Deanship of Graduate Studies
Al-Quds University

Optimization of using water resources in irrigation of Tomatoes in Jericho area Jordan valley /Palestine

Najeh Ahmad Issa Ghayyada

Master Thesis

Jerusalem-Palestine

1429/2008

Chapter 1 Introduction

1. Introduction

Jericho district is located in the eastern side of the West Bank with an area of approximately 353,300 dunums.

Population density in this district is less than that of other districts in the West Bank, and there is a widely fluctuating in the population number in this district due to the wars and political changes. Between 1948 and 1967, the population of Jericho district was approximately 80,000, while the population of the district was 43,620 estimated at 2006 (PCBS, 2006), distributed mainly in the Jericho city and the four villages (Al-Auja, An-Nuwe'ma, Dyouk Al-Tahta and Dyouk Al-Fouqa) and the two refugee camps (Ein Al-Sultan and Aqbat Jaber).

Jericho city, which is the oldest city in the world (dating from 7,000 BC) and the lowest city on the earth surface (250 m below sea level). It lies 10 km northwest of the Dead Sea and 7 km to the west of the Jordan River. While it has a desert climate, its abundant water sources makes it an important agricultural area, especially for fruits and vegetables.

Agriculture is playing vital role in Palestine economy, and it is contributing between 11-33 % to (GNP). In Jericho district the agriculture is the main economical activity, mainly irrigation agriculture, with area about (45,194) dunums, where the vegetables is the dominant irrigated crop which occupy (33,807) dunums which forms (75%) of the total irrigated area in Jericho district, and production was about (79,354) ton (MOA, 2006).

Water scarcity is one of the most important challenge facing Middle East countries, Palestine is one of middle eastern countries that suffers from water shortage. According to World Bank reports in 2008, agriculture consumes more than 80% of the region’s water that will have reduced water availability per capita to half by the year 2050, which leads to more concern about optimization of using water resources.

1.1 Geography and Topography

The elevation of Jericho district range between 350 m above sea level at the northeast border of the district to about 410 m below sea level close to the Dead Sea. Jericho district extends from eastern slope of mountains of Ramallah and Jerusalem in the west, to Jordan River in the east, and from Fasayel in the north to Dead Sea in the south. While it has desert climate, it also has good water sources that make this area one of the most important agriculture area in west bank. The topography of Jericho is considered flat basin with smooth slope to east (Issac, 1995).

1.2 Climate of Jericho district

The climate of Jericho district is arid, which is hot in summers and warm in winters.

a-Rainfall**:**

The mean annual rainfall for the period 1980-2006 was 151.84 mm according to the Jericho Meteorological Station show in (Figure 1.1).

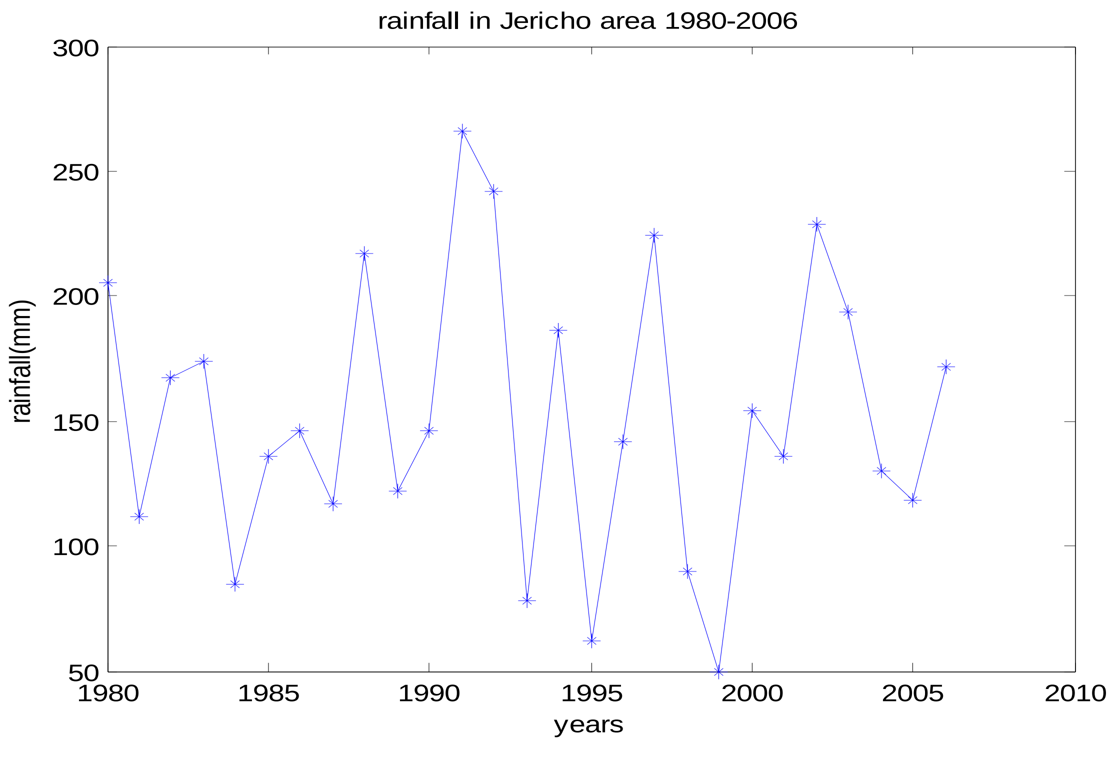


Figure1.1:Annual rainfall for the period 1980-2006 (Jericho Meteorological station, 2006).

b- Temperature:

January is the coldest month with an average of 13.6 °C and August is the hottest month with an average of 32°C. Annual Mean of Air Temperature at 2005 was 23.1 °C, with mean of maximum of 30.3°C and mean of minimum of 16.2°C (Jericho Meteorological station, 2006).

c-Wind:

The average daily wind speed in the district is around 3.27 m/sec throughout the year. (Kessler, (1994), as cited in Issac, (1995)).

c -Humidity**:**

The mean annual relative humidity in Jericho district is about 50%. It reaches its maximum value in winter (69.8%) and the minimum during summer with value of (38.1%). In 2005, mean annual relative humidity was 52.5 % ((Jericho Meteorological station, 2006).

d-Radiation:

According data collected from the Jericho weather station indicate that the solar radiation reaches its peak during July. The total annual solar radiation measured for the period between June1994 and May 1995 reached 62,520 watt/m^2. (Jericho Meteorological station, 1995).

e-Evaporation:

The evaporation rate in the Jericho district is very high, annual evaporation quantity in the Jericho district in 2005 was 2,085.3 mm (PCBS, 2007) .It was varying between 59 mm in December when solar radiation is lowest and 298.5 mm in July when solar radiation is at its highest (Jericho Meteorological station, 1995).

1.3 Geology of Jericho district

The geology of Jericho district is characterized by the Jordan rift valley deposits, which are mainly composed of Marl and Pleistocene Alluvial formations.

Alluvium Formation is of the Pleistocene to Recent in age**,** it covers the area adjacent to the Jordan Valley starting by a width of 1 km in the north and 5 kms in the south. (Rofe and Raffety, 1963).

Lisan & Samra Formation covers the greatest part of the Jericho district. It is of the Pleistocene to Recent age, and includes three local faults of up to 3 kms long. This area is bounded by the alluvium formation in the east and by a greater fault of about 13 kms long in the west. It is mainly composed of marl, chalk and conglomerates (Rofe and Raffety, 1963).

Chalk and Chert Formations in the western part of the Jericho district. They are composed of the Senonian Chert and Chalk deposits (Rofe and Raffety, 1963).
Metamorphic rock formations of Senonian to Neogene ages are composed mainly of calcium silicates. They occupy small areas within the Chalk and Chart formations (Rofe and Raffety, 1963).

Dolomitic Limestone Formation is composed mainly of limestone, dolomite and marl. It is of Cenomanian-Turonian in age, and occupies very small portions of the southwestern and northwestern parts of the Jericho district. The system of faults distributed all over the district is responsible for the main emerged spring (Rofe and Raffety, 1963).

1.4 Water Resources

1- Groundwater Wells

There are 87 irrigation wells in the Jericho district. The annual discharge from wells ≈13 MCM/yr (MOA, 2005). There are 46 wells in Jericho city, 15 of these wells owned by the Arab Development Society (ADS), and 10 wells in AL-Uja village. Electrical conductivity of these wells (as indicate for salinity) range between 351 µS/cm in AL-Uja location to 4110 µS/cm in Jericho city. Depths of the wells range between 50 m to 150 m (PWA, 2002)**.** In the wells, system flow velocities are very slow and the residence time is very long prevailing groundwater ages of some thousand years. The groundwater flow is determined by the structure following the regional dip and joint directions. The normal fault of the lower Wadi El-Qilt has an important influence on the groundwater movement (Wolfer, 1998). Groundwater generally flows towards the east in Jordan valley, shown in Figure (1.2).

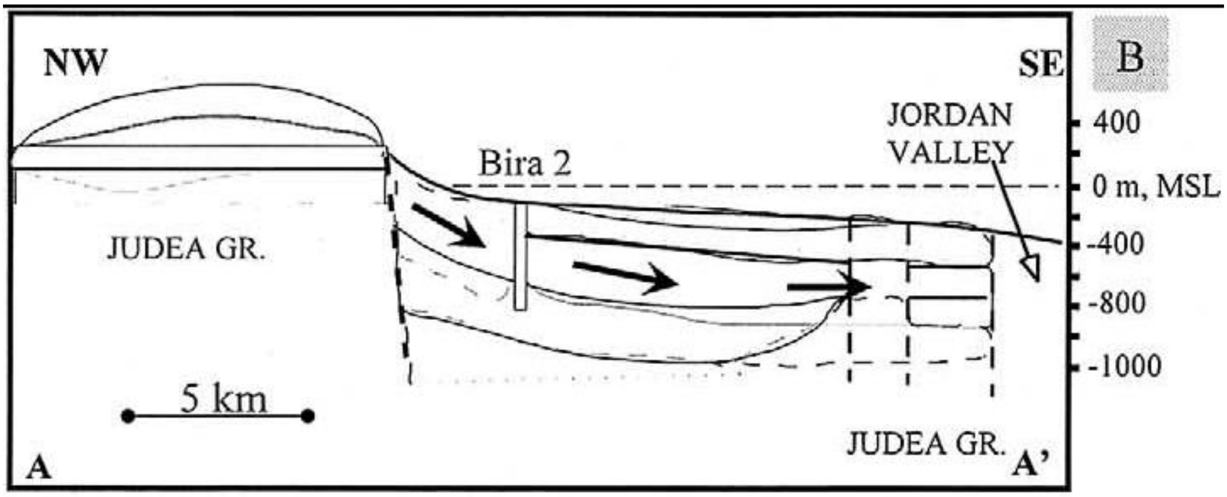


Figure 1.2: Groundwater flow in Jericho area (Efrate F., et al. 2003)

2- Springs

The Jordan Valley springs divide into tow groups according to their salinity (fresh water and brackish water) , the TDS range between 210-4670 mg/l (Abed Rabbo, 1999) .

There are four main fresh water spring systems in the Jericho district

1. Wadi Al-Qilt Spring System. The total average annual discharge of this system is about 6 MCM (MOA, 2005).
2. Ein Al-Sultan Spring System: Its annual flow discharge of about 5.702 MCM used to fulfill the municipal and agricultural needs (Martin B. & Joseph G.2004).
3. Dyouk Spring System: This system is composed of three springs; Dyouk, Nuwe'ma, and Shosah. The average annual discharge of Dyouk≈4.836 MCM, Nuwe'ma 2.934 MCM/yr (Martin, Joseph, 2004), and Shosah 0.7 MCM/yr (MOA, 2005) .
4 .Al-Auja Spring System The average annual discharge of this system is about 8.76 MCM , its water is used for irrigation purposes and its discharge affected by rainfall variation (Sbeih, 2003).

Springs with high salinity like Fashka system and Wadi Almalih can be classified as medium sodium-very high salinity causes unsuitable for irrigation (Abed Rabbo, 1999).

1.5 Statement of the problem

Water is the key factor in sustaining agriculture, while agriculture is the main economical activity in Jericho district. The problem is scarcity of water resources in Jordan valley as the whole of West Bank, due to arid to semi arid climate, over exploitation, mismanagement, in addition to un even distribution between Palestinians and Israeli's and population pressures by increasing demand for domestic and irrigation (more than 64% of total water used in West Bank are used in irrigation (MOA-2005) which cause diminishing water supplies, combined with water quality problems indicates of importance of optimization of using water recourses in irrigation which means is to add the amount of water needed when the plant requires.

High evaporation rate varying between 59 mm when solar radiation is lowest, and 298.5 mm in July when solar radiation is at its highest (Meteorological service, 1994). During the spring and autumn, the total amount of evaporation reaches 200-250 mm/month (Kessler, 1994 as cited in Issac.1995).

1.5.1 Salinity of soil:

Soil salinity has negative impact on crop physiology and yield, salinity of soil may be caused by:

- Naturally present as products of geo-chemical weathering of rocks and parent materials or derived from the Lisan and Samra formations.
- Caused by irrigation mismanagement and intensive application of chemical fertilizers.
- High evaporation and the low amounts of annual precipitation which to drain the soil.

1.5.2 Salinity of water:

One of the major problems in the lower Jordan Valley is the increasing salinization (i.e., chloride content) of local ground water. The high levels of salinity limit the utilization of ground water for both domestic and agriculture applications. In the Jericho area the hydrochemistry shows that the high Cl value, in the eastern part is derived from three main sources, there are anthropogenic effects of sewage inflow, agricultural backflow, deep brine water and dissolution of salts from Lisan layers (Ali, et.al, 2004).

According to the salinity, springs of the Jordan Valley divide into tow groups (fresh water and brackish water),TDS range between 210-4670 mg/l, For groundwater wells in the Jericho district which are used primarily for irrigation purposes, the salinity indicator (EC) ranges from 369 to 2280 μS/cm with an average of 994 μS/cm (Laboratories of Al-Quds University– 1995). Electrical conductivity (EC) in groundwater in different areas of the Jericho district increases towards the Dead Sea (Abed Rabbo, 1999).

The increasing salinity in both K1 and K2 subaquifers (Upper and Lower Cenomanian age) is derived from mixing with deep-seated brines that flow through the Rift fault system. The salinization rate depends on the discharge volume of the fresh meteoric water in the Cenomanian Aquifer **(**Marie A, Vengosh A.2001).

1.5.3 Sodium adsorption ratio (SAR):

The United State Salinity Laboratory (USSL) of the department of agriculture recommended sodium adsorption ratio (SAR), (Richard, 1954). SAR shows direct relationship with the water adsorption by the soil. Sodium adsorption ratio (SAR) ranges from 0.4 to 7.714 for springs of Jordan Valley, indicate that water class lies between S1 (Low sodium) and S2 (Medium sodium). S1 means water can be used for irrigation on almost all soils with little danger. S2 means water can cause an appreciable sodium hazard. Integrated these results with classification based on TDS and EC indicate that water class lies between S1 C2 (like Dyuk, Nueima) and S2C4 like Fashka. Springs (S1 C2) classified as low sodium- medium salinity hazard water is suitable for irrigation, but springs (S2C4) classified, as Medium sodium- very high salinity water is not suitable for irrigation. C2 means medium salinity hazard water, and C4 indicates very high salinity water (PHG, 1999).

1.5.4 Other obstacles for developing agriculture sector

a- Production Inputs***:*** Since the year 2000 the prices of agricultural inputs (e.g. fertilizers and pests control chemicals) have increased, some of them are not permitted by Israelis and there is often a shortage of alternative inputs (Hrimat N. 2006) .

b- Competitiveness with the Israeli produce: Palestinian goods can enter the Israeli market just to cover shortages there, while the Israeli commodities are freely entering the Palestinian markets without control, in addition to suffers from the limited free movement of Palestinian farmers and their products (Hrimat N. 2006) .

c- Limited training programs for farmers (MOA, 2005).

1.6 Hypotheses

In order to conduct this research, following hypotheses were developed. The developments of these hypotheses were abstracted from literature review and current problem status in the area.

1) Crop tolerance and yield potential of selected crops as influenced by irrigation water volume.

2) The irrigation water amount which used by farmers is more than optimal water need by crops.

3) Current water use and current irrigation methods are suitable for irrigation vegetables.

4) Soil type and soil salinity were took into consideration in calculation irrigation water amount.

5) Water productivity can be increased by good water management.

1.7 Objectives

Main objective:

The main objective is to identify and investigate the optimal uses of water in term of quantity and quality for growing vegetables Tomato in Jericho area.

Specific objective:

1- To optimize the irrigation volume of water needed for growing vegetables tomato at different stages.

2-To save water without decline the production.

3-To increase water productivity.

Chapter 2 Literature Review and Theoretical Framework

2.1 Literature Review

Brouwer, C., Heirloom, M., FAO (1986) ″Irrigation water management.″
This manual describes in general terms the principles to determine the water need of standard grass and how the irrigation water needs can be estimated for the various crops. It covers in principle reference crop evapotranspiration, crop evapotranspiration or crop water needs and irrigation water needs. It provides methods to calculate these.
The crop factor, Kc, mainly depends on type of crop, growth stage of the crop and the climate.
The total growing period (in days) is the period from sowing or transplanting to the last day of the harvest. It is mainly dependent on type of crop and the variety, climate and planting date.

Dehayr, R., and Gordon, **I., (2006**) ″ Irrigation water quality Salinity and soil structure stability″. One of the major concerns with water used for irrigation is decreased crop yields and land degradation because of excess salts being present in water and in soils. Salinity is the term used when referring to the presence of soluble salts in or on soils, or in waters. To assess the suitability of irrigation water concerning salinity management, other factors must be considered besides water quality. These include salt tolerance of the crop being cultivated and the characteristics of the soil under irrigation. Climate, soil management and water management practices can also affect the extent of salinity.

Ministry of agriculture (MOA), (2005) ″Guidance program for Tomato crop under plastic houses″. Vegetable produced in Palestine at 2000 was about 477 ton, which form about 91% from total consumed. At 2002, the total area cultivated by Tomatoes was about 25291 dunum that produced 197,944 ton under different cropping patterns. Main types of Tomatoes used under plastic houses was Rahabot144, 593, FA175, R19 They used for their characteristics such as abundant of its production ,suitability for local market , suitability for export, size and color of fruit and resistance to diseases.

Issac, J., Sabah, W. (1998) ″ Water resources and irrigated agriculture in the West Bank - ARIJ″. Irrigated agriculture in the west bank is of the vital importance and source of income. Productivity of vegetable crops increased as result of improvement in the level of production technology such as planting improved crops under plastic houses, using new irrigation techniques. Modern irrigation methods can save at least 25-30 percent of irrigation water.

Water Management is very important issue in the West Bank since the available water resources that can be used for agriculture are very limited due not only to natural meteorological and hydrological reasons but also to the complete Israeli control over all the Palestinian natural resources. Water management includes both water quantity and quality management where the irrigated lands can be increased several fold if the water quantities with suitable quality for irrigation were applied.

