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Optimization of Using Water Resources in Irrigation of Cucumber (*Cucumis sativus*) in Jericho Area Jordan Valley/ Palestine

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Optimization of Using Water Resources in Irrigation of Cucumber (*Cucumis sativus*) in Jericho Area Jordan Valley/ Palestine

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Dedication

To the all pillars of my life: My family, my parents, and my friends. Without you, my life would fall apart. I might not know where the life's road will take me, but walking with their support, through this journey has given me strength.
My wife and my kids, you are everything for me, without your love and understanding I would not be able to make it.
Mom, you have given me so much, thanks for your faith in me, and for teaching me that I should never surrender.
Daddy, you always told me to "reach for the stars." I think I got my first one. Thanks for inspiring my love for graduate study.
My friends who supported and encouraged me in my study especially those who are absent for ever (***Taleb and Abedal-Ruhman***)and never see my happiness to over my study.

Mohammad Omar Ahmad Shakarneh

Declaration:

I Certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Signed…………………………

Mohammad Omar Ahmad Shakarneh

Date:11/6/2008

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Abstract

The water scarcity in the region is available in the area since many decades due to the lack of sustainable water resources and rainfall fed, which consider as the main source of water in the area which fed the groundwater and springs.

Our country is a development country and depends mainly on both irrigated and rain fed agricultural sector. The agricultural sector is consumed more than tow third of the water resources. So the research proposed a method to quantize the water requirement in the irrigation of cucumber crops in Jericho.

Hence climate of Jericho is suitable for any off season crop ,so it was selected to apply the experiment in the months of December of 2007 and January, February and March of 2008 with duration of 130 days, in order to determine the optimized value of water consumed by cucumber crop in the greenhouses.

The main aim of the study was to optimize the use of water resources in cucumber irrigation. Crop water requirement for cucumber in greenhouse were investigated in Jericho/Jordan valley. The actual water requirement for cucumber was estimated by using evapotranspiration estimation through applied the FAO procedure which depends on the equation: Etc = Kc * Eto.

Where Etc is water requirement, Kc is the adjusted crop coefficient for cucumber in greenhouses and Eto is the daily reference evapotranspiration, which was measured in al Karamah station for grass. The values are used after taking the average daily values of Eto through December, January, February and march months in the last five years.

The experiment designed to construct five treatments (T1, T2, T3, T4 and T5) consist of three replicates distributed randomly. Four of them controlled by certain percent of reference evapotranspiration (Eto) (80% Eto, 90% Eto, 100% Eto and 110% Eto) from T1 to T4 respectively to determine water volume delivered to each treatment. The 5th was used

as control treatment through delivered water by mulch factor was taking in consideration, in addition the use drip irrigation system.

The greenhouse environment was investigated to support the crop cultivation, water delivered for each treatments measured by using water flowmetr and cucumber product was weighted in each harvest case.

The results proved that T4 with 110% Eto had the baggiest production and saving more than 36% of water consumed by the farmer method.

The water use efficiency (WUE) was calculated and compared the production of treatments with water consumed and found that T5 had the value of 35.6 kg per cubic meter of water consumed, while other treatment from T1 to T4 had the values 69.1, 65.3, 56.3 and 57.1 respectively. Mathematical second order polynomials have been verified related production and water consumed by the age of plant in days for each treatment. One of the benefits of the results that farmer can save from 36% to 53% of using water which can be used in cultivation land expanding and increasing productivity or in other useful way to sustain and improve the Palestinian daily life. Many recommendations were subjected such as further researches must be done in different condition and the necessity to train and rehabilitate farmers to be more environmentally awareness in dealing with fertilizers and pesticides ,use efficient methods in saving water such as greenhouses ,mulches, schedule irrigation and applied the method used in this research .so farmer can increase the productivity with less water consumed and protect the environment and will increase the farmer income and improve the socioeconomic level of the society.

ملخص : ـ

إن ظاهرة ندرة المياه وقلة مواردها الموجودة في منطقتنا منذ القدم وذلك لافتقار المنطقة إلى المصادر المائية الدائمة وشح مياه الأمطار التي تعتبر الرافد الرئيسي لمصادر المياه في بلادنا حيث تعتمد اعتماداً يكاد يكون كلياً على المياه الجوفية والينابيع .

وبما أن بلادنا من المناطق النامية والتي تعتمد في اقتصادها على الزراعة بشقيها البعلي والمروي بشكل رئيسي ، وأن الزراعة تستهلك أكثر من ثلثي مصادر المياه ، لذلك جاء هذا البحث كمحاولة جادة لتحديد كمية المياه التي تصرف في عملية الري لأحد محاصيل الخضروات ألا وهو الخيار .

وقد اختيرت منطقة أريحا لتطبيق التجربة وذلك خلال الأشهر (كانون أول/ 2007-و كانون ثاني- وشباط وآذار من عام 2008) وعلى مدى 130 يوما لتحديد القيمة المثلى لكمية الماء اللازمة لري الخيار في البيوت البلاستيكية ، علماً أن هناك العديد من الدراسات التي تحدثت عن كمية المياه المستهلكة في ري الخيار والتي قد تكون في معظمها تقديراً نظرياً وليس عملياً لذلك احتوت على أرقام تكاد تكون مبالغ فيها .

وعند تطبيق التجربة والتي صممت باستخدام نظام الري بالتنقيط وذلك بالاعتماد على تحديد كمية مياه الري اللازمة لنبات الخيار في منطقة الأغوار باستخدام أسلوب التقدير بواسطة عملية النتح المرجعية(Reference Evapotranspiration:Eto) المعتمدة كأساس في احتساب كمية الماء اللازمة للري والمقاسة في محطة الكرامة في الأغوار الأردنية بعد اخذ معدل قيم (Eto) اليومية خلال اشهر تطبيق التجربة لمدة خمس سنوات متتالية وبإيجاد قيمة ثابت المحصول المعدل(Kc) بالنسبة للبيوت البلاستيكية ، حيث تم احتساب كمية مياه الري اليومية اللازمة لنبات الخيار في أيام التجربة . وذلك بتطبيق المعادلة التالية المعتمدة في منظمة الأغذية والزراعة العالمية (FAO):-

$$\mathbf{Etc = Kc \times Eto}$$

كمية مياه الري اليومية للمحصول = ثابت المحصول المعدل x معدل قيمة النتح المرجعية

وقدنفذت التجربة والتي طبقت عن طريق تزويد وحدات تم اختيارها عشوائي ا لأحد البيوت البلاستيكية لنبات الخيار بنسب مئوية متفاوتة هي 80% Eto , 90 % Eto ، 100% Eto ، 110% Eto، ووحدة أخرى ضابطة خاصة بالمزارع ليتم ريها بطريقته الخاصة .

