5 | 1.3 | 7.4 | 6.3 | 6.2 |
| 24 | 4.2 | 2.1 | 2.6 | 8.2 | 7.3 | 6.0 |
| 25 | 4.2 | 2.7 | 2.9 | 7.0 | 7.5 | 6.1 |
| 26 | 3.4 | 3.5 | 2.0 | 7.0 | 8.2 | 6.7 |
| 27 | 1.3 | 3.4 | 2.7 | 8.8 | 5.6 | 6.7 |
| 28 | 2.7 | 2.8 | 4.8 | 5.7 | 5.5 | 5.8 |
| 29 | 3.8 | 1.7 | 5.7 |  | 4.2 | 5.5 |
| 30 | 5.3 | 1.9 | 2.9 |  | 4.6 | 5.1 |
| 31 |  | 1.9 | 2.1 |  | 3.3 |  |

## Appendix-D

Table D. 32: Daily Wind Speed (m/sec) during Experiment Period

| Days | November | December | January | February | March | April |
|---|---|---|---|---|---|---|
| 1 | 8.33 | 3.05 | 4.72 | 6.39 | 9.58 | 13.57 |
| 2 | 17.50 | 3.19 | 14.02 | 7.50 | 10.97 | 10.79 |
| 3 | 5.83 | 2.50 | 8.05 | 6.39 | 9.58 | 14.01 |
| 4 | 2.50 | 1.53 | 10.41 | 1.25 | 7.50 | 7.83 |
| 5 | 2.36 | 1.25 | 7.91 | 2.92 | 5.28 | 11.09 |
| 6 | 1.53 | 3.33 | 9.58 | 7.78 | 8.33 | 10.32 |
| 7 | 1.81 | 0.42 | 9.16 | 4.86 | 12.77 | 23.63 |
| 8 | 2.36 | 0.00 | 6.53 | 5.55 | 11.94 | 14.48 |
| 9 | 5.28 | 1.25 | 4.44 | 7.91 | 9.44 | 17.22 |
| 10 | 2.36 | 3.19 | 15.41 | 6.53 | 8.33 | 14.16 |
| 11 | 1.25 | 12.36 | 18.74 | 7.78 | 5.00 | 4.40 |
| 12 | 1.25 | 5.14 | 12.36 | 7.91 | 15.55 | 10.37 |
| 13 | 0.97 | 1.67 | 7.50 | 5.28 | 4.58 | 10.18 |
| 14 | 0.28 | 5.28 | 7.36 | 1.67 | 5.97 | 5.93 |
| 15 | 2.50 | 3.19 | 2.64 | 8.75 | 6.94 | 9.12 |
| 16 | 4.30 | 1.53 | 7.78 | 12.64 | 2.22 | 6.90 |
| 17 | 0.69 | 1.39 | 8.33 | 12.50 | 12.77 | 13.14 |
| 18 | 1.11 | 4.58 | 7.50 | 6.94 | 35.55 | 7.54 |
| 19 | 3.89 | 4.58 | 5.83 | 6.66 | 49.57 | 12.55 |
| 20 | 4.86 | 6.39 | 4.44 | 7.08 | 48.46 | 9.75 |
| 21 | 4.30 | 10.00 | 6.11 | 6.25 | 42.77 | 9.61 |
| 22 | 6.39 | 8.47 | 4.44 | 12.64 | 32.49 | 13.08 |
| 23 | 2.50 | 3.47 | 0.14 | 10.83 | 21.38 | 16.00 |
| 24 | 5.00 | 1.11 | 1.94 | 9.30 | 21.38 | 7.11 |
| 25 | 5.00 | 2.08 | 2.64 | 10.55 | 27.77 | 17.04 |
| 26 | 3.89 | 5.00 | 0.00 | 12.36 | 8.75 | 12.57 |
| 27 | 0.14 | 4.30 | 3.47 | 8.47 | 19.16 | 6.05 |
| 28 | 2.50 | 4.03 | 7.36 | 10.55 | 7.78 | 9.30 |
| 29 | 6.94 | 3.61 | 8.05 | | 12.08 | 8.09 |
| 30 | 7.36 | 4.00 | 2.64 | | 19.72 | 4.32 |
| 31 | | 3.50 | 5.28 | | 16.20 | |