Danny, H., Federals, R, Mahbob A., Todd P. **(1997).** ″Efficiencies and water losses of irrigation system, Kansas State University″.

Water conveyance efficiency (Ec) is the percentage of source water that reaches the field, and irrigation water losses include air losses, canopy losses, soil and water surface evaporation, Runoff and deep percolation.

Reagan, M., Waskom, (1994) ″Best Management Practices for Irrigation Management″. Best Management Practices (BMPs) for the use of irrigation water can help increase efficiency and uniformity and reduce contamination of water resources. Proper irrigation scheduling, based on timely measurements or estimations of soil moisture content and crop water needs, is one of the most important BMPs for irrigation management.

Steve, E. (2006). ″ Crop Water Use Measurement & Estimation in Support Irrigation Management″. Crop models usually employ some method of estimating ET. These may be based on $ET = KC \cdot ETR$, where ETR may be estimated using Penman, Penman-Monteith, Jensen-Hai Thornthwaite or one of several other ET estimation equations.

California Irrigation Management System (CIMIS -2005). Evapotranspiration (ET) is the loss of water to the atmosphere by the combined processes of evaporation (from soil and plant surfaces) and transpiration (from plant tissues). It is an indicator of how much water your crops, lawn, garden, and trees need for healthy growth and productivity .Evapotranspiration , aerodynamic term of hourly evaporation calculated by Penman equation, radiation term of hourly evaporation calculated by Penman equation .Many factors affect ET including: weather parameters such as solar radiation, air temperature, relative humidity, and wind speed; soil factors such as soil texture, structure, density, chemistry, and plant factors such as plant type, root depth .

Klocke, Norman L., Fischbach, **P. (1998)**″ Estimating Soil Moisture by Appearance and Feel, Publication G84-690-A, 1998, Nebraska Cooperative Extension Service″.
Prior to the collection of samples for estimating soil moisture, the producer must determine the soil type, texture and available water holding capacity of each layer sampled. Soil texture, which is the relative amounts of sand, silt, and clay contained in soil, plays an important role in determining the amount of water a soil will hold. The portion of water in the soil that can be readily used by plants is the available water capacity (AWC) of the soil.

Steven, A., Sargent, Jeffrey, K., Teresa, O., (2003). ″Handling Florida Vegetables Series - Round and Roma Tomato Types″. Optimization of irrigation and nutrient management is a key practice leading to optimum plant growth and high yields and preventing ground water pollution. Actual practices vary depending upon location and irrigation system .According nutritional value -Tomatoes rank first in the "relative contribution to human nutrition" when compared to 39 major fruits and vegetables.

Whiting, D., Tolan, R., Mecham, B. and Bauer, M., (2005). ″Soil Water Holding Capacity and Irrigation Management, Colorado State University″. Several complex factors work together in irrigation management, soil's water holding capacity (i.e., the quantity of water held by the Soil); evapotranspiration (ET), rooting depth; and the plant's ability to extract water from the soil. Rooting depth is also another primary factor influencing irrigation management. Roots only grow where there are adequate levels of soil oxygen. In clayey or compacted soils, where a lack of large pore space restricts oxygen levels, roots will be shallow. Plants with a shallow rooting depth simply have a smaller profile of soil water to use.

Eng. Mohammed Yousef Sbeih, (2003), ″Pricing the irrigation water in the Jordan Valley as a mean of water saving in Palestine ″.

Water is always considered as an essential factor of life and development in arid and semi-arid countries. Irrigated area in the Jordan valley constitutes of more than half of the irrigated area in the whole country Palestine. In addition to that more than of 50%of the irrigation water in west bank is consumed in the Jordan valley. Most of the irrigation water in the Jordan valley is due to springs where the water is flowing by gravity and the farmers have access to this water free of charge, so farmers irrigate his crop without taking into consideration the value of the water and without taking into consideration the amount of water needed especially the evapotranspition in Jordan valley is the biggest in the world since the location of the Jordan valley (Jericho) is the lowest point in elevation in the world.

Richard, G., Luis, S., (2006) ″Guidelines for computing crop water requirements ″.

ET0 can be computed from meteorological data. As a result of an Expert Consultation held in May 1990, the FAO Penman-Monteith method is now recommended as the sole standard method for the definition and computation of the reference evapotranspiration. The FAO Penman-Monteith method requires radiation, air temperature, air humidity and wind speed data. Calculation procedures to derive climatic parameters from meteorological data and to estimate missing meteorological variables required for calculating ET0.

Savva, P., Frenken, K. (2002) ″Crop water requirements and irrigation scheduling″

The crop evapotranspiration (ETc) is the crop water requirement (CWR) for a given cropping pattern during a certain time. Crop water requirement (CWR) refers to the water used by crops for cell construction and transpiration, the irrigation requirement (IR) is the water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirement. The Net Irrigation Requirement (IRn) does not include losses that are occurring in the process of applying the water. IRn plus losses constitutes the Gross Irrigation Requirement (IRg).

Papadopoulos A.P. (1991), Minister of Supply and Services Canada ″ Growing greenhouse tomatoes ″. After several leaves have formed (7-12) the growing point changes from vegetative to reproductive, and a cluster of flower buds are formed that ultimately develop into the first flower cluster or truss. The number of leaves that form before the first flower truss varies from cultivar to cultivar but is also influenced by environmental conditions. Most cultivars produce a minimum of seven leaves before the first flower truss and thereafter usually three leaves between trusses. The optimum space per plant is generally agreed to be 0.35-0.40 m2. Ideally, the same spacing should be used between rows of plants as between plants in the row However, to facilitate working among the plants, use double rows for planting. Place the first two rows 80 cm apart and allow 1.2 m for a walking path before repeating two more rows spaced at 80 cm apart.

2.2 Theoretical Framework

2.2.1 Agriculture in Jericho area:

The Jordan Valley has special agricultural characteristics regarding the crop production season and diversity of crops. This area has the potential for developing and improving its agricultural activities as it is rich in available agricultural lands and water, and benefits from special weather conditions. The area cultivated by the Palestinians ranges between 48,000 to 50,000 dunums.Vegetables rank first in growing area and production, followed by fruit trees then field crops and forages (Hrimat N. 2006). Figure (2.1) shows plant production in the Jordan Valley by cultivated area (dunums) and production (tons) in 2003/2004.

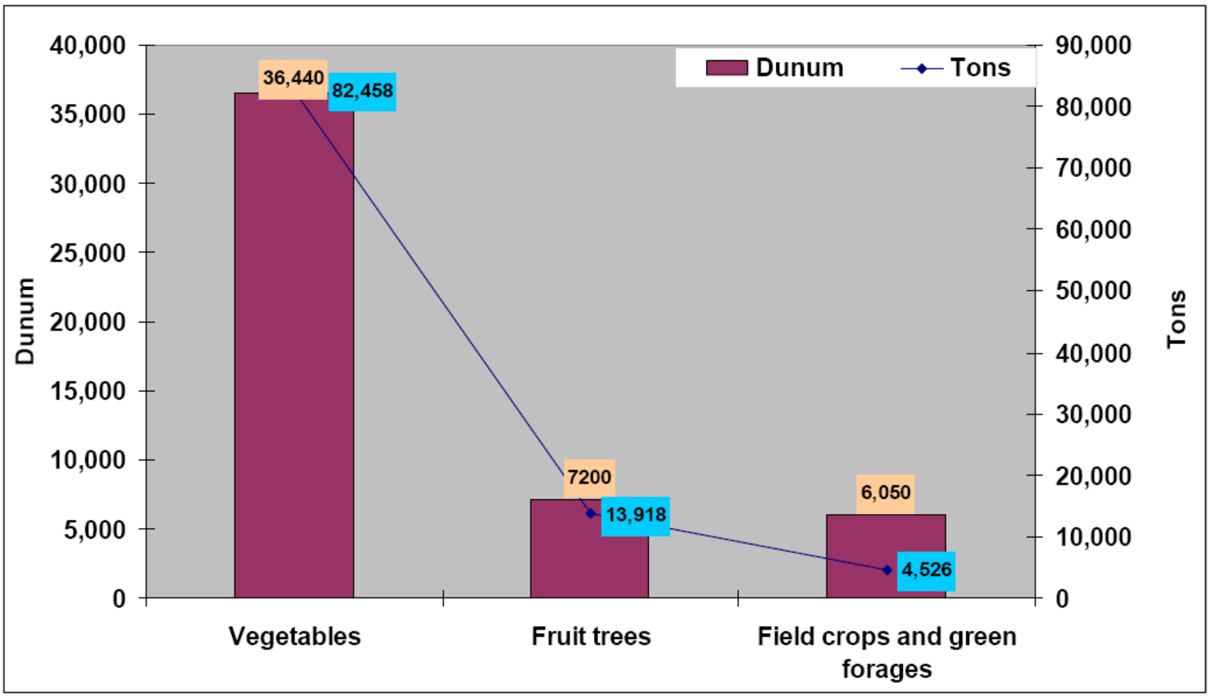
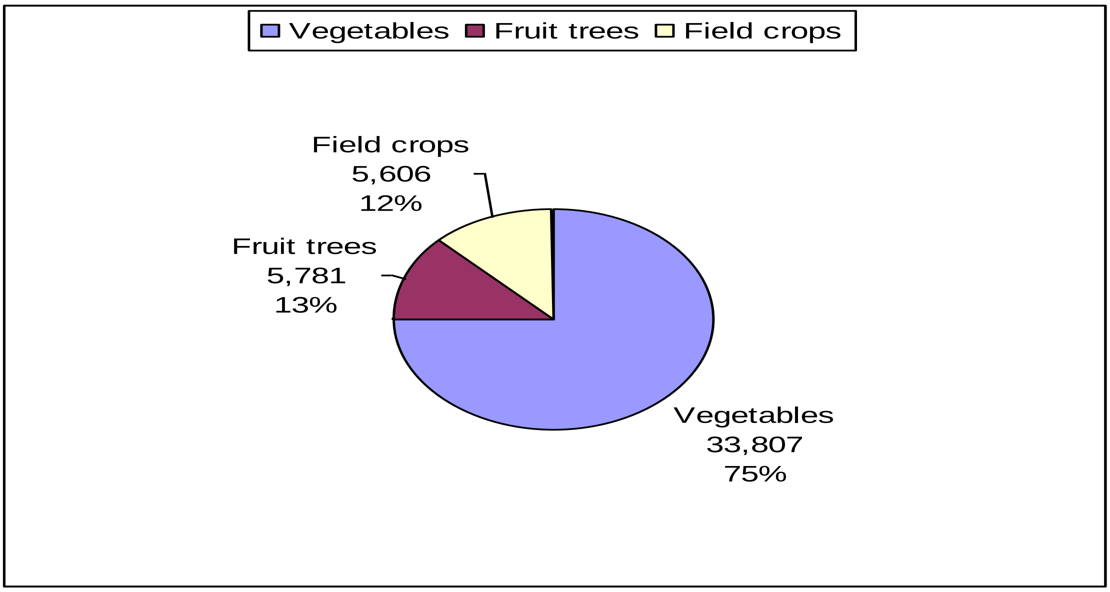


Figure 2.1: Plant production in the Jordan Valley (dunums and tons) Hrimat N. (2006).

Jericho district has three main agriculture regions: Jericho city, Al-Auja, Dyouk and Nuwe'ma. The warm winter temperature in the Jericho district, which would not be possible during this season in other parts of Palestine, help cultivates vegetable crops. Thus, agriculture in Jericho district should have a high economic potential both in the local and export markets, due to its characteristics, which seems natural green houses. Agriculture can divide to irrigation agriculture and rain fed agriculture. According to Ministry of Agriculture (MOA, 2005), irrigation agriculture area occupies 99.9% of total agricultural areas in Jericho district.

In the 2005/ 2006, about 14 vegetable crops were grown throughout the Jericho district over an area of 33,807 dunums and under different types of cropping systems forming about 75% of the total cultivated areas and 84% of total production. Due to water resource limitations in the district, most vegetable crops are irrigated using drip systems. Fruits trees covered an area of 5,781 dunums with an average total production of 10,554 tons in the 2005/ 2006. Banana has the largest cultivated area of all fruit trees forming 27.6%, and making up 30% of the total fruit production in weight but it requires large amounts of water, up to 1,700 CM/yr/du. Field crops are cultivated under rainfed and irrigated conditions where sprinkler irrigation is commonly used. Wheat and barley are the main cultivated field crops covering an area of 5,125 dunums in the Jericho district (MOA, 2006), Figure 2.2 shows total cultivated area of different cropping patterns in 2005/2006.



Figures 2.2: Cultivated area (dunum) of vegetables, fruit trees and field crops.

Cropping systems are divided as irrigated open field, low tunnels (crops grown under low plastic tunnels of 80 cm in height, usually used for early plantations to protect the crops from low temperatures during winter). Medium and high tunnels (2-3.5 m in height), and plastic houses (more than 3.5 m in height) (Jericho Agricultural Station, 1994). Based on Ministry of Agriculture (MOA, 2006), there were 32, 907 dunums of vegetables were grown in irrigated open fields and 900 dunums of vegetables were planted under plastic houses. Of the total cultivated vegetables, tomato, cucumber, squash, Jews mallow eggplant and sweet corn have the largest areas and production.

2.2.2 Tomatoes

The tomato (Lycopersicum esculentum) of the family Solanaceae is believed to originate in the coastal strip of western South America (Papadopoulos A.P. 1991).

2.2.2.1 Tomatoes world production:

Tomato (*Lycopersicon esculentum*) is the second most important vegetable crop next to potato. Present world production is about 100 million tons fresh fruit produced on 37 million dunums. Tomato production has been reported for 144 countries (FAOSTAT Database, 2004), the major country being China in both dunums of harvested production (12,551,000 dunums) and weight of fruit produced (30.1 million tons). (FAOSTAT Database, 2004). The top five leading fruit-producing countries are the United States, China, Turkey, Italy, and India. Per capita consumption of fresh tomato fruit was increasing, for example in 1985, per capita consumption in the United States was 6.7 Kg, increasing to 8 Kg in 2000 (ERS-USDA, 2000). It is anticipated that per capita fresh fruit consumption will continue to increase since the tomato fruit has been found to have considerable health benefits.

2.2.2.2 Tomatoes production in Jericho district:

Table 2.1 shows tomatoes production in Palestine from 2002 to 2006 year. That clearly indicates increasing in crop production, and the assuming of the agriculture as main source of livelihood. Based on Ministry of Agriculture (MOA, 2006) and Palestinian Central Bureau of Statistics (PCBS, 2006) tomato production was the highest in Palestine during 2004-2005. It was 212,148 ton planted in 27,763 dunum.

Table 2.1: Tomatoes production in Palestine (2002-2006) – MOA, 2006).

Year	2002-2003		2003-2004		2004-2005		2005-2006	
Crop	Area (du)	Prod. (ton)	Area (du)	Prod. (ton)	Area (du)	Prod. (ton)	Area (du)	Prod. (ton)
Tomato	26,291	197,944	26,174	205,809	27,763	212,148	24,759	207,188

Tomatoes are produced under different cropping patterns; under open field, plastic houses, low and high plastic tunnels. Tomatoes production under open fields in the West Bank through the period 2004-2005 (PCBS, 2006) is presented in Table (2.2), which indicates that the Jordan valley was the leader in production tomato fruit in open fields, followed by Jenin district. The 29.8% of production and 26.4% of total planted areas by tomato in open field in West Bank are located in the Jordan Valley. The production in open field divides into rainfed and irrigated. In Jericho district, the production of vegetables in open field depends on irrigation (MOA, 2005)

Table 2.2: Tomatoes production in the West Bank under open field /2004-2005

District	Tomatoes area(du)	Tomatoes prod.(ton)
Jordan valley	3,705	13,125
Jenin	2,986	11,473
Tulkerm	253	1,771
Nablus	141	448.5
Rammallah	1,189	879
Bethlehem	427	1,357
Hebron	3,017	2,829
Salfit	204	360
Tubas	1,883	10,714
Qalqiliya	143	829
Jerusalem	74	247
Total	14,022	44,032

Tables (2.3, 2.4 and 2.5) show tomatoes production under plastics through the period 2004-2005 in different districts (PCBS, 2006).

Table 2.3: Tomatoes production under Plastic Houses / 2004-2005

District	Tomatoes area(du)	Tomatoes prod.(ton)
Jordan valley	303	5,454
Jenin	703	16,872
Tulkerm	199	3,582
Nablus	72	1,368
Rammallah	10	150
Bethlehem	18	270
Hebron	119	2,443
Salfit	37	740
Tubas	290	5,220
Qalqiliya	1,345	11,712
Jerusalem	12	120
Total	3,108	47,931

Table 2.4: Tomatoes production under low Plastic Tunnels 2004-2005

District	tomatoes Area-(du)	Tomatoes prod. (Ton)
Jenin	546	1,638
Tubas	130	780
Nablus	50	175
Others	----	----
Total	726	2,593

Table 2.5: Tomatoes production under High Plastic Tunnels 2004-2005

District	Tomatoes Area(du)	Tomatoes prod. (Ton)
Qalqiliya	1	1.5
Others	---	---
Total	1	1.5

Comparing average production of tomatoes per dunum in Jericho district to average production in other districts in West Bank shows by (Tables 2.6 and 2.7). Table (2.6) shows a lower average production of Tomatoes per dunum is in open field in Jericho district, while Table (2.7) shows higher average production per dunum in Jericho district under plastics houses (MOA ,2004) **.**

Table 2.6: Production area and average production in open field for Tomatoes (MOA, 2004).

District	Tomatoes Area-Dun	Average prods. Ton /dun.
Jericho dis.	2680	3.5
West Bank	8289	4

Table 2.7: Production area and average production under plastic houses for Tomatoes (MOA, 2004**).**

District	Tomatoes Area-Dun	Averages prod. Ton /dun.
Jericho des.	150	18
West Bank	2938	14.7

In 2007, tomatoes growing under plastic houses were increased to about (200 dunums) more than 2006, (MOA, 2007). Cherry Tomato 1335 (Cluster) was planting in Jericho area, and it was the first time farmers used this type of tomato in this district. The average production of cherry tomato is 13 ton/dunnum (PAPA engineers, 2008). Average production related to full growing season in Jericho district of 250 days.

Actual amount of used water by Tomatoes is about 600-700 CM/ dunum per crop season in open fields and about 1200 CM of water/ dunum under plastic houses, (MOA, 2008). Higher amount of water use in tomatoes production under plastic houses due to intensity of vegetation and its long life cycle, which expands from September to June.

Reference to a study prepared by Applied Research Institute about water resources and irrigated agriculture in the West Bank; shows agriculture water demand for irrigated crops under various agriculture patterns, they used CROPPWAT software and formulas for calculating seasonal irrigation requirements, a according to this study different results obtained: water demand for tomatoes is about 608 CM/dunum in open fields .In plastic houses water demand for tomatoes is about 1023 CM/dunum (Isaac, Walid, 1998) .

2.2.2.3 Main types of Tomatoes:

Essential characteristics in selection crops are economic yield, productivity, resistance to pests, adaptability to local soil and climatic conditions, fruit color, quantity and quality and acceptance by markets**.** Table (2.8) shows main types of Tomatoes planting in Jericho district under different cropping patterns according (MOA, 2007).