وعند تطبيق قيم الري التي كانت تضبط بعدادات مياه خاصة بنسبها المئوية السابقة ومقارنة الكميات المستهلكة مع كمية الإنتاج تبين أن الوحدة ذات النسبة 110% Eto كانت أكثر إنتاجا للمحصول وقد قلت الكمية المروية فيها بنسبة تزيد عن 36% من كمية الماء التي تم ريها لمحصول المزارع وذلك تحت نفس الظروف الزراعية لجميع وحدات المحصول المعتمدة في التجربة، وعليه فإن استخدام هذا الأسلوب سيكون مثمرا وموفرا للمياه وذو فاعلية عالية في الإنتاج (عشرة طن للدنم الواحد) و سيساهم في زيادة رقعة المساحة المزروعة بنبات الخيار كذلك بينت التجربة ان إنتاج الذروة لنبات ا لخيار يكون في نفس الوقت مهما كانت كمية المياه المروية له .

وقد كانت الكمية المستهلكة من المياه في عملية الري تقل بكثير عما هو منشور في بعض الأبحاث المحلية ،وكان من توصيات الدراسة ضرورة الاهتمام بإرشاد وتأهيل المزارع وتهيئته ليصبح واعيا من ناحية بيئية من حيث استخدام الأسمدة والمبيدات وتأهيله ليصبح قادراً على توظيف الطرق الفاعلة في توفير المياه في مجال الري مثل الطريقة التي اعتمدت في هذا البحث ، وإتباع الطرق الحديثة في الزراعة من حيث استخدام البيوت البلاستيكية والري بالتنقيط واستخدام الملش واعتماد اسلوب الجدولة في الري .فان مثل ذلك سيؤدي وحسب التجربة إلى توفير أكثر من ثلث المياه المستهلكة في الري وزيادة في إنتاجية المحصول وحماية البيئة من التلوث وخاصة من الأسمدة والمبيدات.

حيث يوظف الفائض من المياه الموفرة في مجالات أخرى نحن بحاجة ماسة إليها مثل زيادة الرقعة المروية وبعض الاستخدامات الضرورية لبيئة آمنة ومجتمع صحي متطور .

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Abbreviations:

ARIJ	Applied Research Institute of Jerusalem
AWC	available water capacity
BD	bulk density
CM/donum	cubic meter per donum
CPE	cumulative pan evaporation
CWSI	crop water stress index
DAT	days after transplant
DSB	dead sea basin
EC	electrical conductivity
Etc	reference evapotranspiration
Eto	crop evapotranspiration
FAO	food and agriculture organization of the united nation
FC	field capacity
GHs	greenhouses
IW	irrigation water
IWUE	irrigation water use efficiency
Kc	crop coefficient
L./hour	liter per hour
MCM	million cubic meter
MCM/yr	million cubic meter per year
MERIMIS	Middle East Regional Irrigation Management Information System
mg/l	milligram per liter
m^3/hr	cubic meter per hour
mm/year	millimeter per year
mS/m	millisenens per meter
NCARTT	National Center for Agricultural Research and Technology Transfer
NRC	National Research Council
OM	organic matter
PCBS	Palestinian Central Bureau of Static
pH	potential of hydrogen is a measure of the acidity or alkalinity of a solution
PIALES	The Palestinian Institute for Arid Land and Environmental Studies
R	replicate
SAR	Sodium adsorption ratio
SSP	Soluble sodium percentage
T	treatment
TDS	total dissolved salt
t/ha	ton per hectare
Wca	water capitalization coefficients
WB.	West bank
WP	welting point
WUE	water use efficiency
W/W	weight by weight
Ya	yield

Chapter : 1

1: Introduction

Palestine is characterized by semi-arid conditions with varied amounts and distribution of rainfall. Water shortage is the most important factor constraining agricultural production all over the world. The irrigated area in the Jordan valley is the spinal cord for the agricultural sector. Even small savings over irrigation methods are thus of great value and can be diverted into domestic or agricultural use by expanding the irrigated area. Appreciation of the value of saving irrigation water and using it efficiently motivated the government, farmers and other interested groups, to think in new methods and systems in irrigation. New irrigation strategies must be established to use the limited water resource more efficiently (most crop with least drop). Many methods have been developed for more than 20 years and are able to increase both irrigation water use efficiency and crop water use efficiency of many crop species. These irrigation techniques are promising for application in drought-prone regions for saving water.

Declining water resources and limited clean water reservoirs will make it difficult to satisfy food requirements in the future as 70% and in some places 90% of the available water resources is used in food production and to cope with the water shortage, it is necessary to adopt water-saving agriculture countermeasures (Mao et al., 2003). Efficient use of water by irrigation is becoming increasingly important. Agronomic measures such as varying tillage practices, mulching greenhouse, and irrigation systems can reduce the demand for irrigation water and improve irrigation water use efficiency. Development of novel water saving irrigation techniques represents another option for optimal water resources use with great efficiency. During the last two decades, water–saving irrigation techniques such as drip irrigation in greenhouses with mulching and applying Food and Agriculture Organization of the United Nations (FAO) methodology in irrigation by using different irrigation alternative techniques have been more interested .Most recently, these irrigation techniques are being tested also in some vegetable crops (Zegbe-Domínguez, 2003). In this review, we discuss the principals of water- saving irrigation strategies such as calculating water requirement for cucumber in Jordan valley (Jericho) by taking the average of reference evapotranspiration through five years ago measuring in Alkarama station in Jordan valley which is similar to Jericho in climate , weather, latitude and topography, and their prospective for improving irrigation and optimal water resources use more efficiency in horticultural and agricultural production.