Table 2.8: Types of Tomatoes planting in Jericho district (MOA 2007)

Vegetable crop	Cropping patterns	Type
Tomato	open field , low plastic tunnels	Vaculta 56 , Vaculta 38 ,D-20 ,OxandraN/56 ,Super red NV ,Muna, 18/84 ,Silk 916
Tomato	plastic houses , high plastic tunnels	Huda , Ezabela ,Kreen ,Maysa , Nora ,Karank, IV-257, 593 ,FA 175 ,R19, Cherry Tomato 1335 (Cluster)

2.2.3 The effects of soil texture, types on the growth of Tomatoes:

Soil consists of mineral matter, organic matter, water, and air. An average soil in optimum condition for plant growth might consist of 45% mineral matter, 5% organic matter, 25% water, and 25% air space. The mineral matter is made up of a great diversity of small rock fragments. The organic matter of a soil is derived from plant and animal remains and is a mixture of these materials at various stages of decomposition. In the process of decomposition, some of the organic entities are oxidized to their products and others to an intermediate product called humus. Both the type and the relative quantity of the mineral and organic constituents of a soil determine its chemical properties. Chemical properties of a soil are the amounts of the various essential elements present and their forms of combination, as well as the degree of acidity or alkalinity, known as PH. The extent of nutrient availability to the plants depends not only on the chemical properties of the soil but also on its physical Properties. The physical properties of a soil describe its texture, i.e., the size distribution of its mineral constituents, expressed as a percentage of content of sand, silt, and clay and its structure, i.e. the type and extent of formation of the various mineral and organic constituents into crumb-like soil aggregates. The organic matter of a soil plays an important role in soil structure because of the diversity in the size of its components, but even more importantly, because of the role of humus in cementing together the various soil constituents into crumb-like aggregates. Soil structure in turn plays an important role in soil fertility (the ability of soil to sustain good plant growth and high yields) because it determines, to a great extent, the water-holding capacity and aeration of a soil. The air located in the soil pores supplies oxygen for the respiration of root and soil microorganisms and removes the carbon dioxide and other gases produced by them (Papadopoulos, 1991).

There are nine type of soil association is located in Jericho district Alluvial Arid Brown Soils, Loessial Arid Brown Soils, Reg Soils and Coarse Desert Alluvium, Brown Lithosols and Loessial Serozems, Calcareous Serozems, Solonchalks, Loessial Serozems, Regosols and Brown Lithosols and Loessial Arid Brown Soils (Issac,1995) .

Alluvial Arid Brown Soils is located mainly in the Jericho city, Fasayil areas and Al-Auja areas. It covers an area of about 64,700 du. It formed as a result of erosion of calcareous silty and clayey materials. The A horizon is brown and usually loamy and the B horizon is somewhat darker and somewhat finer textured. This soil type supports Herbaceous vegetation and responds well to irrigation, producing various crops, mainly subtropical and tropical fruits, such as citrus, bananas, and dates, as well as winter vegetables (Issac,1995).

Brown Lithosols and Loessial Serozems are found in the areas southwest of Aqbat Jaber Camp and northwest of Nuwe'ma, covering an area of about 4,670 hectares. The soil is originally formed from limestone, chalk, dolomite and flint. The A horizon is yellowish brown or vary pale brown and relatively coarse textured (mainly very fine sandy loam), the B-horizon is darker, usually brown and finer (loam to clay loam). The soil is restricted to the pockets among rocks. The soil association is also suffering from salt accumulation due to limited salt leaching capabilities (Issac, 1995).

Most of soil texture in Jericho district is sandy loam (Isaac, Walid, 1998).Table (2.9) shows Physical soil properties of sandy loam (Cuenca, and Richard H. 1989).

Table 2.9: Physical soil properties of Jericho district in the West Bank

Soil texture	Total available soil moisture (mm/m)	Maximum rain infiltration rate (mm/day)
Sandy Loam	120	600

Tomatoes do very well on most mineral soils, but they prefer deep, well-drained sandy loams. Deep tillage can allow for adequate root penetration in heavy clay type soils, which allows for production in these soil types. Soils extremely high in organic matter are not recommended due to the high moisture content of this media and nutrient deficiencies. But, as always, the addition of organic matter to mineral soils will increase yields. Tomato is a moderately tolerant crop to a wide pH range. A pH of 5.5- 6.8 is preferred though tomato plants will do well in more acidic soils with adequate nutrient supply and availability. Calcium availability is also very important to control soil pH and nutrient availability. Soil and tissue analyses should be taken throughout the growing and production season to insure essential nutrients are in their proper amounts and ratios**.** Loamy sand soil is the best for Tomato, which contains more or less equal amounts of sand, silt, and clay. They have properties that are intermediate between those of sand and clay. They classify as medium textured soil. Such soils are considered most favorable for plant growth because they hold more available water than sand and are better aerated and easier to work than clay (Harry, Mills, 2000).The most commonly used classification of soil according to size particle (Table 2.10), are proposed by the United States Departments of Agriculture (USDA) and by the International Soil Science Society (ISSS).

Table 2.10: Classification of soil according to size particle (USDA & ISSS)

Fraction	USDA (mm)	ISSS (mm)
Gravel	> 2	>2
Very coarse sand	1-2	-
Coarse sand	0.5 - 1	0.2-2
Medium sand	0.25-0.5	-
Fine sand	0.1-0.25	0.02-0.2
Very fine sand	0.05-0.1	-
Silt	0.002-0.05	0.002-0.02
Clay	<0.002	<0.002

2.2.4 Salinity of soils and Leaching:

In irrigated areas, soil salinity is mainly affected by water quality, irrigation methods and practices, soil conditions and rainfall. Salinity of soils affect on crop productivity (Table 2.11), so additional water for leaching salts and avoid its effect is needed .Saline soils have been define with electrical conductivity ECe value, and with increasing electrical conductivity of Soil (ECe) increase affects on growth and yield, and this effect depend on the tolerant of plant (Silva, Uchida, 2000).

Table 2.11: ECe value and effect on the growth and yield (Silva, Uchida, 2000)

ECe value (dS/m at 25◦C)	Effect on the growth and yield of plants
< 2	Little no effect on the growth and yield of plants
2 – 4	Affects only very sensitive plants
4 – 8	Affects many plants
8 – 16	Affects tolerant plants
> 16	Affects even very tolerant plants

ECe threshold means average root zone salinity at which yield starts to decline. Root zone salinity is measured by electrical conductivity of the saturation extract of the soil, reported in decisiemens per meter (dS m-1) at 25°C (Richard, Luis ,2006). Table (2.12) shows effects of saline soil on productivity of tomato.

Table 2.12: Effects of saline soil on productivity of Tomato (Silva, Uchida, 2000)

Tomato productivity	100%	75%	50%	0%
Soil Salinity ECe(ds/m)	2.5	5.0	7.6	13

Average root zone salinity threshold of tomato is 2.5ds/m, but this value differ with different types of soils , ECe threshold of tomato growing in sand 3.2 ds/m, in loam 1.8 ds/m and in clay 1.1 ds/m (Dehayr, Gordon, 2006).

Where irrigation water need above crop requirements, leaching requirements (LR) can be calculated using this equation, (Cardon, 2007):

$$LR = \frac{ECw}{2 \times ECe\ max} * 100\% \qquad (2.1)$$

LR is leaching requirements ECemax is the maximum soil EC wanted in the root zone ECw is electrical conductivity of irrigation water.

2.2.5 The effects of water salinity and chemical contents on the growth and yield of vegetables (Tomatoe):

Water uses for irrigation in Jericho district originated from different resources, and have different chemical composition (Ca^{+2}, Mg^{+2}, Na^{+1}, K^{+1}, $HCO3^{-1}$, $NO3^{-1}$). In order to identify water quality for irrigation, electrical conductivity (EC), the water salinity indicator, and sodium adsorption ratio (SAR) were used. Chemical analysis of for the major springs with low salinity in the Jericho district shows all springs (Wadi Al-Qillt, Ein-Sultan, AL-Auja and Dyouk) springs system are suitable for irrigation. However, springs with high salinity like Fashka with saline of chloride concentration greater than 2000 ppm is not suitable for irrigation (PHG, 1999).

Salinity restricts the availability of water to plants by lowering the total water potential in the soil. Salinity also has an impact on crop physiology and yield. Visible injury can occur at high salinity levels. Usually, crop yield is independent of salt concentration when salinity is below some threshold level, then yield gradually decreases to zero as the salt concentration increases to the level, which cannot be tolerated by a given crop (Silva, Uchida, 2000).

Various crops show different sensitivities to different water salinity levels, so each group has its function with salinity. Some crops are much more tolerant than others are. Plants are generally divided into four salinity-rating groups: sensitive, moderately sensitive, moderately tolerant and tolerant (Ayers, Westcot, 1985). Table (2.13) shows salinity rating for these groups.

Table 2.13: Salinity rating (Jensen, 1980)

Salinity Rating	**Threshold Salinity** dS/m	**Zero Yield Level** dS/m
Sensitive	1.4	8.0
Moderately Sensitive	3.0	16.0
Moderately Tolerant	6.0	24.0
Tolerant	10	32.0

Tomato classified as moderately sensitive (Jensen, 1980), their threshold point is 3 dS/m and zero yield level is 16 dS/m. A conductivity of 1 dS/m (decisiemens per meter) indicates a salt concentration of ≈700 ppm.Tolerance and yield potential of Tomato crops as influenced by irrigation water salinity (EC_W) (Ayers, Westcot, 1985), explain in Table (2.14).

Table 2.14: Tolerance of Tomato to water salinity (EC_W).

Tomato Productivity	100%	75%	50%	0%
Water salinity (dS/m)	**EC_w** 1.7	**EC_w** 3.4	**EC_w** 5.0	**EC_w** 8.4

(FAO, Drainage Paper 29)

2.2.6 Affects of Climate condition on the growth and yield of vegetables (Tomatoe):

Tomatoes are a warm season crops therefore, temperatures should not be allowed to drop below 18°C. Seed germination can occur with media temperatures above15°C, but optimal germination occurs at 29° to 35°C. Tomatoes are sensitive to frost, and will be killed by freezing temperature. Air temperature is the main environmental component influencing vegetative growth, cluster development, fruit setting, fruit ripening, and fruit quality. The flowers are self-pollinated. The optimum temperatures are 20-24°C at night and 16-32 ° C at day. At prolonged temperatures of less than 12°C or greater than 35°C, flowers can drop from the plant. High humidity (greater than 80%) can also adversely affect pollination, means the pollination is linked to temperature and humidity (USDA-2005).

The greenhouse environment has a profound effect on crop productivity and profitability. environment includes temperature, light, relative humidity, carbon dioxide, and air movement. Horizontal air movement is beneficial for several reasons. An approximate, which causes leaves to move slightly, air speed of 1 m/s is recommended. Horizontal air movement helps minimize air temperature gradients in the greenhouse, removes moisture from the lower part of the greenhouse (under the foliage), distributes moisture in the rest of the greenhouse, helps the carbon dioxide from the top of the greenhouse to travel into the leaf canopy where it is taken up and fixed in photosynthesand may even assist pollination (Papadopoulos, 1991).

The climate of Jericho district is classified as arid, which has hot summers and warm winters (natural green house) with very rare frosts incidents. The weather conditions and availability of water resources in the form of springs and groundwater wells combined with soil type make the Jericho district suitable for irrigated vegetables agriculture tomatoe (MOA 2005).

2.2.7 Crop Water Requirements:

Crop water requirements vary from season to season depending on the amount of rainfall and planting date. Low rainfall, high rates of evaporation, high of transpiration and radiation, low relative humidity and relatively high soil salinity make the crop water requirements in Jericho district higher than other districts in the West Bank (Isaac, Walid, 1998).

There are many factors affect on crop water requirements (Najem & Badir, 1980)

1. Climatic factors such as relative humidity, temperature, sunshine or radiation, rainfall and wind speed.
2. Soil factors such as the soil physical characteristics, water potential and hydraulic conductivity.
3. Plant factors such as the planting date, growth stage, type, the size (coverage percent), the leaf orientation and the stomata numbers.

The crop evapotranspiration (ETc) is the crop water requirement for a given cropping pattern during a certain time. Crop water requirement is equal to reference evaportranspiration (mm/day) multiplied by a crop coefficient (Kc). The (Kc) value represents the evaportranspiration of crop under optimum conditions and producing optimum yield, the irrigation requirement (IR) is the water that must be supplied through the irrigation system to ensure that the crop receives its full crop water requirement. The Net Irrigation Requirement (IRn) does not include losses that are occurring in the process of applying the water. IRn plus losses constitutes the Gross Irrigation Requirement (IRg). The gross irrigation requirements account for losses of water incurred during conveyance and application to the field. This is expressed in terms of efficiencies when calculating project gross irrigation requirements from net irrigation requirements (Savva P., Frenken K.2002), as shown below:

$$IRg = \frac{IRn}{E} \qquad (2.2)$$

IRg= Gross irrigation requirements (mm) IRn= Net irrigation requirements (mm)

E = Overall project efficiency

Crop water requirement was determined by FAO method, which divides the crop growth in to four stages as follows according K_c (crop coefficient):

1. Initial period: time of planting to time of 10% ground cover.
2. Crop development period: From end of initial period to time of effective full cover, that is 70 to 80 % ground cover.
3. Mid season period: from the end of crop development period to start of plant maturity as indicated by leaf discoloration.

4. Late season period: from the end of mid season period to time of full maturity of harvest.

At initially period, a crop uses water at a relatively slow rate. As growth develops this rate will increases, reaching a maximum in most crops at the approach of flowering and then declining towards maturity. Table (2.15) explains these relations by using tomato crop.

Table 2.15: Tomato (Kc) values related with growth stage, according (FAO-I992)

Crop growth stage	Initial (A)	Crop development(B)	Mid season (C)	Late season (D)
Tomato(Kc)	0.4-0.5	0.7-0.8	1.05-1.25	0.8-0.9

A: Initial period, B: Crop development period, C: Mid season period, D: Late season period.

Water stress at certain critical stages of plant growth causes more injury than at other stages. Each crop has certain critical stages at which if there is a shortage of moisture yield is reduced drastically. A critical stage for Tomatoes is when flowers are formed and fruits are rapidly larging (FAO, 1977).

2.2.8 Crop Water Requirements effected by surface mulches:

Mulches are used in vegetable production especially under trickle irrigation system to reduce evaporation losses from the soil surface, to increase crop development in cool climates by increasing soil temperature, to reduce erosion, or to assist in weed control. Mulches may be composed of organic plant or synthetic of plastic sheets. Plastic mulches consist of polyethylene or a similar material placed over the ground surface along the plant rows. Plastic mulches can be transparent, white or black. Kc values decrease by an average of 10-30%over the season as compared to using no mulches (Richard G., FAO, 1998).

2.2.9 Application efficiency:

Application efficiency is measure of irrigation performance. Common application efficiencies for various types of irrigation system, under good to excellent management, are listed below in Table (2.16), (USDA, 1997).

Table 2.16**:** Application efficiency under good to excellent management

System	**Application efficiency (in percentage)**
Furrow	70-85
Sprinklers	70-85
Drip(Trickle)	80-90

Modern irrigation techniques (Sprinklers and Drip systems) have been adopted since the seventies. In Jericho districts, 97% of the vegetables are irrigated by the drip systems, and 2.4% are irrigated by sprinklers (Isaac, Al-Juneidi., Walid, 1997). Drip irrigation increase agricultural productivity of vegetables by 50% (FAO,1998), and solves the problems of water losses to 35% when comparing with traditional irrigation methods (Abed Al-Razaq &; Abu Saleh,1991).

2.2.10 Evapotranspiration:

Evapotranspiration (ET) is the loss of water to the atmosphere by the combined processes of evaporation (from soil and plant surfaces) and transpiration (from plant tissues). It is an indicator of how much water your crops, lawn, garden, and trees need for healthy growth and productivity. Estimates of ET are necessary for system design, irrigation scheduling, water transfers, planning, and other water issues. Many factors affect ET including: weather parameters such as solar radiation, air temperature, relative humidity, and wind speed; soil factors such as soil texture, structure, density, and chemistry; and plant factors such as plant type and root depth (CIMIS,2005) .

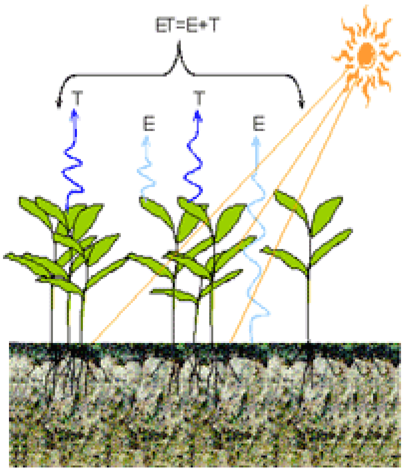


Figure 2.3: Evapotranspiration (ET) California I.M.I.S

$$ET = E + T \qquad (2.3)$$

ET- Evapotranspiration E –Evaporation T -Transpiration

Potential evapotranspiration (ETP) is defined as the water loss from a continuous surface of turf, which fully shades the ground, exerts little or no resistance to the flow of water into the atmosphere, and always has an adequate supply of soil water.

Potential evapotranspiration is useful in predicting the water requirements of turf grown under irrigation. Because the actual on-site measurement of ET is often impractical or impossible, empirical methods have been developed to estimate water use.

2.2.10.1 Methods use for calculating evapotranspiration :

a. Methods depend on climatic data

Thornthwaite-1984, Penman-1948, FAO Penman-Monteith equation-1990 and Blaney-Criddle-1998 methods are common empirical procedures for calculating potential evapotranspiration. Other methods have been developed for specific crops and locations.

1. Thornthwaite equation for predicting ETP uses temperature and day length data. It is a simple method, but has significant errors in short term prediction. Potential evapo-transpiration (mm/day):

PET = if Ta > 0 dl*16*(10*Ta/I)^a (2.4)

Where Ta: is mean monthly temperature (Celsius)

a = 0.49+0.079*I-7.71*10^ -5*I^2+6.75*10^ -7*I^3

dl = day length in hours / 12

I = sum (i)

i is a monthly heat index given by

i = if Ta>0 then (Ta/5) ^1.5

2. Blaney-Criddle method uses a consumptive use coefficient, temperature, and percent daylight to predict monthly ETP. This is a popular method for estimating ETP, and its accuracy depends on the proper coefficient and light levels. The Blaney-Criddle formula:

ET0 = p (0.46 T mean +8) (2.5)

ET0= Reference crop evapotranspiration (mm/day) as an average for a period of 1 month T″mean″ = mean daily temperature (°C), p = mean daily percentage of annual daytime hours.

3. Penman equation predicts daily ETP based on net radiation, vapor pressure, and wind speed. This method has been found to consistently underestimate water loss under conditions of strong sensible heat advection.