Vegetables providing 91% of domestic consumption food, but the climate variability in Palestine, and with the current use of green-houses in the coastal and semi-coastal areas allows production of vegetables all year round (PCBS ,1996). Open field vegetables are the most common pattern of planting covering about 9 thousand hectares, which is 70% of the total area devoted for vegetable growing. The total area of the irrigated vegetables is 65591.5 dunums which can be classified into: Vegetables planted under open fields with 52409 dunums, forming about 80% of the total vegetable crops. 55.7% of this area is located in Jordan Valley, 44.3% is located in the semi-coastal region and high lands. The total area of the vegetable crops planted under low plastic tunnels is 7219 dunums, forming about 11% of the total irrigated vegetable crops. About 91% of this area is found in the Jordan Valley. The total irrigated area of vegetable crops planted under high plastic tunnels is 801.5 dunums, which forms 1.2% of the total area of irrigated vegetable crops. Cucumber forms 70% of the area of the vegetable crops planted under high plastic tunnels, followed by green beans (21%). The most common vegetable crops are tomatoes, cucumbers, eggplants and squash.The Jordan Valley’s contribution to the total irrigated agriculture in the West Bank is 43%. As for agricultural water, 55.57 MCM are used on irrigation, which makes up 59.8% of the total irrigation water in the West Bank (PCBS, 1996).

Cucumbers, scientifically known as *Cucumis sativus* (Wikipedia, 2008), are grown to either be eaten fresh or to be pickled. Those that are to be eaten fresh are commonly called slicing cucumbers. They are cylindrical in shape and commonly range in length from about ten to eighteen cm, although they can smaller or much larger. Their skin, which ranges in color from green to white, may either be smoothed or ridged depending upon the variety (Duke,1997). There are two major types of cucumbers grown in the greenhouse for both home and commercial production. The most popular are the long seedless varieties often referred to as European, Japanese or English. The old traditional varieties have seeds and white spines (Schouten et al, 1999).

Inside a cucumber is a very pale green flesh that is dense yet aqueous and crunchy at the same time, as well as numerous edible fleshy seeds. Some varieties, which are grown in greenhouses, are seedless, have thinner skins and are longer in length. These varieties are often referred to as "burpless" cucumbers since people find them easier to digest than the other varieties of cucumbers (Adams, et al, 1992). Cucumber, *Cucurnis satives*, belongs to the family *Cucurbitacea*. Written evidence indicates that cucumber originated in India (Nonnecke et al, 1992), which spread Westward and became popular throughout the Egyptian and the Greek-Roman eras.

Cucumber is a typical vegetable of warm temperate and cool tropical areas. The optimum temperature for growing them is between 18°C and 30°C (Yamaguchi, 1983.) Owing to the development of new varieties and new technologies, cucumber can be cultivated nowadays everywhere as both field and green house crops. It can also be grown in place with artificial conditions, and health professional consider cucumber is man’s primary source of vitamins and minerals. (Mach , 1989). Cucumbers also were thought to originate over 10,000 years ago in southern Asia. Early explorers and travelers introduced this vegetable to India and other parts of Asia. It was very popular in the ancient civilizations of Egypt, Greece and Rome, whose people used it not only as a food but also for its beneficial skin healing properties. Greenhouse cultivation of cucumbers was originally invented during the time of Louis XIV, who greatly appreciated this delightful vegetable. The early colonists introduced cucumbers to the United States. While it is unknown when the pickling process was developed, researchers speculate that the gherkin variety of cucumber was developed from a plant native to Africa. During ancient times, Spain was one of the countries that were pickling cucumbers since Roman emperors were said to have imported them from this Mediterranean country (Ensminger , 1986).

Cucumbers are grown successfully in greenhouses in different climates. Economic yields are obtained in both hot and cool temperatures (from 8°C to 37°C). Under extreme conditions, heating and ventilation are required (Adams,et al,1992).

1:1: Environment:

Cucumber plants grow well in relatively humidity ranged between (65-85%). They suffer in extremely dry weather. In dry conditions, increasing humidity should be considered (Ensminger, 1986). Cucumbers grow best in warm, humid conditions. Optimum air temperatures for growth and high yields are 27 to 28°C, but cucumbers will grow well in temperatures up to 35°C .Growth stops below an air temperature of 12°C and damage increases as temperatures drop below this level. Cucumbers are severely damaged by strong winds and must be protected by a good windbreak (Schouten et al, 1999).

Rainfall over a long period may result in a build—up of various leaf diseases. Cucumbers develop well under high light intensity (250 to 1000 watts/sq meter). In higher light intensity, shading is required. Lack of light (below 100 watts/sq meter) severely decreases plant development (Duke,1997). Adaptable many types of soil provided the soil has a fairly deep profile and a pH of 6.5-7.5. Soils must be well drained for growing cucumbers. The optimum pH is 6 to 7, but cucumbers also grow well on alkaline soils where the soil pH is 7 to 8.5 (Schouten et al, 1999).Cucumbers are not recommended on acidic soils with a pH of less than 5.5.Calciferous and alkaline soils require constant follow-up of microelement levels (Ensminger , 1986).

Low plastic tunnels (cloches) provide higher air and soil temperatures, hasten crop growth, reduce pest problems and give protection from wind, heavy rain and sand blasting. Plastic mulch also helps in the production of early crops and may be used with the tunnels. It raises soil temperature, aids moisture retention and is the most effective way of controlling weeds through the season (Cook, et al, 1988).

The tunnel/mulch system protects plants from frost damage in most cases. On cold clear nights it may be necessary to apply other methods of frost control, such as overhead irrigation to prevent or reduce damage (Schouten et al, 1999)

1:2 Planting layout

Plant population should be decided according to the season and the characteristics of the particular variety. During the research experiment execution the average plant population density is 2.5 plants per m^2. And planting in double rows, row spacing is 40 cm, and bed spacing 1.8 meters (center to center), and spacing along the row 35-40cm.The average production per donum for cucumber is about 9 tons for protection cultivation and the total production of cucumber in westbank is about 89084 tons (PCBS, 2004).

1:3:Irrigation

Cucumbers are irrigated by many irrigation systems; but in the research experiment drip irrigation was used, one drip line per row. Spacing between drippers is 35-40 cm, according to plant spacing Cucumbers have a shallow root system and must be well watered for high yields and fruit quality with good water quality. Researchers consider Cucumber as heavy water requirement (Abou-Hadid et al .,1991), this is due to the nature of the root zone, which needs successive watering period and need warm water, which must not be less than 20C , hence cold water will cause chilling to roots and this will affect negatively the growth and yield (Lee,et al,2005)

1:4:Fertigation

Fertilizer application levels should be adapted to growing stage, soil type and climate. Fertilizer dosages should be applied according to soil and irrigation water analysis (Jackson , 1964). Intensive planting of greenhouse crops in soil requires pre-plant fertilization based on soil analysis, followed by continuous supplemental fertilization (Hochmuth, 1988).The fertigation of the cucumber crop was executed by the farmer by using fertilization bump through the PVC pipeline which is used to irrigate plants.