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma \left(1 + \frac{r_s}{r_a}\right)} \qquad (2.6)$$

Where Rn is the net radiation, *G* is the soil heat flux, (*es* - *ea*) represents the vapor pressure deficit of the air, *.pa* is the mean air density at constant pressure, *cp* is the specific heat of the air, ▲ represents the slope of the saturation vapor pressure temperature relationship, γ is the psychometric constant, and *rs* and *ra* are the (bulk) surface and aerodynamic resistances.

Aerodynamic resistance (ra)

The transfer of heat and water vapor from the evaporating surface into the air above the canopy is determined by the aerodynamic resistance:

$$r_a = \frac{\ln\left[\frac{Z_m - d}{Z_{om}}\right] \ln\left[\frac{Z_h - d}{Zoh}\right]}{k^2 u_z} \qquad (2.7)$$

ra aerodynamic resistance [s m-1],

zm height of wind measurements [m],

Zh height of humidity measurements [m],

d zero plane displacement height [m],

Zom roughness length governing momentum transfer [m],

Zoh roughness length governing transfer of heat and vapour [m],

k von Karman's constant, 0.41 [-],

uz wind speed at height z [m s-1].

(Bulk) surface resistance (rs)

The resistance of vapor flow through the transpiring crop and evaporating soil surface.

$$r_s = \frac{r_1}{\mathbf{LAI}_{active}} \qquad (2.8)$$

rs (bulk) surface resistance [s m-1],

rl bulk stomatal resistance of the well-illuminated leaf [s m-1],

LAIactive active (sunlit) leaf area index [m2 (leaf area) m-2 (soil surface)].

4. FAO Penman-Monteith Equation

$$ET_o = \frac{0.408\Delta (R_n - G) + \gamma \dfrac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma (1+0.34\, u_2)} \qquad (2.9)$$

ETo reference evapotranspiration [mm day-1], Δ slope vapour pressure curve [kPa °C-1],

Rn net radiation at the crop surface [MJ m-2 day-1], *ea* actual vapors pressure [kPa],

G soil heat flux density [MJ m-2 day-1] , *Es* saturation vapors pressure [kPa]

T air temperature at 2 m height [°C], *u2* wind speed at 2 m height [m s-1],

es-ea saturation vapour pressure deficit [kPa], γ psychometric constant [kPa °C-1].

ET_0 for plastic house

ET_0 for plastic house = (0.67 * R_g * Kt)/ L (2.10)

Where:

L = potential heat for evaporation (constant value) = 2.51 MJ/Kg

R_g = sunshine radiation MJ/m^2/day

Kt = transfer factor of sunshine to the plastic house and equal 0.7 for plastic houses and 0.9 to glass houses.

b- Methods depend on water balance

1. Soil water balance

$$ET = I + P - RO - DP + CR \pm \Delta SF \pm \Delta SW \qquad (2.11)$$

ET Evapotranspiration, *(I)* Irrigation, (*P)* rainfall add water to the root zone, *(RO)* surface runoff, *(DP)* deep percolation. *(CR)* capillary rise. Subsurface flow in *(SFin)* or out of (*SFout)* the root zone, *(ΔSW)* change in soil water content.

2. Pan evaporation

Evaporation pans provide a measurement of the combined effect of temperature, humidity, wind speed and sunshine on the reference crop evapotranspiration ETo.The principle of the evaporation pan is the following:

a- The pan is installed in the field

b- The pan is filled with a known quantity of water (the surface area of the pan is known and the water depth is measured).

c- Water is allowed to evaporate during a certain period (usually 24 hours). For example, each morning at 7 o'clock a measurement is taken. The rainfall, if any, is measured simultaneously, after 24 hours, the remaining quantity of water (i.e. water depth) is measured the amount of evaporation

per time unit (the difference between the two measured water depths) is calculated; this is the pan evaporation E pan (in mm/24 hours), the E pan is multiplied by a pan coefficient, K pan, to obtain the ETo (FAO 1998) .

$$ET0 = K\ pan \times E\ pan \qquad (2.12)$$

ET0: reference crop evapotranspiration, *K pan*: pan coefficient, E *pan*: pan evaporation

3. Lysimeter method

Specific devices and accurate measurements of various physical parameters or the soil water balance in lysimeters are required to determine evapotranspiration. The methods are often expensive, demanding in terms of accuracy of measurement and can only be fully exploited by well-trained research personnel. Although the methods are inappropriate for routine measurements (FAO 1998).

FAO Penman-Monteith method is recommended as the sole standard method. It is a method with strong likelihood of correctly predicting ET_o in a wide range of locations and climates and has provision for application in data-short situations. The relatively accurate and consistent performance of the Penman-Monteith approach in both arid and humid climates has been indicated in both the American Society of Civil Engineers ASCE and European studies, while the radiation methods show good results in humid climates where the aerodynamic term is relatively small, but performance in arid conditions is erratic and tends to underestimate evapotranspiration.

Temperature methods remain empirical and require local calibration in order to achieve satisfactory results. Pan evapotranspiration methods clearly reflect the shortcomings of predicting crop evapotranspiration from open water evaporation. The methods are susceptible to the microclimatic conditions under which the pans are operating and the rigour of station maintenance and their performance proves erratic (FAO 1998).

Chapter 3 Methodology

3. Methodology

3.1 Calculate evapotranspiration

Different values of reference evapotranspiration (ET0) were calculated for the Jericho area. ARIJ in 1997 used CROPWAT software to calculate reference and crop evapotranspiration depending on modified Penman –Monteith method. ET0 was obtained from ARIJ search "Water Resources and Irrigated Water". In 1998 Jericho Municipality with the help of ANERA engineers crop used the average value" mean" of pan evaporation for the period 1989 to 1997, then they calculated the ET0 depending on following equation.

ET0= pan evaporation * 0.8

In this research reference evapotranspiration (ET0) was obtained with reference to NCARTT "National Center for Agricultural Research and Technology Transfer" in Karamah Station. Karamah local to the east of the Jordan River. It is opposite to the study site "New'ma" and has same climatic conditions**.** ET0 was calculated as an average of ET0 for the period between 2002 – 2006. These values were used as the value of November to December 2007. For the growing months which in 2008, ET0 was calculated as an average value for period between 2002 – 2007. Table (3.1) shows an average value of ET0 for Jericho district calculated by different sources.

Table 3.1: ET0 for Jericho district, calculated by different sources

Month	**ET0**/NCARTT (mm/day)	**ET0**/Jericho Municipality (mm/day)	**ET0**/ARIJ (mm/day) in Jericho	**ET0** under plastic houses in Jericho/ARIJ (mm/day)
Nov.	1.8551	2.680	3.33	2.3
Dec.	1.2098	1.544	2.15	1.7
Jan.	1.1509	1.719	2.2	1.8
Feb.	1.5685	1.714	2.98	2.3
Mar.	2.3919	2.479	4.7	3.4
Apr.	3.2807	4.319	7.18	4.0
May	4.1752	6.134	8.92	4.6

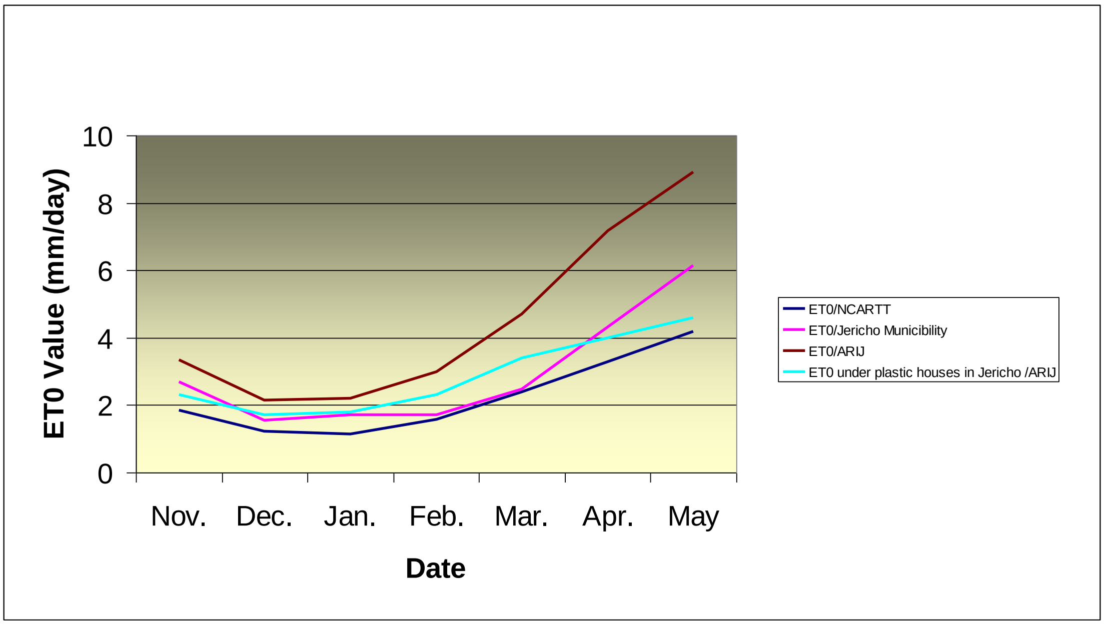


Figure 3.1: Average ET_0 for Jericho district

The maximum ET0 was calculated by ARIJ 1997, and the lowest one was calculated by NCARTA. ET0 of Jericho Municipality 1998 and. ET0 of ARIJ under plastic houses in Jericho were locating between both and crossed in December & April. ET0 of NCARTT is used in this experiment due to more updated climatic data that was used in calculation reference evapotranspiration.

3.2 Calculate irrigation water

3.2.1 Calculate crop water requirements (ETc):

Crop water requirements is defined as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime. ETc is calculated by multiplying Eto by a crop coefficient Kc (FAO, 1998)

ETc= ET0* Kc, where (3.1)

ETc: Crop water requirements (mm/day)

ET0: reference evapotranspiration (mm/day) Kc: Crop coefficient

3.2.2 Graphical determination of crop coefficient (Kc):

The crop coefficient is a dimensionless number (usually between 0.1 and 1.2) that is multiplied by the ETo value to arrive at a crop ET (ETc) estimate. Crop coefficients vary by crop, stage of growth of the crop, and by some cultural practices (CIMIS, 2005).

Values Kc for tomato (see Table 2.15) was identified with reference to FAO-1992, and used to construct Kc curve, and from the crop coefficient curve the Kc value for any period during the growing period can be graphically or numerically determined.

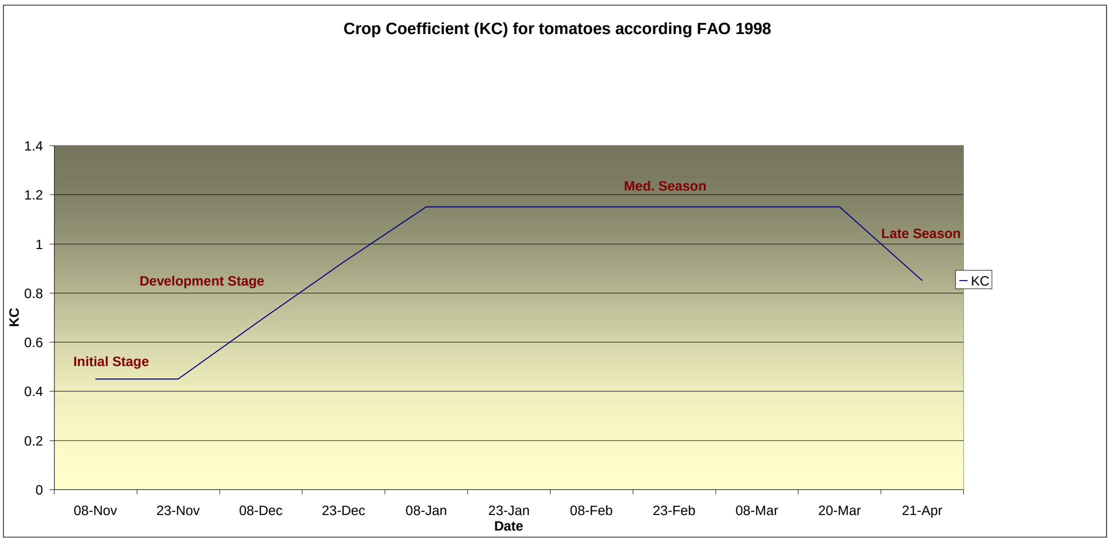


Figure 3.2: Crop coefficient curve for tomato

The growing period for tomato is 180 days from sowing, or 160 days from transplant (FAO, 1998). Table (3.2) shows the growing period from transplants to late season stage.

Table 3.2: The growing period of tomato (FAO, 1998)

Initial Stage	Development stage	Mid-season stage	Late season stage
15 days	45 days	70 days	30 days

3.2.3 Calculate Gross irrigation requirements (mm):

The gross irrigation requirements account for losses of water incurred during conveyance and application to the field. This is expressed in terms of efficiencies when calculating project gross irrigation requirements from net irrigation requirements (Savva., Frenken ,2002), as shown below

$$IRg = \frac{IRn}{E} \qquad (3.2)$$

IRg= Gross irrigation requirements (mm) IRn= Net irrigation requirements (mm)

E = Overall project efficiency Net irrigation requirements is the amount of irrigation water needed in actual irrigated area effected by factor of management practices such as effects of surface mulches which reduce loss by evaporation. The Net Irrigation Requirement (IRn) does not include losses that are occurring in the process of applying the water. Volume irrigation affected by leaching requirements, mulch factor and wetted area.

leaching requirements is the amount of additional irrigation water required to move salts out of the root zone. It can be approximated using guide for predicting crop water requirements (B.C.Ministry of agriculture, 2001) by using following equation:

$$LR = \frac{ECw}{4} \qquad (3.3)$$

A leaching fraction (or percent of additional water needed above crop requirements) can be calculated for irrigated fields using this equation(G.E. Cardon.2003)

$$\% LR = \frac{ECw}{2 \times ECe\ max} * 100\% \qquad (3.4)$$

LR:is leaching requirements

ECe max: is the maximum soil EC wanted in the root zone.

ECw: is electrical conductivity of the irrigation water (ds/m)

$$\textbf{Net irrigation} = \frac{ETc * \text{mulch factor} * \text{wetted area}}{1000} \qquad (3.5)$$

$$\textbf{Gross irrigation} = \frac{\text{Net irrigation}}{\text{Field efficiency}}$$

3.3 Soil investigation

3.3.1 Soil Color:

Soil color can provide information about organic matter in the soil, drainage, biotic activity, and fertility. Table (3.3) can give you some insight into the condition of your soil just from its appearance. To identify the color of your soil, you should take a garden spade or shovel, and dig a shallow hole, at least 3" - 4" deep, and gauge the color (you should do this quickly before the sun can dry it out) (Klocke,Normane L. 1998).

Table 3.3: Color soil and soil condition (Klocke, Normane L. 1998)

Condition	Color		
	Dark	Moderately dark	Light
organic matter	high	medium	low
erosion factor	low	medium	high
aeration	high	medium	low
available nitrogen	high	medium	low
fertility	high	medium	low

3.3.2 Soil texture:

Soil texture is determined by the relative amounts of sand, silt and clay in soil has. Several methods for determine soil texture. Sieving is often used, and classification of soil according to size particle is used by United States Department of Agriculture (USDA), or the International Society of Soil Science (ISSS). The USDA textural triangle then used for determine soil textural class (Doornbos, Pruitt,1975).

The USDA textural triangle is a graphical representation of the 12 soil textural classes. Each side of the triangle has a scale from 0 to 100% for the three soil separates, sand, silt, and clay (Figure 3.3).

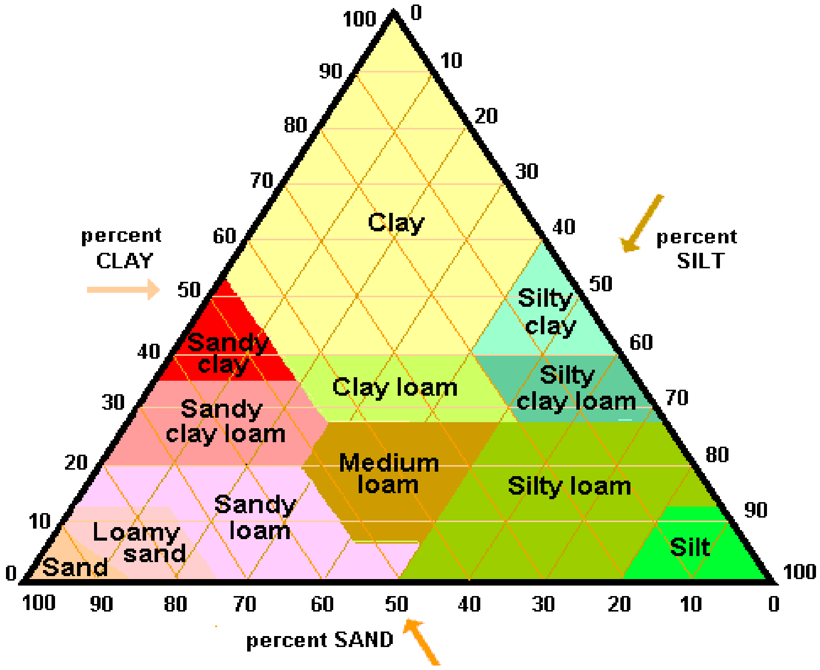


Figure 3.3: USDA textural triangle

3.3.3 Organic Content:

The organic content of soil is very important for the growth of plant because decomposing organic material provides many necessary nutrients to soil. The amount of organic material can be determined by ignition process (by using oven). Organic material is made of carbon compounds, which when heated to high temperatures≈500 °C are converted to carbon dioxide and water. In the ignition process, a dry solid sample is heated to a high temperature. The organic matter in the soil is given off as gases. This results in a change in weight, which allows for calculation of the organic content of the sample (Klocke, Normane L. 1998).

3.3.4 Measuring Soil Water Holding Capacity:

Firstly, establish the depth of the root zone, either by observing the depth to which roots from the previous crop have extended, or by noting the depth to a restrictive layer. Secondly, use Table (3.4) to calculate the water holding capacity of each soil layer in the root zone. For example, 25cm of clay loam with an available water of 1.8mm water per cm of soil, can store 45mm of available water and 80mm holding capacity .The water holding capacity of a soil is calculated by summing the capacity of each layer in the root zone (Whiting, Tolan, 2005).

Table3.4: Soil Water Holding Capacity (Department of Agriculture Bulletin 462, 1960)

Texture	Field Capacity mm/cm	Wilting point mm/cm	Available water mm/cm
Coarse sand	0.6	0.2	0.4
Fine sand	1.0	0.4	0.6
Loamy sand	1.4	0.6	0.8
Sandy loam	2.0	0.8	1.2
Light sandy clay loam	2.3	1.0	1.3
Loam	2.7	1.2	1.5
Sandy clay loam	2.8	1.3	1.5
Clay loam	3.2	1.4	1.8
Clay	4.0	2.5	1.5
Self-mulching clay	4.5	2.5	2.0

Field capacity refers to the situation when excess water has drained out due to gravitational pull .Wilting point refers to the situation when a plant wilts beyond recovery due to a lack of water in the soil. At this point, the soil feels dry to the touch. However, it still holds about half of its water, but the plant just does not have the ability to extract it. Plants vary in their ability to extract water from the soil. Available water is the amount of the water held in a soil between field capacity and the permanent wilting point. This represents the quantity of water available or usable by the plant (Whiting, Tolan**,** 2005)**.**

5.3.5 Moisture content:

Soil moisture can be measures or estimated in a variety of ways ranging from the simple, low cost feel method to more accurate, conventional drying oven. Using drying oven in laboratory is recommended in measuring moisture of soil by placing samples in the oven at

105 degree centigrade for 24 hours, and compares the weight of the soil before drying to the weight after drying (Schneekloth J., Bauder T 2007).

3.4 Field investigation and data collection

3.4.1 Choosing of investigation sites:

a- To determine soil type and water quality.

b- To determine affect water uses in crop yield

3.4.2 Soil sampling:

For a general assessment of soil quality, select sample sites within a field that are representative of the field. The number of samples or measurements to take will depend on the variability of different soils in the field. It is recommended that a minimum of three samples or measurements be collected on any one-soil type and management combination. In general, the greater the variability of the field, the greater the numbers of measurements are needed to get a representative value at the field scales. A good time to sample is when the climate is most stable and there have been no recent disturbances, such as after harvest or the end of the growing season (Klocke, Normane L. 1998).

3.4.3 Laboratory work:

-Soil sieving (soil texture and type).

-Soil chemistry analysis

-Water analysis (Na^{+1} , Ca^{+2}, Mg^{+2}, Cl^{-}, NO_3^{-}, SO_4^{-2})

- Calculate TDS, SAR, and SSP.

3.4.4 Optimize the use of water in irrigation vegetables Tomato:

By irrigation management and increasing, the application of modern technologies of irrigation such as drip method, which provide to saving the irrigation water and this decrease water needs and this cause an increase in the water use efficiency and the crop productivity.

Chapter 4 Experimental procedure

4. Experimental procedure

4.1 Determine field location

The field location was a plastic green house with 2.5 dunum in Nueama, Jericho area near Hisham palace. Dr. Adnan Manasra is the owner. The selected area Nueama lies within co-ordinates 31.52N.L, 35.28 E.L and with altitude -250m. It lies to the west side of Jordan River near al-karamah to the east side of Jordan River. A cherry tomato variety 1335 (cluster) was planted in the green house in 28 lines with double rows, 15 lines of them under study control.

4.2 Random complete block design

Experimental design was divided into three blocks B1, B2, B3, each block includes five lines with five treatments TI, T2, T3, T4, T5, treatments were randomly selected without replacement, the results are presented in Table (4.1).

Table 4.1: Random complete block design

B1	**B2**	**B3**
T3	T5	T4
T5	T1	T3
T4	T2	T5
T1	T4	T2
T2	T3	T1

Each treatment value refers to irrigation percentage of ETc, relationship between treatments ETc is shown in table (4.2).

Table 4.2: Treatments with %Etc

TREATMET	TI	T2	T3	T4	T5
%ETc	85%ETc	90%ETc	100%ETc	110%ETc	Farmer Irrigation

T5 is connected with other 13 lines irrigated by farmer, irrigation amount depend on experience of farmer (25 years of experience) and controlled by engineers of PAPA project.

On this design, the only variable item is the irrigated water amount, while other parameters are fixed such as pesticides, fertilizers for each trial, and recorded using global gab supervised by engineers of PAPA project.

4.3 Install flow meters

Five flow meters have been installed in order to control water quantity for each trail and to be compared with water used by farmer.

Figure 4.1: Install flow meters

4.4 Growing tomato

Pre- planting, a soil sample was taken and tested by the Hebron University laboratory. After approved, land was prepared before planting by added 6 ton of cow manure compost, cultivation, grading, and pre plant irrigated for about three hours, with 56 CM water. Cultivation is usually done for weed control and soil aeration. It is effective but only temporary solution to water infiltration problem. Pre-plant irrigation is used to remove surface salt concentration in one side, in other side to wet the deeper part of crop root zone and to fill it to field capacity (Ayers R.S. FOA, 1985). Plastic house was constructed according with PAPA specification in 20th October 2007. Its total area 2.5 dunum of 62.5m long, 40m wide, and 4m high (Figure 4.2). The drip irrigation method was used , the best application method for saving water with efficiency 90%, while sprinklers or furrow methods efficiency range between 70-85%, that means ability to save 5-20% of irrigation water by drip irrigation (USDA,1997).

Figure 4.2: Plastic house

Planting date was on 8th November 2007. Healthy transplants were planted with hight of 10 cm, lower leaves removed for planting. The plants seted deep into the plastic mulch into the soil because the part of the stem that is buried in the soil will send out roots.Normally planting date in Jericho area is in the mid of September, thus the planting was late for about 60 days and will affect on the lowering total yield. Plastic mulch of 1.2 m wide was used. In all treatments, the only variable item is the irrigated water amount, while other parameters are fixed such as pesticides, fertilizers that recorded and supervised by engineers of PAPA project. The irrigation water was analyzed tow times in different periods to determine water quality. The irrigation water requirement per each treatment and irrigation scheduling were presented in irrigation section (see Appendixes 1 and 2). On 8th December 2007, flower tomato began to arise in all treatments, but more clearly in T1, T2, T3. Average of flowers per cluster is about 10-14. The bunches of flowers are formed along the stem repeatedly after about three leaves (Katerji, 1998).

Tomato is self-pollination (McGregor 1976).For developing pollination, the hormones and bio bees were used, but the very cold days in January month caused die of most bees, so another bio bees was purchased. Usually seven hives per hectare (3 hives per acre) are sufficient to ensure complete pollination throughout the tomato crop (Portree 1996).

Figure 4.3: Tomato blossom; December 8, 2007

The young green fruit started at January 3, 2008 (Figure 4.4). The approximate time from pollination to market maturity under warm growing conditions for most tomato varieties from 35 to 60 days, with the days to maturity depending on the stage of maturity when harvested: Mature green 35 to 45 days, Red ripe 45 to 60 days (Katerji, 1998). The first harvested day was in17th March 2008. The production yields of tomato per each treatment were presented in production of tomato section (5.4).

Figure 4.4: green fruit, January 3, 2008

When the height of tomato exceeded 2.5 m, the tomatoes were lowered. Handly harvesting was used. Careful handling, primarily by avoiding physical damage to the fruit and. minimizing the height that the tomatoes will increase the shelf life of the tomato (Portree,1996).

Chapter 5 Results and interpretation

5. Results and interpretation

5.1 Chemical and physical characteristics of irrigation water

The Nuwema spring is the main water resource for irrigation in the field location, the distance between Nuwema spring and field is about 4 km , then the water is collected in open ponds .

The pond is a hole digs in soil with volume of 3,500 CM, plastic sheet used to cover the ground and sides of pond to prevent water loss through filtration ,but waters loss caused by evaporation due to open surface of the pond . Over the plastic sheet fine soils used to fix the plastic. The irrigation water naturally flows to field without pumping due the difference in elevation. The first pond was constructed in 1970 with capacity of 1,650 CM (Jericho Agriculture Station, 1994). There are approximately 273 soil ponds were located in Jericho district (Agriculture Department, Jericho, 2007). Other benefit of ponds is increasing biodiversity; the fish were shown in it, which mean that the ponds suitable for fish faming.

The samples of water from pond were collected and analyzed in the laboratories at Hebron University and Al-Quds University by Water & Environmental Research Laboratory in different times.

The physical and chemical results of ponds irrigation water by Hebron University at 8th November 2007 are shown in Table (5.1).

Table 5.1: The physical and chemical results of irrigation water / Hebron University

pH	Ec(ds/m)	Ca^{+2} (ppm)	Mg^{+2} (ppm)	Na^{+1} (ppm)	HCO_3^{-1} (ppm)	Cl^{-1} (ppm)	Coliform/100ml
7.95	0.68	19.2	11.8	22.03	54.9	62.07	15000

The suitability of water for irrigation affected by Sodium Adsorption Ratio (SAR) ,which was recommended by the United Statee's Salinity Laboratory (USSL) of the department of Agriculture (Richard, 1954), soluble sodium percentage (SSP) and electrical conductivity (Wilcox, 1995). Sodium adsorption ratio (SAR) is calculated according to the equation 5.1

$$SAR = \frac{Na^{+}}{\sqrt{\frac{(Ca + Mg)^{++}}{2}}} \qquad (5.1)$$

SAR=0.975

The cations are expressed in milliequivalent per liter.

Soluble Sodium Percentage

(SSP) = (Na^{+1} / Ca^{+2} + Mg^{+2} + Na^{+1} + K^{+1}) *100 (5.2)

SSP = [soluble sodium concentration (meq/litre) / total cations concentration (meq/litre)] x 100

SSP =0.3318

Based on the SAR classification (Wilcox, 1995), water class S1 which mean low sodium and can be used for irrigation on almost all soils with little danger .According to SAR-EC relationship (U.S.Salinity laboratory, 1954), classified irrigation water as class S1C2, which indicates the water is low sodium but with medium salinity, it can be used to irrigate plants with moderate salt tolerance. Table (5.2) shows the results which obtained by Water & Environmental Research Laboratory in Al-Quds University at 18th February 2008.

Table 5.2: The physical and chemical results of water/ Al-Quds University

pH	Ec (μs/cm)	Ca^{+2} (ppm)	Mg^{+2} (ppm)	Na^{+1} (ppm)	K^{+1} (ppm)	HCO_3^{-1} (ppm)	Cl^{-1} (ppm)	SO_4^{-2} (ppm)	NO_3^{-1} (ppm)	PO_4^{-3} (ppm)
8.39	642	66.5	44.8	90	7.19	500	58.85	35	28.4	0.21

Sodium Adsorption Ratio (SAR) =2.0811

Soluble Sodium Percentage (SSP) =36.7

Total dissolved solids (TDS) = 581 mg/l.

Since irrigation began in 8th November2007 there has been a slow deterioration in water quality. There were increasing in concentration of cations anions concentration, pH, sodium adsorption ratio , soluble sodium percentage and total dissolved salts (Table 5.2).The source of degradation is thought to be salts being leached from the pond. The irrigation water class still as S1C2; water with low sodium but with medium salinity. It can be used to irrigate plants with moderate salt tolerance if moderate amount of leaching occurs (Richared, 1954). The pH of water indicates that the water is alkaline with increased and prevailing bicarbonates.

5.2 Soil analysis results

5.2.1 Chemical and physical characteristics of soil:

Chemical and physical characteristics of soil and to depth (0-25cm) was analyzed in the Hebron University lab., the results are presented in table 5.3.

Table 5.3: Chemical characteristics of soil

Depth	pH	ECe (ds/m)	Ca^{+2} (ppm)	Mg^{+2} (ppm)	K^{+1} (ppm)	Na^{+1} (ppm)	N-NO_3 (ppm)	P (ppm)	Cl^{-1} (ppm)
0-25cm	7.32	2.68	2297.74	228.86	779.8	169.00	24.99	21.35	2.02

5.2.2 Soil Texture:

Soil texture was analyzed in Al-Quds University in Water & Environmental Research Lab., for test used sieve shaker to determine amounts of sand, silt, and clay.Atextur triangle (see Figure 3.3) was used to generalize soil texture, results are shown in table (5.4).

Table 5.4: Percentage of sand, silt, and clay and soil texture

Depth(cm)	Clay%	Silt%	Sand%	Soil texture
0-25	39.52	24.36	36.12	Clay Loam
25-50	34.54	42.58	24.98	Loam

These types of soils are clay loam, loam is clayely and compacted soils with lack of large pore space restricts oxygen levels, roots will be shallow. Plants with a shallow rooting depth simply have a smaller depth and more coverage area. Figure (5.1) shows plants with a deeper rooting system reach a larger supply of water and can go longer between irrigations. Plants with a shallow rooting depth, reducing the supply of available water (Whiting, Tolan, 2005).

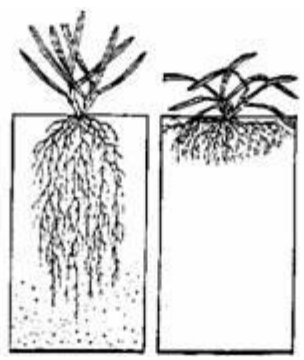


Figure 5.1: Rooting depth and soil texture

Tomato rooting depth concentrated in above 25 cm, thus chemical and physical characteristics of soil depth (0-25cm) was also another primary factor influencing irrigation management. ECe threshold of tomato growing in clay loam not more 2ds/m, in loam 1.8 ds/m and in clay 1.1 ds/m (Dehayr and I. Gordon 2006). ECe was 2.68 (see table

5.3), so needed additional water for leaching .Leaching requirement was calculated in irrigation requirements section (5.3.1).

5.2.3 Measuring Soil Water Holding Capacity

Soil water holding capacity was calculated for 25 cm, the depth of root zone in clay loam soil, depending on Department of Agriculture Bulletin 462, 1960.The results are shown in Table (5.5).

Table 5.5: Soil Water Holding Capacity

Texture	Field Capacity mm/cm	Field Capacity mm/25cm	Wilting point mm/cm	Wilting point mm/25cm	Available water mm/cm	Available water mm/25cm
Clay loam	3.2	80	1.4	35	1.8	45

5.2.4 Soil color

Figure (5.2), shows the color of soil is yellow light brown soil. These soils often have poorer drainage than red soils. The iron compounds in these soils are in hydrated form and therefore do not produce the rusty colour.The amount of organic matter and available nitrogen is low, (Klocke, Normane L. 1998).

Figure 5.2: Soil color

5.2.5 Organic content, moisture content and bulk density of soil

The organic content, moisture content and bulk density of soil were analyzed in the laboratory of Sinokrot Food Company. Palestinian Standards Institute calibrated all instruments, which used in tests. The results are shown in table 5.6.

Figure 5.3: Furance oven

Figure 5.4: Moisture analyzer

Table 5.6: Organic content, moisture content and bulk density of soil

Organic content%	2.26
Moisture content%	6.3
Bulk density (g/ml)	1.46

Organic content indicate that the soil includes low organic content depending on Walky – Black method (1930), and this result meets expectations of organic content by soil color.

5.3 Irrigation requirements

5.3.1 Daily ET_0, K_C, ET_C and stages for tomato in Jericho area

Crop water requirements (ETc) were calculated by multiplying reference evapotranspiration (ET0) by a crop coefficient (Kc) (FAO, 1998). ET0 was calculated with reference to NCARTT as cited in methodology (3.1). The value of November to December 2007 was calculated as an average of ET0 for the period between 2002 – 2006. For the growing months which in 2008, ETo was calculated as an average value for period between 2002 – 2007. Crop coefficient Kc value for any period during the growing period was graphically determined (Figure 3.2). Appendix 1 summarizes the results and includes period time per each stage.

Irrigation efficiency depends on field efficiency, and can be expressed as the ratio between the amount of used water by the plant and the total quantities delivered. It is affected by the degree of land preparation, seepage from irrigation network and uneven distribution of water due to difference in elevation. The gross irrigation is the irrigation water includes losses that are occurring in the process.

$$\textbf{Gross irrigation} = \frac{\text{Net irrigation}}{\text{Field efficiency}} \qquad (5.3)$$

Net irrigation requirements is the amount of irrigation water needed in actual irrigated area effected by factor of management practices such as effects of surface mulches which reduce loss by evaporation. The Net Irrigation Requirement (IRn) does not include losses that are occurring in the process of applying the water. Volume irrigation affected by leaching requirements, mulch factor and wetted area.

$$\textbf{Net irrigation} = \frac{\text{ETc * mulch factor * wetted area}}{1000} \qquad (5.4)$$

Mulch factor = 0.9

Wetted area = No. of plants per line * space per plant

= 500 * 0.4 = 200 m^2

The optimum space per plant is generally agreed to be 0.35-0.40 m2 (A. Papadopoulos, 1991).

$$\text{Net irrigation} = \frac{ETc * 0.9 * 200}{1000} = 0.18\ ETc$$

Leaching Fraction (Lr) is the amount of additional irrigation water required to move salts out of the root zone

$$Lr = \frac{ECw}{2 * ECe} * 100\% \qquad (5.5)$$

ECe max: is the maximum soil EC wanted in the root zone.

ECw: is electrical conductivity of the irrigation water (ds/m)

$$Lr = \frac{0.680}{4} * 100\% = 17\%$$

Preparation field with shallow cultivation and some difference in elevation estimated up to 8% that causes the Field efficiency = 75%

$$\text{Gross irrigation} = \frac{0.18\ ETc}{0.75} = 0.24 * ETc$$

The gross irrigation need per each treatment is calculated by multiplying gross irrigation by a treatment factor (see Table 4.2).

Gross irrigation for T1=0.85* 0.24 *ETc

=0.204 *ETc

Gross irrigation for T2=0.9 *0.24 *ETc

=0.216 *ETc

Gross irrigation for T3=1.0 *0.24 *ETc

=0.24 *ETc

Gross irrigation for T4=1.1 *0.24 *ETc

=0.264 *ETc

Based on above calculations, Appendix 2 shows irrigation amount and scheduling for TI, T2, T3, T4, T5 and interval days for tomato crop with field efficiency 75%.

Figure 5.5 shows that the farmer irrigation (T5) was the highest in the most times and there are relatively increasing in irrigation amount from initial stage to mid growth stage, then relatively decreasing in the end stage. In controlled trials (T1, T2, T3 and T4) the largest amount of water was used in14th March , while farmer used maximum amount of 3 CM water on 21th March.