1.5 **location of the study area**

1.5.1. **Geographical setting**

Jordan Valley is a narrow strip between the low mountain ridges in the Palestine and Jordan with Jordan River is in between. It is 70 km long started from south the lake of Tibarias to the north of Dead Sea; see figure (1.1), (NRC, 1999) and drops to about 400 m below sea level near the Dead Sea. Rainfall is low between 100 at the shore of Dead sea and 350 mm at the shore of Lake Tabaria, with mild winters and hot summers. Soil types are sandy and calcareous, while the most part of it covered by diluvial marls which frequently display a dissected topography and tertiary limestone also occurs in some localities (Dudeen, 2003). The Jordan Valley which composes lowest depressions of the earth has been formed as a result of an "earth fissure" (Bender, 1975),

Locally direct renewable water sources are virtually nonexistent because the rate of precipitation is very low comparing to the high evaporation rate. Locally available water sources (local springs and wells that are renewed outside the valley) make up 255 million cubic meters per year (MCM/yr) but are inadequately distributed (Orthofer et al, 2002).

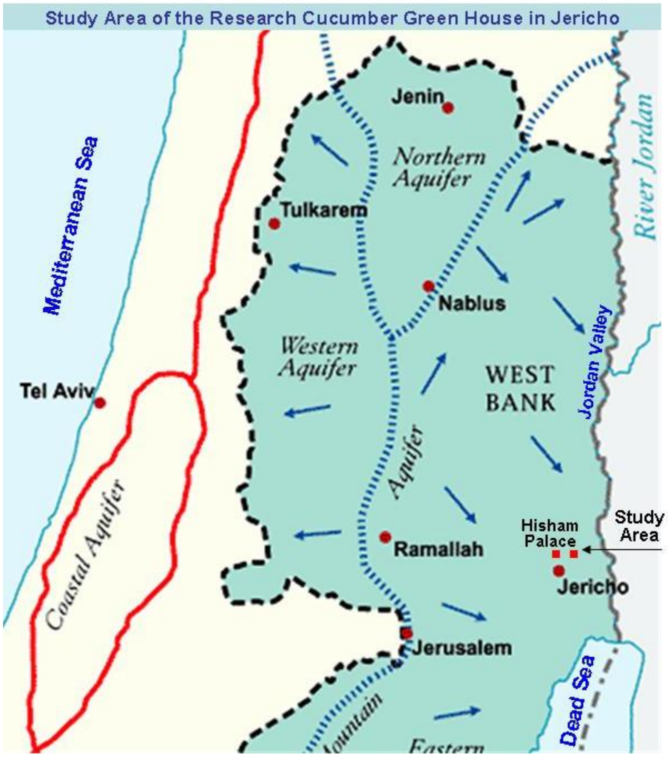

Fig1.1: location of the study area in Jericho

The Jordan valley has been shared between three different political states, Jordan, Israel and Palestine. The size of the Jordan valley is about 1300 km². The current population is about 250.000, which results in a population density of 200 people per km². The Jordan valley has a transitional arid climate, between dry steppe characteristics in the north and extreme desert conditions in the vicinity of the Dead Sea. The annual potential evaporation is about 1.500-2.500 mm and the annual precipitation range between 200 and 300 mm in the north . About 75 % of the precipitation falls during December to March . Because of the high evaporation the net groundwater recharge through rainfall in the Jordan valley is very small (Orthofer, et al ,2002).

The major ecological concern according to the surface water is the disappearance of the Jordan River; 50 years ago the River Jordan carried 1300-1400 million cubic meters per year (MCM/yr) of freshwater into the Dead Sea. This discharge has now been reduced to less than 100-200 MCM/yr of saline and polluted water (Shavit et al. 2001).

The following figure (1.2) shows the amount of rainfall in different sites in the area, that fall in different seasons. This indicate that the rainfall event decrease from north to south in the area during the year 2001.

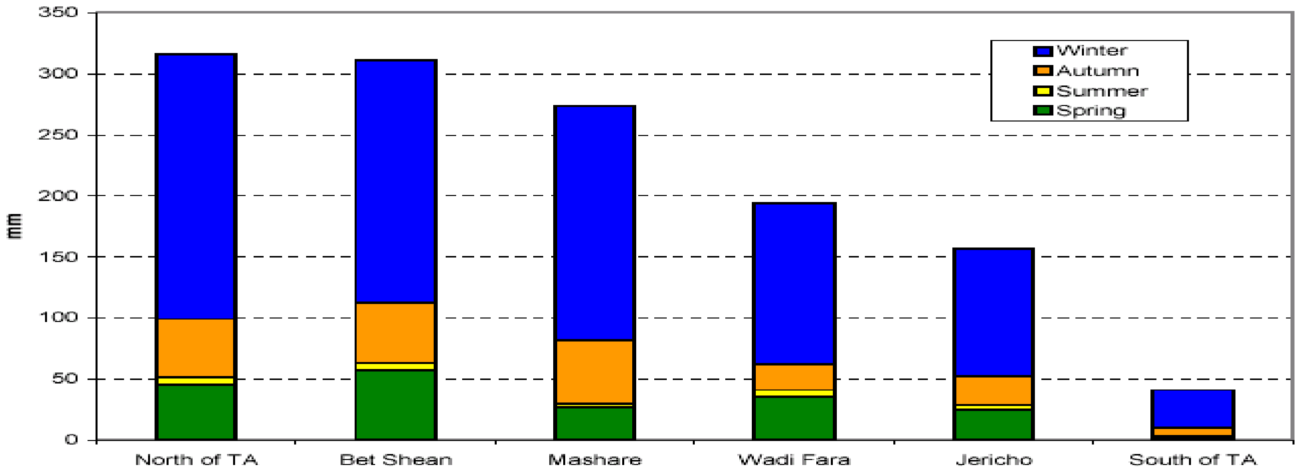

Figure (1.2): Seasonal distribution of rainfall in the target area in the year 2001. Data from the ARCS precipitation mode (Orthofer et al, 2002).

1.5.2 Evapotranspiration in the Jordan valley

It is clear that of high evaporation rates natural precipitation is certainly insufficient to sustain any commercial agricultural crops Figure (1.3) gives an example of the relation of temperature, precipitation, relative humidity and evapotranspiration over the year 1999.