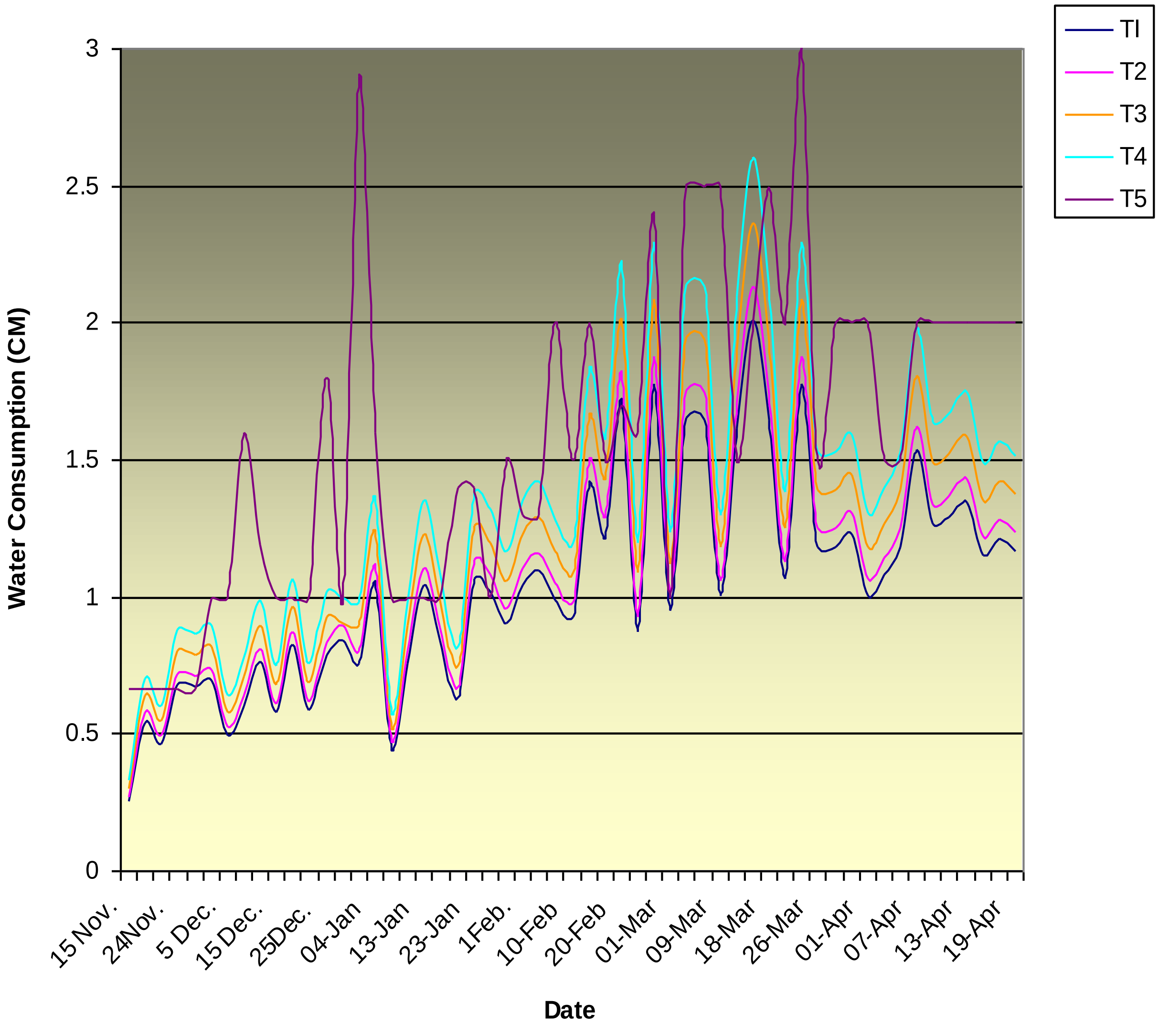


Figure 5.5: Water consumption for T1, T2, T3, T4 and T5.

The Accumulation of irrigation scheduling per each treatment is shown in Table (5.7), Figures 5.6 and 5.7. T1 treatment used 57.6280 CM of water, T2 used 61.0140 CM, T3 used 74.5507 CM and the T5 (farmer irrigation) used more water than any controlled trial 86.9233 CM of irrigation water.

Table 5.7: Accumulation of irrigation scheduling for TI, T2, T3, T4 and T5.

Date	TI (CM)	T2 (CM)	T3 (CM)	T4 (CM)	T5 (CM)	Stage
15 Nov.	0.2584	0.2736	0.3040	0.3344	0.666	A
18Nov.	0.7993	0.8501	0.9445	1.039	1.332	A
21Nov.	1.2645	1.3427	1.4918	1.641	1.998	A
24Nov.	1.9470	2.0653	2.2947	2.5242	2.664	B
27Nov.	2.6187	2.7765	3.085	3.3935	3.330	B
1 Dec.	3.3132	3.5110	3.9021	4.2923	4. 330	B
5 Dec.	3.8073	4.0342	4.4834	4.9317	5.330	B
8 Dec.	4.4137	4.6763	5.1968	5.7164	6.930	B
11 Dec.	5.1777	5.4852	6.0955	6.7052	8.1233	B
15 Dec.	5.7566	6.0981	6.7766	7.4544	9.1233	B
18Dec.	6.5808	6.9708	7.7462	8.521	10.1233	B
22Dec.	7.1680	7.5926	8.4370	9.2809	11.1233	B
25Dec.	7.9556	8.4266	9.3636	10.3002	12.9233	B
29 Dec.	8.8010	9.3217	10.2678	11.2948	13.9233	B
1 Jan.	9.5622	10.1276	11.1633	12.2799	16.5233	B
4 Jan	10.6135	11.2412	12.4006	13.6409	18.1233	B
8 Jan	11.0631	11.7168	12.9291	14.2222	19.1233	C
10Jan	11.8246	12.5231	13.8250	15.2077	20.1233	C
13Jan	12.8691	13.6290	15.0538	16.5594	21.1233	C
17 Jan	13.7096	14.5189	16.0426	17.6471	22.1233	C
20Jan	14.3442	15.1908	16.7892	18.4684	23.5233	C
23Jan	15.4144	16.324	18.0483	19.8533	24.9233	C
26Jan	16.4359	17.4056	19.2501	21.1752	25.9233	C
29Jan	17.3391	18.3620	20.3128	22.3442	26.9233	C
1Feb.	18.3826	19.4669	21.5405	23.6947	28.7233	C

Date	TI (CM)	T2 (CM)	T3 (CM)	T4 (CM)	T5 (CM)	Stage
4 Feb	19.4812	20.6301	22.8329	25.1164	30.0233	C
7 Feb	20.4732	21.6804	23.9999	26.4002	32.0233	C
10Feb	21.3988	22.6604	25.0889	27.5982	33.5233	C
13Feb	22.8148	24.1598	26.7549	29.4308	35.5233	C
17Feb	24.0391	25.4561	28.1952	31.0151	37.0233	C
20Feb	25.7540	27.2719	30.2128	33.2344	38.7233	C
24Feb	26.6271	28.1964	31.3005	34.4308	40.3233	C
26Feb	28.4031	30.0770	33.3901	36.7298	42.7233	C
1Mar	29.3563	31.0863	34.5115	37.9634	43.7233	C
3Mar	31.0125	32.8322	36.4600	40.1067	46.2233	C
6Mar	32.6614	34.5781	38.3999	42.2406	48.7233	C
9Mar	33.6648	35.6405	39.5803	43.5391	51.2233	C
11Mar	35.2814	37.3522	41.4822	45.6311	52.9233	C
14Mar	37.2943	39.4834	43.8502	48.236	54.9233	C
18Mar	38.940	41.2263	45.7867	50.366	57.4233	C
21Mar	40.0079	42.3571	47.0431	51.7480	59.4233	D
23Mar	41.7825	44.2361	49.1309	54.0445	62.4233	D
26Mar	42.9645	45.4877	50.5215	55.5742	63.9233	D
28Mar	44.1456	46.7383	51.9111	57.1027	65.9233	D
30Mar	45.3767	48.0419	53.3595	58.6959	67.9233	D
1April	46.3852	49.1098	54.5460	60.0011	69.9233	D
3April	47.4656	50.2538	55.8171	61.3991	71.4233	D
5April	48.6511	51.5090	57.2118	62.9333	72.9233	D
7April	50.1864	53.1346	59.0180	64.9202	74.9233	D
9April	51.4523	54.4749	60.5073	66.5585	76.9233	D
11April	52.7449	55.8436	62.0281	68.2313	78.9233	D
13April	54.0936	57.2717	63.6149	69.9767	80.9233	D
15April	55.2466	58.4925	64.9714	71.4688	82.9233	D
17April	56.4586	59.7758	66.3973	73.0373	84.9233	D
19April	57.6280	61.0140	67.7731	74.5507	86.9233	D

Figure (5.6) shows accumulation of irrigation scheduling starting from planting date to the end of November including initial stage.

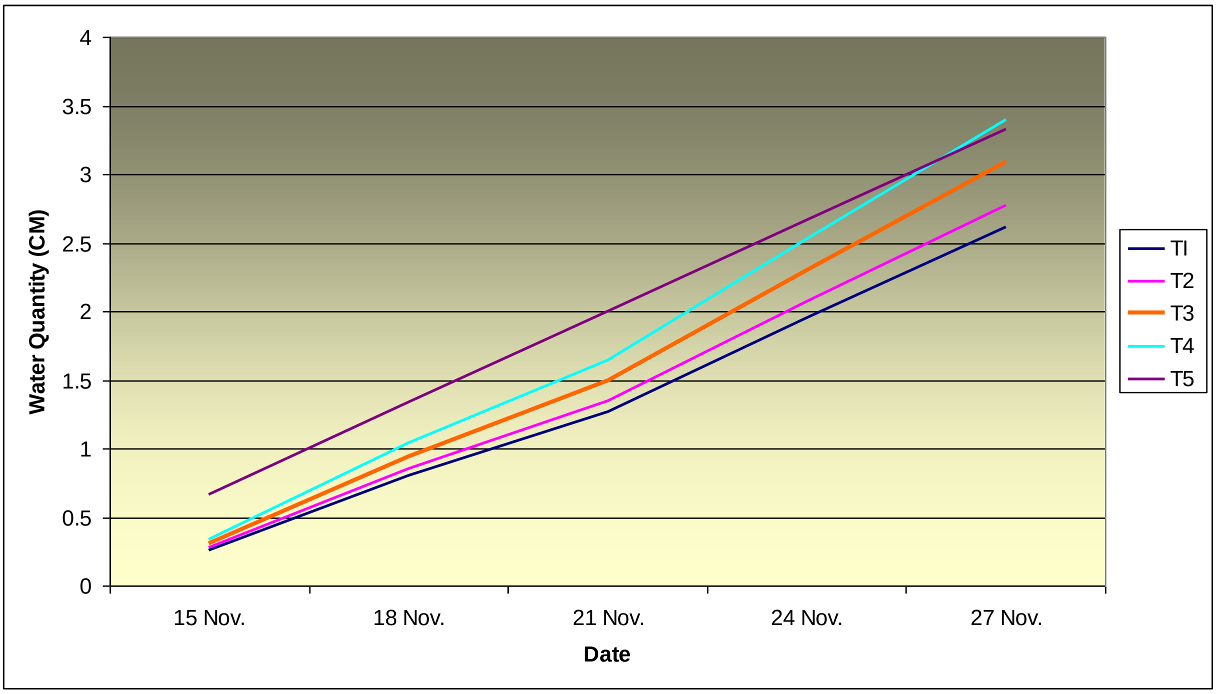


Figure5.6: Accumulation of irrigation scheduling

The difference between four trials (T1, T2, T3, T4) and T5 (farmer) reached maximum in 21th November at the end of initial stage. Starting from 27th Nov., the difference between four trails and T5 (farmer) decreased and accumulation of irrigation of T4 exceeded T5 (farmer), but T1, T2, T3 still lower than T5.

Figure 5.7 shows the accumulation of irrigation scheduling from beginning of December 2007 to 20th March 2008. This period is known as the development (B) and mid season (C). The difference between four trials T1, T2, T3, T4 and T5 (farmer) still increasing with irrigation time, which indicates that the farmer used more water in irrigation than any controlled trial .The difference between T2, T3, and T4 are relatively constant, while difference between T1 and T2 was the lowest due to the factor which used in multiple with ETc (Figure 5.7).

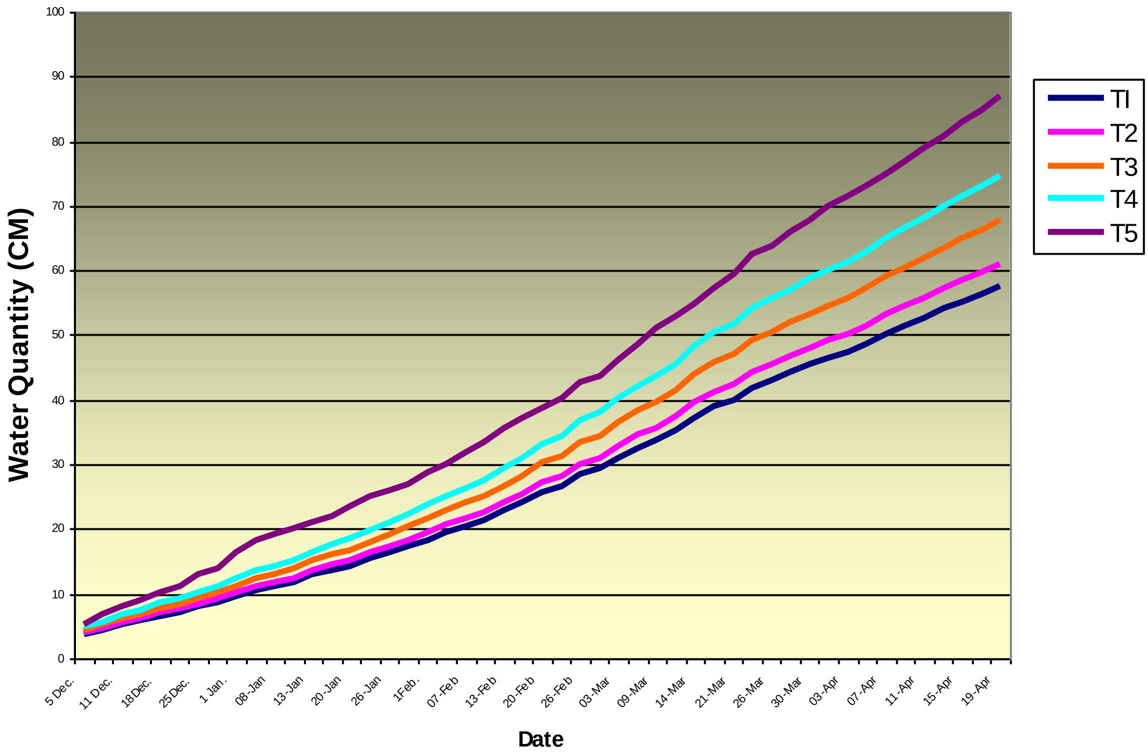


Figure5.7: Accumulation of irrigation scheduling

5.4 Production of Tomato

The first harvested day was on17th March 2008 after 130 days of planting which more than usual, because of very cold weather conditions prevailed in January. Maturity of the fruit at harvest time is important , the maturity degree depends on market needs , for local market the a red-fruited tomato is harvested, but for export the fruit harvested before it is fully developed with pink color to increase the resistance of tomato fruit in shipping . Harvest fruit in the early morning, when it is cool and when fruit temperature is not too high. it is essential that fruit be handled well at harvesting and transportation to the market. The production yields of tomato per each treatment were presented in Table (5.8).

Table 5.8: Production of Tomato

Date	TI (kg)	T2 (kg)	T3 (kg)	T4 (kg)	T5 (kg)
17/3/2008	48.730	64.200	43.790	53.280	40.629
21/3/2008	224.595	255.780	214.785	257.43	174.728
28/3/2008	292.125	286.980	295.368	218.975	279.300
5/4/2008	355.990	354.880	349.820	383.475	377.000
12/4/2008	339.060	377.300	294.222	262.400	307.600
20/4/2008	246.500	180.900	163.015	277.550	240.800
Total (kg)	1,507	1,520.04	1,361	1,453.11	1,420.056

Accumulation of the production as Figure (5.8) shows**,** T2 with total production of 1520 kg is the best productive trial, followed by T1 with 1507 kg , then T4 with 1453 kg , T5 (farmer) production is 1420 kg , and the T3 is the lowest productive line with 1361 kg.

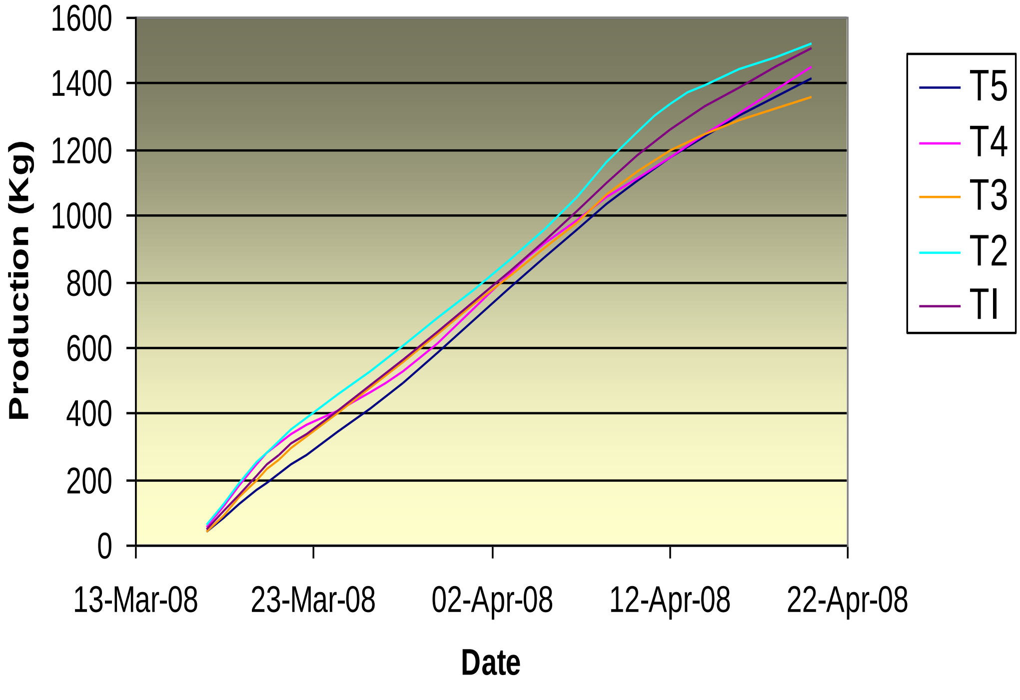


Figure 5.8: Accumulation of Production Tomato

While first line of T3 located closer to the door of the green house, it is affected by the frost during January month, also the not smooth elevation affect this area. It is expected that T3 should have higher yield betweenT2 and T4 without these problems.

5.5 Relation between production and water consumption

Water productivity or water use efficiency is the amount of the production of harvested crop in kg per the volume of irrigation water in cubic meter used in irrigation. Table (5.9) summarizes the relation between production and water consumption.

Table 5.9: Relationship between production and water consumption

Treatment	TI	T2	T3	T4	T5
∑Production (kg)	1507	1520.04	1361	1453.11	1420.056
%Prod.	20.75	20.94	18.74	20.01	19.56
∑Water Consumed(CM)	57.6280	61.0140	67.7731	74.5507	86.9233
% Water Consumed	16.57	17.54	19.48	21.43	24.98
Water productivity Kg/CM	26.15	24.91	20.08	19.49	16.33

It is clear from Table (5.9) that T2 more productive than other treatments, but less than T1 in term of water productivity. To evaluate which of these trials was the preferable, the economic value should be taken into consideration.

Figure 5.9 shows the percentage relationship between production and water consumption. It represents that T2 with 17.54% of total irrigation volume produced 20.94% of total production, while T5 used 24.98% of total water but produced only19.56% of the production, that indicates that T2 produced more from less water as shown in Figure (5.9).

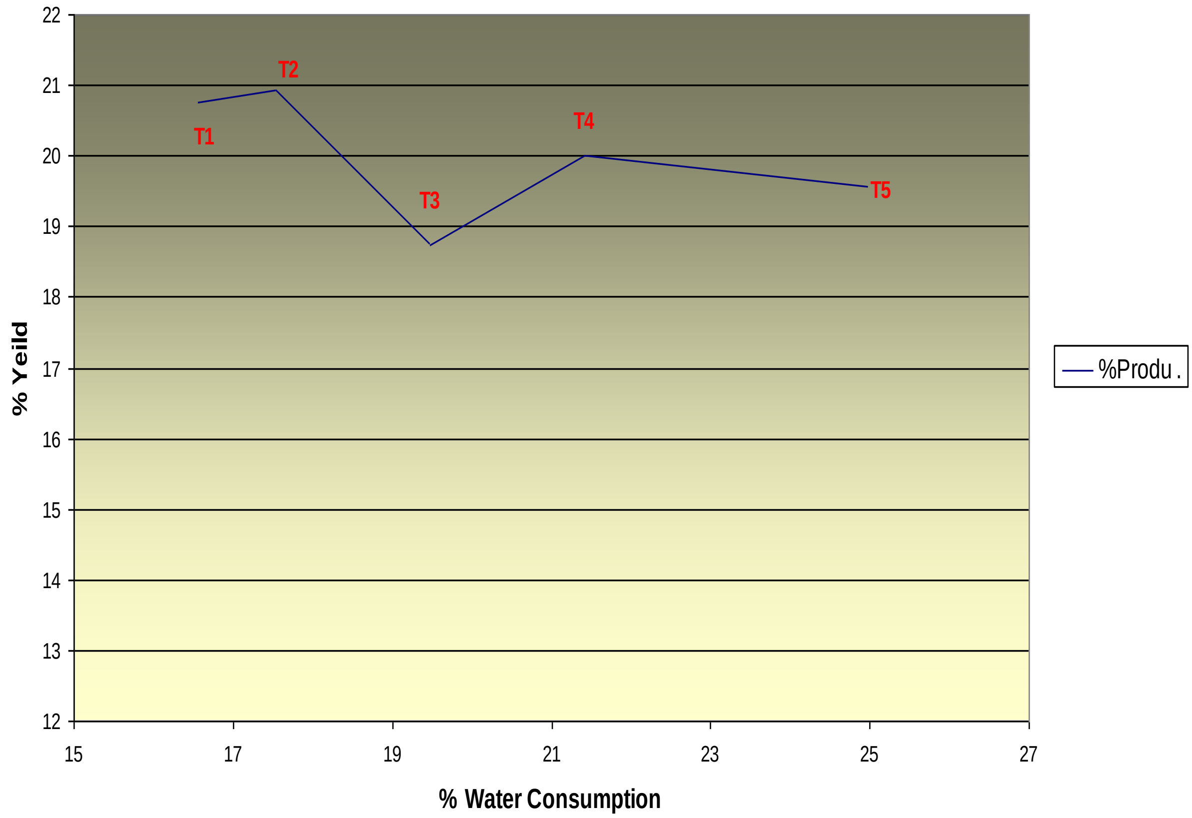


Figure 5.9: Percentage relationship between production and water consumption

As discussed before larger quantities of water can be saved, and the optimal water use is much lower than actual water applied by farmer. To see the effect of optimization water in irrigation: the main objective of this study, the water productivity should be taken into Consideration.

Figure (5.10) shows the water productivity of treatments. The water productivity of T1 is the highest with 26.15 kg/CM, followed by T2 with 24.91 kg/CM, T3 and T4, while T5 (farmer) is only 16.33 kg per cubic meter. Based on Ministry of Agriculture the average water productivity of tomato in Jericho district is 15 kg/CM. Our Investigation shows the productivity can reach more than15 kg per cubic meter.

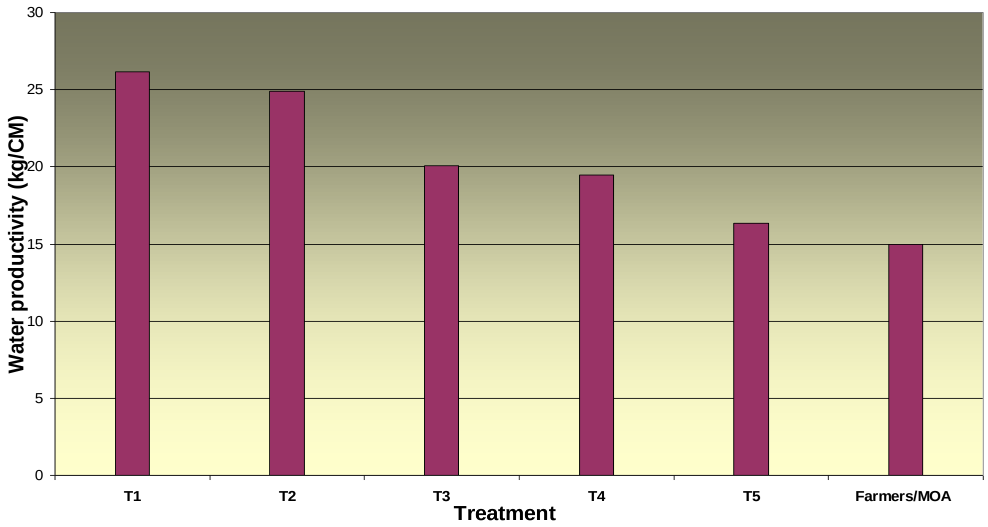


Figure 5.10: Water productivity

As seen in (Figure 5.10), the benefit of unit water in T1 reached to 160% of T5, and to 174% of average obtained by MOA.

Comparison results obtained from trials with farmer irrigation (T5) is presented in Table (5.10). All treatments gave more production with saving water, except T3 due to reasons mentioned before in page 64. Through this water management about 12.37% - 33.6% % of water can be saved, that can be used to expand agriculture area. Thus, good water management practices provide to maximize tomato production per unit land base. Maximum benefit from irrigation will be achieved only by adding proper amounts of water.

Table5.10: Percentage increasing of production and saving water related to T5

Treatment	**T1**	**T2**	**T3**	**T4**
%Increasing Production (related to T5)	6.123	7.04	-4.16	2.33
% Saving Water (related to T5)	33.66	29.81	22.031	12.37
%increase of agriculture area	33.7	29.8	22.0	14.2

By comparing the results of water consumed in irrigation which obtained from the experiment (Table 5.9) to average water used by farmers in irrigation of tomato under plastic house in Jericho district, which obtained by MOA, 1,200 CM/dunum was calculated for full growing season of about 250 days, extends from mid of September to end of May, so the results of trial were converted to 250 days per dunum (Table5.11).

Table 5.11: Percentage of saving water and increasing of agriculture area related to average water used (MOA)

Treatment	**T1**	**T2**	**T3**	**T4**	**T5**
Water volume(CM)	450.2	476.7	529.5	582.4	679.1
Production (ton)	11.77	11.88	10.63	11.35	11.09
% Saving Water (related to average water used)	62.5	60.3	55.9	51.5	43.4
%increase of agriculture area	166.7	151.7	126.6	106.0	76%

According to above table and related to average water used in irrigation tomato in Jericho distract, through water optimization used in experiment, T1 treatment gave maximum results in both water saving and ability to increasing agriculture area, 62.5% of water can be saved whereas 166.7% of agriculture area can be expanded. The production range between 10.63 ton in T3 to 11.88 ton in T2. The water amount, which is recommended by Technical Manual of PAPA project for cherry tomato is 700CM/season, which relatively meet the water which used by farmer (T5). Figure 5.11 summarizes the results of water used in irrigation by different sources with the water used in experiment.

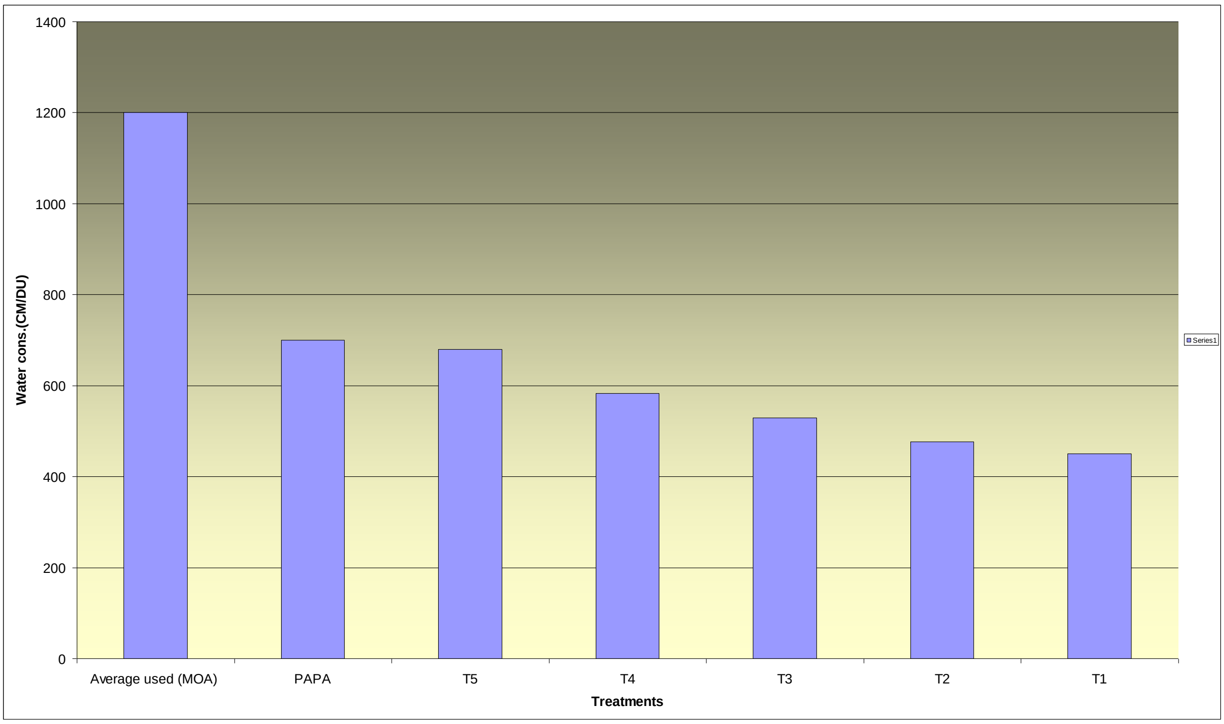


Figure 5.11: Water irrigation volume (CM/dunum) per season

5.6. Economic value

Economics plays important role in agriculture .This study includes the economic evaluation of tomato production in terms of both output and input values and net benefits for tomato under different treatments (Table 8.1). Output value is determined on basis of average prices of the products per dunum. Input value includes the costs of production per dunum such as labor, fertilizers, pesticides, seedlings, water, plastic, transportation, depreciation and marketing fees. Economic value is calculated for full-growing season per dunum, the production and water needs are shown in Table 7.13. The costs and prices were determined by PAPA Technical Manual for Export Cherry Tomato, 2008.

Table 8.1: Economic value for production tomato on different treatments under plastic houses.

Different cost expenses	**Unit**	**T1**	**T2**	**T3**	**T4**	**T5**
Fertilizer cost	NIS/Dunum	1,450	1,450	1,450	1,450	1,450
Water	NIS/Dunum	788	834	927	1019	1,188
Pesticides	NIS/Dunum	1,176	1,176	1,176	1,176	1,176
Land preparation	NIS/Dunum	185	185	185	185	185
Compost	NIS/Dunum	238	238	238	238	238
Plastic	NIS/Dunum	149	149	149	149	149
Seedlings	NIS/Seedling	1.5	1.5	1.5	1.5	1.5
Seedlings	NIS/Dunum	3,750	3,750	3,750	3,750	3,750
Bio bees	NIS/Dunum	525	525	525	525	525
Labor	Day/Dunum	250	250	250	250	250
Labor	NIS/Dunum	12,500	12,500	12,500	12,500	12,500
Marketing fees	NIS/Dunum	455	455	455	455	455
Transportation	NIS/Dunum	440	440	440	440	440
Packaging cartons	NIS/Dunum	4,120	4,185	3,721	3,973	3,882
Ties	NIS/Dunum	300	300	300	300	300
Depreciation	NIS/Dunum	2,576	2,576	2,576	2,576	2,576

Sub total cost	NIS/Dunum	**28,652**	**28,763**	**28,393**	**28,736**	**28,814**
Yield	Kg/Dunum	11,770	11,880	10,630	11,350	11,090
Price	NIS/Kg	4.8	4.8	4.8	4.8	4.8
Production value	NIS/Dunum	**56.496**	**57,024**	**51,024**	**54,480**	**53,232**
Net benefit	NIS/Dunum	**27,844**	**28,261**	**22,631**	**25,744**	**24,418**

As Table 8.1 is shown, T2 is the best according to economic value, followed by T1, T4, T5, and T3, that indicates the calculated of crop water requirement based on 90% ETc, and field efficiency 75% provide to the best results , which combined between better increasing production and optimization of water resources.

According to T2, there is 101,185 CM of water can be saved per season in 500 dunums of tomato green houses in Jericho district related to T5.

Chapter 6 Conclusions and Recommendations

6. Conclusions and Recommendations

■ Tomatoes grow very well on most mineral soils, but they prefer deep, well-drained sandy loams. Clay loam soil of pH 7.32 can be used for growing tomato but it is not the best. For increasing productivity in this type of soil, good practical management should be taken in consideration.

■ Different values of reference evapotranspiration (ET0) were calculated for Jericho area, e.g. ARIJ calculated ET0 in 1997, and Jericho Municipality with the help of ANERA calculated ET0 in 1998. In this research reference evapotranspiration (ET0) was obtained with reference to NCARTT for Al-Karamah station.

■ Quantity of irrigation by the farmer (T5) was the highest in the most times.

■ In all treatments, there are relatively increasing in irrigation amount from initial stage to mid growth stage, then relatively decreasing in the end stage.

■ The maturity degree depends on market needs, for local market the red-fruit tomato is preferred, but for export, the fruit picked before it is fully developed with pink color.

■ T2 of total production of 1520 kg is the best productive trial, followed by T1 with 1507 kg, then T4 with 1453 kg, T5 (farmer) production is 1420 kg, and the T3 is the lowest productive line with 1361 kg. T3 is affected by the frost, and the not smooth elevation.

■The optimal water use is much lower than actual water applied for irrigation higher quantities of water can be saved. Through this management about 12.37% - 33.6% % of water can be saved related to T5 (farmer irrigation) in experiment, a bit more related to PAPA technical manual, while 51.5%-62.5% of water can be saved related to average water used by farmers in Jericho district. This will cause a decrease in the water expense used by farmers, and increase in water quality and availability.

■ The water productivity of T1 was the best with 26.15 kg/CM , followed by T2 with 24.91 kg/CM, T3 with 20.08 kg/CM and T4 with 19.49 kg/CM, while T5 (farmer) is only 16.33 kg per cubic meter. The average water productivity in the district is 15kg/CM.

■ Through this water management the area of agriculture land could be increased from 14.2% to 33.7% % related to T5. However, while referring to the average of what farmers used in Jericho district , the agriculture land area could be enlarged from 76%-166.7%

■The T2, which based on 90%ETc, and field efficiency 75% provide the best results, according to economic value, then followed by T1, T4, T5, and T3. T2 can save more than 100,000CM of water per season in 500 du of tomato green houses in Jericho district related to T5.

Consequently, the following recommendations are presented:

■ Update calculation reference evapotranspiration (ET0) for all districts in Palestine by using modified Penman moneith equation, or by establish lysometer units.

■ Increase public knowledge about optimization of water and introducing its positive effect on agriculture and environment.

■ Encourage more studies which focus on optimization of irrigation water in different districts in Palestine.

■ Encourage planting of improved varieties with low crop water requirements and salt tolerant crops.

■Apply surface mulch with suitable width to cover roots area, which increases water efficiency by reducing evaporation.

■ Increase capacity building for farmers and provide more training programs in agriculture activities, irrigation practices and its impacts on environment.

■ Encourage more investments in agro-industries, such as tomato industry.

References

Abed Aziz A.(2008) : Technical Manual for Export Cherry Tomato. PAPA project, Ramallah, Palestine.

Abed Rabbo, A., Scarpa, D., Alfred, A., Qannam, Z., Abedul –Jaber Q., Younger, P. (1999): Springs in the West Bank, Water quality and chemistry. Palestinian Hydrology Group, Newcastle University and Bethlehem University, Palestine.

Agriculture and Rural Development, (2003): Commercial Greenhouse Tomato Production. (http://www.agric.gov.ab.ca/app21/ 20.11.2007)/

Ali, W. et.al, (2004): Hydrogeological Investigation on the Aquifers along the Jordan Rift Valley Escarpment". Department of Applied Geology, Karlsruhe University, German. (http://www.ipcri.org/watconf/papers/ali.pdf 11.3.2007)

Awartani H , Joudah S. (1991): Irrigated agriculture in the occupied Palestinian territories, Rural research center, An-Najah National University –Nablus, Palestine.

Ayers R., Westcot D. (1985): Water quality for agriculture. FAO irrigation and drainage paper 29, Rev.1, Rome, Italy.

British Columbia, Ministry of Agriculture, Food and Fishers (2001): Guide to irrigation system design with reclaimed water.

Brouwer C. Heibloem M., FAO (1986): Irrigation water management. Training Manual (FAO), no. 3, Rome, Prov. ed., 60 p. Italy

California Irrigation Management System (CIMIS), (2005): Evapotranspiration. , California Department of Water Resources, USA. (http://www.cimis.water.ca.gov/cimis/infoEtoOverview.js 20.3.2007).

Cardon, E. (2007): Salt-Affected Soils. Colorado State University Extension soils, U.S. Department of Agriculture. USA.

Danny, H., Federals, R, Mahbob A., Todd P. (1997): Efficiencies and water losses of irrigation system .Kansas State University .USA. File Code: Engineering 4-3 MS 5-97o3M. (http://www.oznet.ksu.edu/library/ageng2/mf2243.pdf, 20.05.2007)

Dehayr, R., Gordon, I., (2006): Irrigation water quality Salinity and soil structure stability. Department of Natural Resources and Water, State of Queensland.

Derrel L., James R.(1993): Irrigation water management. National Engineering Hand Book, chap.2. Technical Publishing Team, SCS, Washington, PP.1-129.

Dorota, Z. (1997): Irrigating With High Salinity Water. Institute of Food and Agricultural Sciences, University of Florida.

Doorenbos, J., Puritt W. (1975). Guidelines for prediction of crop water requirement. FAO Irrigation and Drainage Paper No.24. Rome, Italy

Efrat, F., et.al (2003): The origin and mechanisms of Stalinization of the Lower Jordan River. Elsevier Ltd, USA .Vol. 68, No.9, pp. 1989–2006.

FAO, Food and Agriculture Organization, FAO (1984) Drainage Paper 24: Crop water requirements. FAO (1985), Drainage Paper 29 Rev: Irrigation and Water quality for agriculture. FAO (1998), Drainage Paper 56: Crop evapotranspiration, Guidelines for computing crop water Requirements. Rome, Italy

FAOSTATE, 2004: FAOSTAT is a statistical database of FAO that currently contains more than 3 million time-series records. Agricultural production indices (1961 to 2004). Statistics Division, FAO, Rome, Italy.

Harry, A. Mills (2000): Vegetable Crop. College of Agricultural and Environmental Sciences Department of Horticulture, University of Georgia, USA.