The data improve the gap between precipitation and evapotranspiration that does not allow plant production with depending on natural precipitation

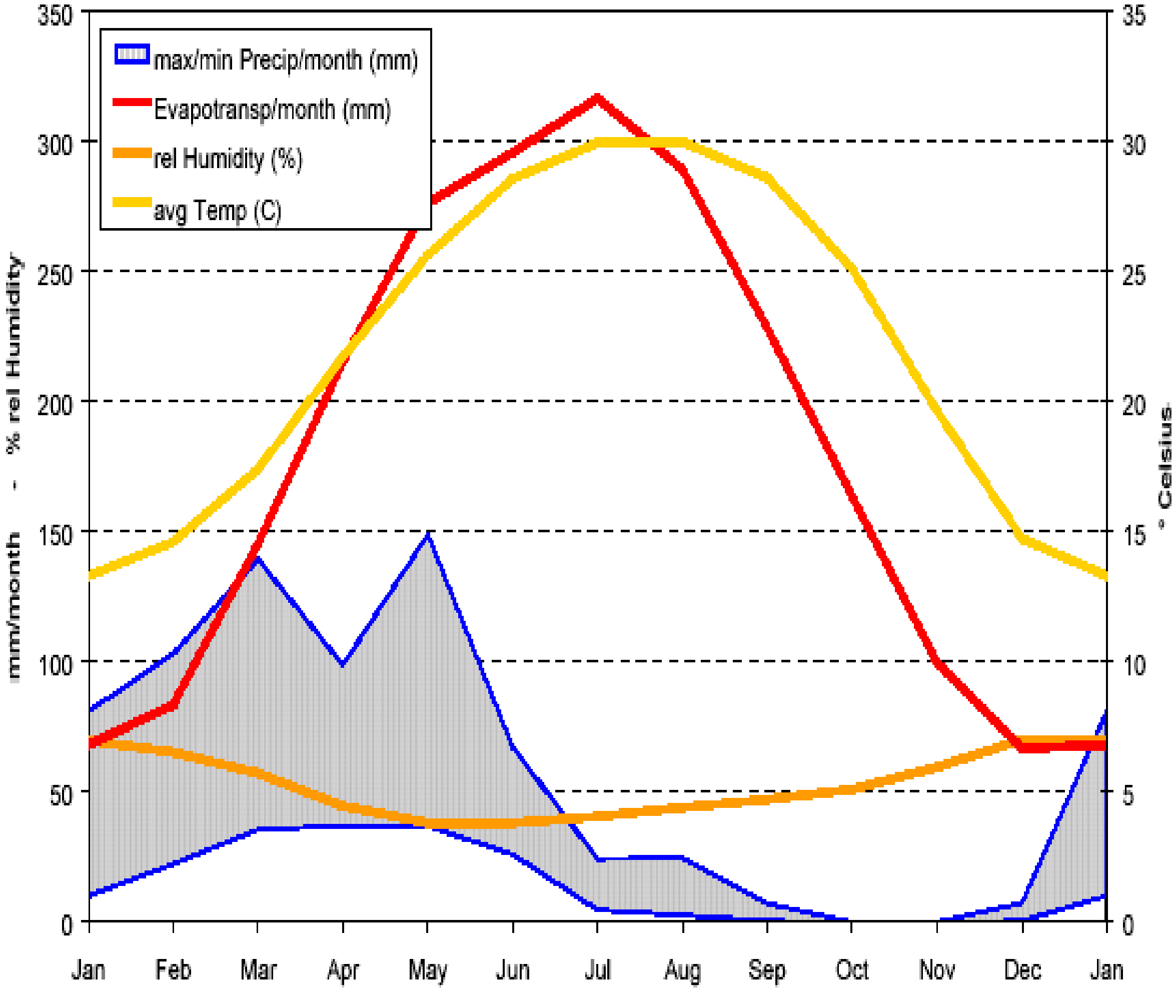

Figure (1.3): the relation of temperature, precipitation, relative humidity evapotranspiration over the year in Jericho (ARIJ, 1999)

From the above figure (1.3) the average temperature is very high especially in months of summer season so, combining with high evapotranspiration with direct proportion with temperature, on the other hand the limited amount of precipitation was very small combining with relatively low relative humidity, so evapotranspiration is much higher than precipitation. In this condition it is impossible to grow plant without irrigation to cope with health growth and good production and on the other hand the soil of the area will suffer from increasing salinity concentration due to the high evaporation.

1.6 Water resources in the area

Water sources include wells, springs and surface water that are available in the valley. These sources are all recharged through precipitation that falls outside the valley. Surface water that has been an important water supply for centuries currently plays only a minor role, because the only major perennial river is the Jordan River .It has been reduced to about 10 % of its 1950 level, (NCR 1999, and Shavit et al. 2001). It consists currently only of brackish and polluted water. The water balances in the year 2002 indicate that supply from local water sources is about 255 MCM/yr. the water sources information in Jordan valley present that Bet Shean is the richest area in wells, springs and surface water, while the target research area (Jericho) is ranked the second with no surface water available and 68 MCM/yr (see appendixes 1 and 2). The calculation of irrigation water demands depends on many factors such as crop-specific requirements ,crop growth stage ,the efficiency of irrigation systems, season ,cultivation patterns and climate. ARIJ has calculated crop water requirements with CROPWAT software that is based on a modified Penman-Monteith method, the total agricultural use for Jericho was 72 MCM/yr and the statistical demand is 64 MCM/yr. The difference between actual water used 72 MCM/year and the statistical value 64 MCM/year, which has been calculated by different methods, prove the amount of water loose (Orthofer et al, 2002), and according to the Jericho agricultural department the water consumed by cucumber was 450 CM/donum in the season.

The main source of water in the area is groundwater in the form of wells and springs. Most of the groundwater supplied in the study area is obtained from Quaternary sand and gravel aquifer system in the Jordan Valley. The major springs in the area are primarily fed from mountains around the valley (Suleiman ,2003).

1.6.1 Springs in the Area

Springs in the Jordan Valley are essential in providing the area with large amount of water; these major springs are (Sbeih,2001):

1. Al Auja spring, 1000 m^3/hr discharge, irrigate 4000 dunums.
2. Al Nweima spring, 316 m^3/hr discharge, irrigate 2600 dunums.
3. Ein Al Sultan spring, 700 m^3/hr discharge, irrigate 3000 dunums.