Hrimat N. (2006) Agro-Marketing System in the Jordan Valley, Constraints and

Potentials.ARIJ, Jerusalem, Palestine.

Jericho Meteorological station, (2005): Climatic data collected from the Jericho Meteorological station.
Jodah, Sh. (2005): Guidelines program for tomato under plastic houses. Ministry of Agriculture, Ramalah, Palestine.

Issac J. (1995): Environmental Profile for the West Bank, Jericho District. ARIJ , Jerusalem.

Issac J., Sabah W. (1998): Water resources and irrigated agriculture in the West Bank. ARIJ, Jerusalem.

Katerji, N.(1998): Response of tomatoes, a crop of indeterminate growth, to soil salinity. Agricultural Water Management, Station de Bioclimatology, 78850 Thiverval-Grignon, France. PP 120-134.

Klocke, Norman L., Fischbach, P. (1998): Estimating Soil Moisture by Appearance and Feel. Publication G84-690-A,, Nebraska Cooperative Extension Service

Laham S. (2007): Average water used by farmers in irrigation tomato in Jordan Valley. Ministry of Agriculture, Department of vegetables. Personal communication.

L. Miles, D., and Broner, (2006): Estimating Soil Moisture. Colorado State University, U.S. Department of Agriculture.
(http://www.ext.colostate.edu/pubs/CROPS/04700.html 18.12.2007)

Martin, B., and Joseph, G. (2004): Groundwater flow and transport model of the Jericho area. Center of Applied Geosciences, University of Tubingen. Version 2004.1.1,PP 1-10.

Ministry of Agriculture (MOA), Palestinian Central Bureau of Statistics (PCBS), (2001-2006): Statistical data about area, and production for crops. Ramallah, Palestine.

Marie, A. Vengosh, A. (2001): Sources of salinity in ground water from Jericho area, Jordan valley. J.Ground Water 39, PP 240–248. Department of Applied Earth and Environmental Sciences, Al Quds University, Jerusalem, P.O. Box 20002, Palestinian Authority. marei@planet.edu.

Papadopoulos A.P. (1991): Growing Greenhouse Tomatoes. Minister of Supply and Services Canada, Agriculture Canada Publication 1865/E, Onttario, Harrow, Canada. PP 65-75.

PWO, Palestinian Water Authority (2002): Wells of the west Bank, Water Data Bank Section. Ramallah, Palestine.

Rofe and Raffty Consulting Engineers, (1963): Geological and Hydrological report. Westminester, London (for the Central Water Authority of Jordan).

Reagan, M., (1994): Best Management Practices for Irrigation Management. Colorado State University. (http://www.ext.colostate.edu/Pubs/crops/xcm173.pdf 15.6.2007)

Richard, G., Luis, S. (2006): Crop Evapotranspiration -guidelines for computing crop water requirements. FAO irrigation and drainage paper 56.Utah State University Logan, Utah, U.S.A., FAO, Rome.

Said, A., (2004): Minimizing the Multi-National Water Conflicts in the Jordan River Basin Countries by Shifting Cropping Patterns. Antalya, Turkey

Savva, P., Frenken, K. (2002): Crop water requirements and irrigation scheduling. irrigation. Manual Module 4 FAO Sub-Regional Office for East and Southern Africa, Harare.

Schneekloth J., Bauder, T, (2007): Measurement of Soil Moisture. Colorado State University Extension soils, U.S. Department of Agriculture. USA.

(http://www.ext.colostate.edu/drought/soilmoist.html 5/11/2007)

Silva J., and Uchida R., (2000): Plant Nutrient Management in Hawaii's Soils, approaches for tropical and sub tropical agriculture. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa.

Steve, E. (2006): Crop Water Use Measurement and Estimation in Support Irrigation Management. USDA-ARS, Conservation & Production Research Laboratory, Bushland, Texas. Workshop on Irrigation Management and Scientific Writing, NCARTT, Amman, Jordan, 10-14 December 2006.

Steven, A., Jeffrey, K., Teresa, O. (2003): Handling Florida Vegetables Series - Round and Roma Tomato Type's .University of Florida. (http://edis.ifas.ufl.edu/VH079 10.1.2008).

Thomas, W. Ley, Robert G. Stevens, Richard R. (1994): Soil water Monitoring and Measurements. Washington State University Cooperative Extension. A pacific Northwest Publication - Washington.

Wolfer, J. (1998): Hydrogeological investigations along the Jerusalem- Jericho transsect (wadi el Qilt), Israel/ Westbank. Master thesis University of Karlsruhe, 106 p

Whiting, D. Tolan R., Mecham, B., M. Bauer, (2005): Soil Water Holding Capacity and Irrigation Management. Colorado State University, Copyright © 2002-2006.

Colorado State University Extension, US Department of Agriculture, Colorado, U.S.A.

10.8.2007) (http://www.ext.colostate.edu/mg/files/gardennotes/261 SoilWater.html -

APPENDICES

Appendix, 1: Daily ET_0, K_C, ET_C and stage for tomato in Jericho area

Date	ET_0	K_C	ET_C	Stage
8 /11/ 2007	2.1243	0.45	0.9559	A
9/11/2007	1.9798	0.45	0.8909	A
10/11/ 2007	2.1905	0.45	0.9857	A
11/11/ 2007	1.8832	0.45	0.8474	A
12/11/ 2007	2.03	0.45	0.9135	A
13/11/ 2007	1.8503	0.45	0.8326	A
14/11/ 2007	1.947	0.45	0.87615	A
15/11/ 2007	1.9267	0.45	0.8670	A
16/11/ 2007	1.7378	0.45	0.7820	A
17/11/ 2007	1.9643	0.45	0.8839	A
18/11/ 2007	2.0558	0.45	0.9251	A
19/11/ 2007	1.7882	0.45	0.8047	A
20/11/ 2007	2.0868	0.45	0.9391	A
21/11/ 2007	1.6727	0.45	0.7527	A
22/11/ 2007	1.7313	0.45	0.7791	A
23/11/ 2007	1.6638	0.45	0.7487	A
24/11/ 2007	1.6755	0.475	0.7959	B
25/11/ 2007	1.7238	0.49	0.8469	B
26/11/ 2007	1.7065	0.5	0.8533	B
27/11/ 2007	1.6332	0.52	0.8493	B
28/11/ 2007	1.5728	0.53	0.8336	B
29/11/ 2007	1.3972	0.55	0.7685	B
30/11/ 2007	1.5025	0.56	0.8414	B
1/12/2007	1.4576	0.58	0.8454	B
2/12/2007	1.2874	0.59	0.7596	B
3/12/2007	1.5596	0.61	0.9514	B
4/12/2007	1.3572	0.625	0.8482	B
5/12/2007	1.264	0.64	0.752	B

Date	ET_0	K_C	ET_C	Stage
6/12/2007	1.3344	0.66	0.827	B
7/12/2007	1.3375	0.67	0.843	B
8/12/2007	1.2396	0.69	0.8553	B
9/12/2007	1.8608	0.70	1.303	B
10/12/2007	1.1304	0.72	0.814	B
11/12/2007	1.2062	0.74	0.8926	B
12/12/2007	1.1502	0.75	0.8627	B
13/12/2007	1.2934	0.76	0.983	B
14/12/2007	1.2916	0.78	1.007	B
15/12/2007	0.98	0.80	0.784	B
16/12/2007	1.2782	0.82	1.0481	B
17/12/2007	1.2046	0.835	1.0058	B
18/12/2007	1.3062	0.85	1.1103	B
19/12/2007	1.2238	0.86	1.0525	B
20/12/2007	1.0252	0.88	0.9022	B
21/12/2007	1.0897	0.895	0.9753	B
22/12/2007	1.1508	0.91	1.0473	B
23/12/2007	0.878	0.925	0.8122	B
24/12/2007	1.084	0.94	1.01896	B
25/12/2007	0.9316	0.95	0.8850	B
26/12/2007	0.8514	0.965	0.8216	B
27/12/2007	1.0942	0.98	1.0723	B
28/12/2007	1.0874	0.995	1.08196	B
29/12/2007	1.1248	1.01	1.2605	B
30/12/2007	1.3868	1.03	1.4284	B
31/12/2007	1.037	1.04	1.0785	B
1/1/2008	1.1597	1.05	1.2177	B
2/1/2008	1.1377	1.07	1.2173	B
3/1/2008	1.2003	1.08	1.2963	B
4/1/2008	1.1715	1.10	1.2887	B
5/1/2008	1.23	1.11	1.3653	B

Date	ET_0	K_C	ET_C	Stage
6/1/2008	1.1177	1.125	1.2574	B
7/1/2008	1.0912	1.14	1.2439	B
8/1/2008	0.924	1.15	1.0626	C
9/1/2008	0.9908	1.15	1.1394	C
10/1/2008	1.008	1.15	1.1592	C
11/1/2008	1.201	1.15	1.3812	C
12/1/2008	1.037	1.15	1.1926	C
13/1/2008	1.114	1.15	1.2811	C
14/1/2008	1. 1162	1.15	1.2836	C
15/1/2008	1.093	1.15	1.2695	C
16/1/2008	1.1177	1.15	1.2854	C
17/1/2008	1.155	1.15	1.3285	C
18/1/2008	1.2368	1.15	1.4223	C
19/1/2008	1.1905	1.15	1.3691	C
20/1/2008	1.0877	1.15	1.2509	C
21/1/2008	0.889	1.15	1.0224	C
22/1/2008	0.7615	1.15	0.8377	C
23/1/2008	1.5248	1.15	1.7535	C
24/1/2008	1.5857	1.15	1.8236	C
25/1/2008	1.4495	1.15	1.6669	C
26/1/2008	1.7047	1.15	1.9602	C
27/1/2008	1.3923	1.15	1.6011	C
28/1/2008	1.2575	1.15	1.446	C
29/1/2008	1.2817	1.15	1.47395	C
30/1/2008	1.2305	1.15	1.4151	C
31/1/2008	1.3383	1.15	1.5390	C
1/2/2008	1.5798	1.15	1.8168	C
2/2/2008	1.3785	1.15	1.5853	C
3/2/2008	1.4898	1.15	1.7133	C
4/2/2008	1.575	1.15	1.8113	C
5/2/2008	1.628	1.15	1.8722	C

Date	ET_0	K_C	ET_C	Stage
6/2/2008	1.4797	1.15	1.7017	C
7/2/2008	1.4502	1.15	1.6627	C
8/2/2008	1.4253	1.15	1.6391	C
9/2/2008	1.353	1.15	1.5559	C
10/2/2008	1.2623	1.15	1.4516	C
11/2/2008	1.4213	1.15	1.6349	C
12/2/2008	1.2615	1.15	1.4507	C
13/2/2008	1.4808	1.15	1.7029	C
14/2/2008	1.759	1.15	2.0229	C
15/2/2008	1.5232	1.15	1.7517	C
16/2/2008	1.2732	1.15	1.4642	C
17/2/2008	1.649	1.15	1.8964	C
18/2/2008	1.7223	1.15	1.9806	C
19/2/2008	1.8472	1.15	2.1243	C
20/2/2008	1.6618	1.15	1.9111	C
21/2/2008	1.8955	1.15	2.1798	C
22/2/2008	1.8335	1.15	2.1085	C
23/2/2008	1.9192	1.15	2.2071	C
24/2/2008	2.2168	1.15	2.5493	C
25/2/2008	1.7240	1.15	1.9826	C
26/2/2008	1.4793	1.15	1.7012	C
27/2/2008	1.7708	1.15	2.0364	C
28/2/2008	2.1437	1.15	2.4653	C
29/2/2008	2.177	1.15	2.5036	C
1/3/2008	2.177	1.15	2.5036	C
2/3/2008	1.8862	1.15	2.1691	C
3/3/2008	2.359	1.15	2.7129	C
4/3/2008	2.3128	1.15	2.6597	C
5/3/2008	2.3878	1.15	2.74597	C
6/3/2008	2.6028	1.15	2.9932	C
7/3/2008	2.3227	1.15	2.6711	C

Date	ET_0	K_C	ET_C	Stage
8/3/2008	2.1030	1.15	2.4185	C
9/3/2008	2.0910	1.15	2.4047	C
10/3/2008	2.1858	1.15	2.5137	C
11/3/2008	2.5263	1.15	2.9052	C
12/3/2008	2.1355	1.15	2.4558	C
13/3/2008	2.2290	1.15	2.5634	C
14/3/2008	2.1393	1.15	2.4602	C
15/3/2008	2.0151	1.15	2.3174	C
16/3/2008	2.2073	1.15	2.5384	C
17/3/2008	2.2183	1.15	2.5510	C
18/3/2008	2.6012	1.15	2.9914	C
19/3/2008	2.3293	1.15	2.6787	C
20/3/2008	2.0858	1.15	2.3987	C
21/3/2008	2.2555	1.141	2.5735	D
22/3/2008	2.6083	1.131	2.9500	D
23/3/2008	2.4508	1.122	2.750	D
24/3/2008	2.6237	1.111	2.915	D
25/3/2008	2.7582	1.10	3.034	D
26/3/2008	2.7133	1.09	2.9575	D
27/3/2008	2.6267	1.08	2.8368	D
28/3/2008	2.6927	1.07	2.8812	D
29/3/2008	2.7440	1.06	2.9086	D
30/3/2008	3.0183	1.05	3.1692	D
31/3/2008	2.7433	1.045	2.8667	D
1/4/2008	2.7730	1.035	2.8700	D
2/4/2008	2.0212	1.026	2.0738	D
3/4/2008	2.8058	1.016	2.8507	D
4/4/2008	2.4310	1.006	2.4456	D
5/4/2008	2.5652	0.997	2.5575	D
6/4/2008	3.2967	0.987	3.2538	D
7/4/2008	3.9732	0.978	3.8858	D

Date	ET_0	K_C	ET_C	Stage
8/4/2008	3.7605	0.968	3.6402	D
9/4/2008	3.1632	0.958	3.0303	D
10/4/2008	3.3600	0.949	3.1752	D
11/4/2008	3.1993	0.939	3.0041	D
12/4/2008	3.5832	0.930	3.3324	D
13/4/2008	3.6315	0.920	3.3410	D
14/4/2008	3.5940	0.910	3.2705	D
15/4/2008	3.5517	0.900	3.1965	D
16/4/2008	2.7558	0.891	2.4554	D
17/4/2008	3.3605	0.882	2.9640	D
18/4/2008	3.4143	0.872	2.9773	D
19/4/2008	3.4992	0.862	3.0163	D
20/4/2008	3.1955	0.85	2.7162	D

A: Initial period, B: Crop development period, C: Mid season period, D: Late season period. ET0: Reference evapotranspiration Kc: Crop coefficient ETc: Crop water requirement

Appendix 2

Appendix, 2: Irrigation scheduling for TI, T2, T3, T4, T5 and Interval days

Date	TI 85% ETc	T2 90%ETc	T3 100%ETc	T4 110%ETc	T5 Farmer	Interval days
15 Nov.	0.2584	0.27355	0.3040	0.3344	0.666	7
18Nov.	0.5445	0.5765	0.6405	0.7046	0.666	3
21Nov.	0.4652	0.4926	0.5473	0.6020	0.666	3
24Nov.	0,6825	0.7226	0.8029	0.8832	0.666	3
27Nov.	0.6717	0.7112	0.7903	0.8693	0.666	3
1 Dec.	0.6945	0.7354	0.8171	0.8988	1.000	4
5 Dec.	0.4941	0.5232	0.5813	0.6394	1.000	4
8 Dec.	0.6064	0.6421	0.7134	0.7847	1.600	3
11 Dec.	0.7640	0.8089	0.8987	0.9888	1.1933	2
15 Dec.	0.5789	0.6129	0.6811	0.7492	1.000	4
18Dec.	0.8242	0.8727	0.9696	1.0666	1.000	3
22Dec.	0.5872	0.6218	0.6908	0.7599	1.000	4
25Dec.	0.7876	0.8340	0.9266	1.0193	1.800	3
29 Dec.	0.8454	0.8951	0.9042	0.9946	1.000	4
1 Jan.	0.7612	0.8059	0.8955	0.9851	2.900	3
4 Jan	1.0517	1.1136	1.2373	1.3610	1.600	3
8 Jan	0.4492	0.4756	0.5285	0.5813	1.000	4
10Jan	0.7615	0.8063	0.8959	0.9855	1.000	2
13Jan	1.0445	1.1059	1.2288	1.3517	1.000	3
17 Jan	0.8405	0.8899	0.9888	1.0877	1.000	4
20Jan	0. 6346	0.6719	0.7466	0.8213	1.400	3
23Jan	1.0702	1.1332	1.2591	1.3849	1.400	3
26Jan	1.0215	1.0816	1.2018	1.3219	1.000	3
29Jan	0.9032	0.9564	1.0627	1.169	1.500	3
1Feb.	1.0435	1.1049	1.2277	1.3505	1.300	3
4 Feb	1.0986	1.1632	1.2924	1.4217	1.300	3
7 Feb	0.9920	1.0503	1.1670	1.2838	2.000	3

Date	TI 85% ETc	T2 90%ETc	T3 100%ETc	T4 110%ETc	T5 Farmer	Interval days
10Feb	0.9256	0.9800	1.089	1.198	1.500	3
13Feb	1.416	1.4994	1.6660	1.8326	2.000	3
17Feb	1.2243	1.2963	1.4403	1.5843	1.500	4
20Feb	1.7149	1.8158	2.0176	2.2193	1.700	3
24Feb	0.8731	0.9245	1.0877	1.1964	1.600	4
26Feb	1.776	1.8806	2.0896	2.299	2.400	2
1Mar	0.9532	1.0093	1.1214	1.2336	1.000	4
3Mar	1.6562	1.7536	1.9485	2.1433	2.500	2
6Mar	1.6489	1.7459	1.9399	2.1339	2.500	3
9Mar	1.0034	1.0624	1.1804	1.2985	2.500	3
11Mar	1.6166	1.7117	1.9019	2.0920	1.500	2
14Mar	2.0129	2.1312	2.3680	2.6049	2.000	3
18Mar	1.6460	1.7429	1.9365	2.130	2.500	4
21Mar	1.0679	1.1308	1.2564	1.3820	2.000	2
23Mar	1.7746	1.8790	2.0878	2.2965	3.000	2
26Mar	1.1820	1.2516	1.3906	1.5297	1.500	3
28Mar	1.1811	1.2506	1.3896	1.5285	2.000	2
30Mar	1.2311	1.3036	1.4484	1.5932	2.000	2
1April	1.0085	1.0679	1.1865	1.3052	2.000	2
3April	1.0804	1.1440	1.2711	1.3980	1.500	2
5April	1.1855	1.2552	1.3947	1.5342	1.500	2
7April	1.5353	1.6256	1.8062	1.9869	2.000	2
9April	1.2659	1.3403	1.4893	1.6383	2.000	2
11April	1.2926	1.3687	1.5208	1.6728	2.000	2
13April	1.3487	1.4281	1.5868	1.7454	2.000	2
15April	1.1530	1.2208	1.3565	1.4921	2.000	2
17April	1.2120	1.2833	1.4259	1.5685	2.000	2
19April	1.1694	1.2382	1.3758	1.5134	2.000	2