Some springs in the Jericho area also are influenced by structural features such as Al Auja spring. Other springs have relatively stable discharge and they are not affected directly by rainfall, the faulting system of the aquifer is important in controlling the flow of these springs. This is apparent at the Dyuk group. (Dyuk Spring, Nwei'meh and Shosha Springs), which are playing a major role in feeding the area by good water, with different quantities, (Sbeih,2001).

Jericho area is the most important irrigated area in the West Bank. The availability of both springs and ground water makes this area most suitable for off-season vegetables and for semi-tropical tree plantations, including bananas, dates and citrus.

Population pressures and diminishing water supplies, combined with water quality problems and high evapotranspiration are some of the challenges in Jericho area.

In terms of evaluating the water demands for the semi-arid areas of the Jericho area, approximately 10,000 cubic meters of water per hectare per year is a fairly typical irrigation rate for different crops (Libiszewski, 1995).

However, actual water application amounts or requirements per area variable according to crops, soil structure, microclimatic conditions, and irrigation methods. Modern irrigation methods and management, could help in reduced water used, if irrigation-scheduling practices were fully implemented (MERIMIS, 2004).

1.6.2 Main Irrigation Systems in the Jericho area

There are two types of irrigation patterns used in the area, the traditional pattern, which contains the surface irrigations such as flood and furrows methods, and the modern pattern, which contains the sprinkler and drip irrigation (Asaf, 2004). The use of the new methods in irrigations which depends on the modern irrigation and scientific programming systems can save at least 25-35 % of irrigation water consequently, total water cost to the farmers decrease, the productivity of the crops increased, quality of the products improved and the prospect of establishing new areas for irrigation arises (Asaf, 2004).Three main irrigation systems are used in the area:

1- Surface Irrigation.

2- Sprinkler Irrigation.

3- Drip Irrigation.

The annual water requirement for cucumber in the Jericho district according to the Jericho agricultural department is 450 m^3 per donum.

The total water needs for a given plant can be defined as that water used by the plant from precipitation and/or irrigation in order to fully and economically produce a product (Asaf, 2004) .The water consumed by cucumber in West Bank is not defined and quantized properly for example agricultural department of Jericho estimated that the water needs for cucumber in the area was 450 m^3 /donum,but J.Issac. and W Sabbah in 1998 claimed that water consumed by cucumber is 307 m^3 /donum in open fields and 849 m^3 /donum in greenhouses cultivation (ARIJ,1998), while Assaf in October 2004 said in one of his presentations that cucumber consumed 850 and 1200 m^3 per donum by drip irrigation systems in both greenhouses and open field patterns respectively. (Water for Life in the Middle East October 2004 – Antalya, Turkey , Minimizing the Multi-National Water Conflicts ,in the Jordan River Basin Countries by Shifting Cropping Patterns).

1.7 - Problem statements

Palestinian territories suffer from shortage in water available for domestic and irrigation use; this is due to the limitation of quantity of rainfall recently due to the harshed climatic and the quality of groundwater in addition to the political conflict. Fluctuation of rainfall will affect both surface water and groundwater, and in the other hand will affect rain fed crops. The amount of springs discharge decrease due to the decline in the water table of the groundwater, which affected available water for irrigation purposes.

Agriculture in Jericho area suffers from high salinity in soil and some kind of groundwater. The irrigation system (canal irrigation system) which was used in the Jericho area was one of the obstacles that faced the water issue, due to high evaporation rate, leakage of irrigation water and method of irrigation, in addition to the traditional farming practice, which is far a way from scientific method in farming and irrigation management (Al – Jayyousi 2004). Weather and climate of Jericho area are suitable for planting and growth of cucumber cultivation. In other hand there are a large area in Jericho area not in used for agriculture, which may be planted by vegetables. Water saving through certain irrigation method, need a certain level of farmers' qualifications.

1.8 Study Justifications:

The situation is so critical according to water scarcity, thinking about method to save water as much as can is very essential, and use optimizing amount to irrigate our crops through a scientific method. Farmers are going to change their banana and citrus crops to other crops due to many reasons such as saving water in irrigation, more tolerant to salinity in water and soil, and more return value (Venot et al. 2007).

So the investigation of the study will be on the optimization of using water resources in irrigation of cucumber in Jericho.

1.9 Questions of the study

This study will answer the following questions:

1) What is the optimized value of water need for irrigation?
2) What are factors affects the optimized water value for cucumber?
3) Can we minimize the evapotranspiration effect on plant?
4) What is the ideal soil moisture should be exist to minimize the water requirement?
5) When we must or must not irrigate?
6) How can we reduce the amount of water needed for irrigation?

1.10 Hypotheses of the research

In order to optimize cucumber consumption of water following hypotheses are developed:

1- Current water use is ideal for cucumber and there is no need to change or to develop it.
2- Current water use is not the best for cucumber plants.
3- Current irrigation methods are suitable for sustainable agricultural sector, including cucumber plants.
4- Physical properties of the soil (soil texture) are important for identifying irrigation method and choosing different types of cucumber plants.
5- The irrigated time table for cucumber plants is efficient and suitable

Chapter:2

2.1 Literature review

Isaac,J.,et al ,1996."Efficiency of irrigated agriculture in the westbank": the crop irrigation requirement has been analyzed and calculating by determining the leaching requirements based on the average salinity in each district of Palestinian territories. Modified Penman-Montieth Method , through applying CROPWAT software to estimate the water requirement for the irrigated crops was applied on the base of monthly weather parameters and the result for Jericho area, the actual water uses 34.84 MCM , and the optimal water needs = 25.138MCM , the expected water loss is 9.702 MCM.

Al-Weshah, R. A. , 2004, Optimal Use of Irrigation Water in the Jordan Valley: A Case Study: This case study shows that water scarcity can be incorporated in irrigation water management by proper choice of crops and farming patters, such as selected proper crops of high revenue and improve agriculture patterns such as, irrigation system, time of irrigation, The objective function is to maximize the net revenue from the agricultural production process subjected to limitation on water and other production and marketing factors. Results of analysis showed that net water saving of about 9% occurred if the objective function is to minimize water use under the same level of profitability.

A study **of Richard G.2006** ″guidelines for computing crop water requirements ″Was on ETo that 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 ETo, and **Medrano**, E.,2005: Study showed that the fitted simplified Penman–Monteith formula accounted for more than 90% of the measured hourly canopy transpiration rate, signifying that this formula could be used to predict water requirements of crops under Mediterranean conditions and improve irrigation control in a substrate culture. However, the model coefficients will have to be adjusted for specific climate and crop conditions.

While the study **of Şimşek M.,et al ,2005** was conducted to determine the effects of different drip irrigation regimes on yield and yield components of cucumber (*Cucumbis sativus* L.) and to determine a threshold value for crop water stress index (CWSI) based on irrigation programming. Four different irrigation treatments as 50 (T-50), 75 (T-75), 100 (T-100) and 125% (T-125) of irrigation water applied/cumulative pan evaporation (IW/CPE) ratio with 3-day-period were studied. Results of this study demonstrate that 1.00 IW/CPE water applications by a drip system in a 3-day irrigation frequency would be optimal for growth in semiarid regions .

Flávio F. Blanco,et al,2003 : this study concentrated on the evapotranspiration (ETc) and crop coefficient (Kc) of cucumber in a greenhouse were determined during the winter-spring season in Piracicaba, SP, Brazil. Crop was irrigated with water of three different levels of salinity: S1 = 1.5, S2 = 3.1 and S3 = 5.2 dS m-1. Electrical conductivity of S1 was obtained only by addition of fertilizers, as fertigation was used, and the S2 and S3 levels in addition to fertilizers received magnesium sulphate, calcium chloride and sodium chloride. Cucumber seedlings, cv. Hokushin, were grafted on squash, transplanted on beds in double rows and directed vertically with a single stem. Irrigation was performed when soil matric potential reached -30 kPa, which was determined by the mean matric potential at 0.15 and 0.30 m depths, and the depth of irrigation was calculated from a reduced-evaporation pan.

A randomized block design was adopted with three replications. The ETc and Kc were found to reduce linearly by the salinity of the irrigation water with reduction in ETc of 4.6% for unit increase of salinity. Due to the reduced evapotranspiration in saline treatments, deep percolation was increased by saline water and corresponded to 4, 7 and 17% of the total applied water in S1, S2 and S3, respectively. Measured Kc values for S1 were very close to the estimated values .

Mao, X., et al, 2003: wrote that fresh fruit yields were highly influenced by the total volume of irrigation water at every growth stage. The treatment with minimum irrigation water applied had the lowest productions. The mathematical functions that better fit for the production obtained with the water volume received were linearism, but the functions of evapotranspiration (ET) and yield were second-degree polynomials. The water use efficiency (WUE) and irrigation water use efficiency (IWUE) decreased with the increase of irrigation water applied from stem fruiting to the end, significantly since harvest of zenith fruits. But WUE and IWUE were ascending with the increase of irrigation water from cucumber field setting to first fruit ripening. Well irrigation along the whole cycle was a clearly advisable irrigation regime. On the other hand, the least advisable regimes were those that lead to deficiencies from harvest of the first fruit to the zenith fruits. But we strongly recommend actions be taken to limit the inefficient soil evaporation that resulted from higher temperature at the last growth stages in order to improve WUE and IWUE.

Orgaz, F..et al,2005: was discuss the effect of large unheated greenhouse on water consumption and cucumber growth in areas are located in the coastal lands of the Mediterranean Basin, based on low-cost structures covered with plastic. Water is a scarce resource in these areas and therefore it is necessary to optimize irrigation practice by applying the crop water needs, thus avoiding waste. This work was undertaken to determine the water requirements of four major horticultural crops grown in an unheated plastic greenhouse located in Almería, Spain. Drainage lysimeters were used to determine the seasonal evapotranspiration (ET) of four crops (melon, green beans, watermelon and pepper), which ranged from 170 to 371 mm and it was associated with the reference ET (ET_0). Compared to irrigated crops outdoors, the seasonal ET of the greenhouse horticultural crops is relatively low due to the lower evaporative demand inside the greenhouse and to a further reduction in solar radiation transmission by whitening in late spring and summer. Additionally, off-season greenhouse crops are grown during low evaporative demand periods, thus the low water requirements. Crop coefficient (K_c) curves were obtained for the four crops under different conditions. The K_c values varied with the crop, stage of development, and with management practices. Measured peak K_c values for crops, which were not vertically supported (melon and watermelon) were between 1 and 1.1, similar to the measured values for the same crops under field conditions. By contrast, peak K_c values for vertically supported (VS) crops (melon, green bean and sweet pepper) varied between 1.3 and 1.4, which are higher than those reported for outdoors. The tall and open canopy structures of the VS greenhouse crops, their high leaf area indices, along with the high proportion of diffuse radiation inside the greenhouse, allowed for more uniform light penetration within the canopies and ET rates in those crops higher than those of the short, non-supported crops. Management and climatic conditions combined to define an unusual K_c curve for sweet pepper. The crop is transplanted in late summer and reaches the peak K_c in early winter. Because of the low temperatures, K_c decreased thereafter down to about 1.0, until climatic conditions inside the greenhouse improved. From late winter to the end of the season, K_c was either stable or increased steadily. A simple K_c model based on thermal time for greenhouse crops with and without pruning was proposed and validated. The model gave accurate estimates of measured K_c values for melon and pepper.

Bajracharya , et al,2005:discuss methods of conservation of water as crucial to sustainable agricultural production in areas of low rainfall or uneven precipitation distribution. Under such circumstances, drip irrigation methods offer a useful option for economic production of vegetable crops. This preliminary study examined the efficacy and performance of two drip irrigation methods on cucumber and tomato crops grown out of season. The initial results of the study indicated surface drip irrigation to give better establishment of the crop and higher yields than sub-surface drip method, in which the water is delivered directly to each individual plant on a gradual and continuous basis. The purpose of this preliminary study was to evaluate the efficacy of two different methods of drip irrigation, namely surface and sub-surface drip, on the performance and yields of cucumber and tomato in the central Nepal mid-hills.

Rahman,et al,2004: Investigate the effect of four irrigation rates and evaporative cooling rate on yields of cucumber, hence combination of aridity, extensive urbanization and expansion of irrigated fanning have brought about substantial water demand increase and intensified the gap between rising water demands and limited existing water supply in the Sultanate of Oman. Results showed an asymptotic increase of greenhouse cucumber yield with increase in water applications from 1 to 4 mm/day. The 2 mm/day applications optimized yields (kg/m^3), whereas 3 mm/day applications maximized yields, with no significant difference from the 2 mm/day applications being observed. Yields were increased by 135% from 27 to 63 t/ha when irrigation was increased from 1 mm/day to 3 mm/day respectively, and declined there after. Field cucumber yields increased linearly as the irrigation water was increased from 3 mm/day to 8 mm/day. Yields were optimized at 6 mm/day applications (35 t/ha). The 8 mm/day maximized yields (40 t/ha) but fell short of the optimum 2 mm/day yields (53 t/ha) obtained in the greenhouse. Optimum yields were obtained at an average crop factor (Kc) of 0.58 ETo and 1.55 ETo in the greenhouse and the field respectively, indicating that water requirements for the greenhouse cucumber is about one third of that in the open field. The irrigation water use efficiency was higher in the greenhouse than that of the open field because of the lower water requirements and higher yields of cucumbers. But the total water use efficiency approached that of the field as the rates were maximized, because of the high quantity of water used in evaporative cooling. The average cooling pad water use was found to be 79.1 l m-2 day-1 of pad area. In the greenhouse, irrigation water use efficiency was highest with 2 mm/day applications (31.3 kg/m ^{3}), whereas in the open field the highest irrigation water use efficiency obtained was only 7.6 kg/m3 for the 6 mm/day applications.

Dirja M., 2003: explain saving water represents a very important aspect, both economically and socially. The research comes to support the cultivators who grow tomatoes, green peppers and cucumbers in solariums. Determining precisely the water consumption of this species will create the possibility of avoiding both the excess and the lack of water of the tomatoes, green peppers and cucumbers grown in solariums, each of them having negative effects on production. Establishing the best water regime of this crop will lead to the application of optimum water quantities, at the right time and by the most efficient irrigation methods. This way, the cultivators will have the possibility of obtaining high productions, of superior quality, justified economically. this proved by the knowledge of the water consumption of the crops and the obtained yields, by comparing these, we obtained the water capitalization coefficients (Wca), which shows the water quantity consumed by the plants to produce 1 kilogram of fruits.

2.2 Objectives

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

Specific objectives:

1) To find mathematically the daily water requirement for cucumber in Jericho .
2) To determine the greenhouse effect on the water requirement on cucumber.
3) To optimize the irrigation volume of water needed for cucumber at different stages.
4) To compare the water use efficiency for cucumber in the case of different water consumption.
5) Try to verify mathematical equations to represent the relation between water consumption and yield with crop age.
6) To evaluate the economic value of the experiment application.

Chapter:3

3 Theoretical frame work

3.1 Soil effect on cucumber

Knowledge about the type of soil and its deep is a required. This gives an indication of how much water is in the soil and how much is available for cucumber. This information, combined with the daily usage of water by the cucumber, enables the determination of when the next irrigation cycle is due. Therefore the determination of soil type is essential for cucumber plants growth and the expanding of root system searching for water availability (water hold capacity). Soil is classified to three classes according to its content of water in the root zone, it is essential in calculating water need to irrigate cucumber .The following table 3.1 shows the mean values of available water for the three major soil classes:

Table 3.1 mean values of available water for the three major soil types (Djerbi, 1980).

Soil class	**Available water**
	mm^3 /meter of the root depth
Light soil	100 mm/m
Medium soil	140 mm/ m
Heavy soil	180 mm/ m

To ensure that cucumber will not be put under water stress, it is the normal practice to allow for only a fraction of the available water to be extracted. (Zaid ,2002).

3.1.1 Soil depth

Soils must be well drained for growing cucumbers. Vine crops are warm-season vegetables which prefer deep, and well drained soils. Cucumber plants can grow well in heavier soils. which can provide sufficient room for proper root development to support the cucumber plants. Besides the importance of root development, soil's depth also influences drainage, and leaching possibilities. Any obstructive layers must be evaluated to determine whether they will influence the root development, and whether they can be corrected (Abrol et al, 1988).

3.1.2 Soil quality

Cucumber plants can grow and produce in different types of soil, in both hot arid and semi-arid regions. Adaptation is possible in a very sandy to a heavy clay soil. The soil quality is related to its drainage capacity mainly when soil is salty, or the irrigation water is characterized with a high salt content. Rare cases of clay soil with drainage systems are found allowing the growth of cucumber plants. The optimum soils conditions are found where water can penetrate to at least 2 m deep (Abrol et al,1988).When evaluating the soil's quality, certain attention must be given to the following:

(i) The soil texture which influences the water retention capacity, and

(ii) The nutrient content to determine the corrective measures necessary for the soil's improvement.

3.1.3 Soil Salinity or Acidity

Plant growth is influenced by either saline or acid soil conditions, which, will result in a loss of potential yield. Saline, and alkaline soils are common in cucumber plants. They are characterized by a high concentration of soluble salts and exchangeable sodium respectively. Soluble salts present in these soils belong to cat ions: sodium, calcium, magnesium and to chloride and sulphate anions. Saline soils have an electric conductivity (EC) of their saturated extract higher than 4 ds/m at 25°C, with a sodium absorption rate less than 15 and a pH generally less than 8.5 (Zaid,2002). Saline soils can be recognized by the presence of a white layer on the surface of the soil resulting from the high salt concentration which may harm the growth and development of the cucumber plants (Abrol et al, 1988). Alkaline soils do contain harmful quantities of alkalis, with the hydroxyl group - OH, especially NaOH . These types of soils are usually difficult to rehabilitate, which is coupled with a low production resulting from low calcium and nitrogen contents . However, it is recommended to eliminate the excess of sodium by the addition of acidifying agents (gypsum, iron sulphate or sulphur).

3.2 Evaptranspiration

Three options to calculate crop evaptranspiration are available: Penman, Priestley-Taylor and Makkink. The choice of the option is governed by: User preference, and the availability of weather data. The Penman method is preferred and applied for the case of water requirement to the vegetables and requires the availability (in the weather data file) of five weather variables which are: radiation, maximum and minimum temperature, wind speed and vapor pressure. While the Priestley-Taylor and Makkink methods only require radiation and minimum and maximum temperature (ORYZA, 2000).This method is used to determine the daily reference evapotranspiration (Eto), which is measured in Al Karama

Agricultural Station in Jordanian side of the Jordan valley, it is available as a data base on NCARTT web site(appendix :3).

3.3 Measuring Soil Characteristics:

The ratio of sand, silt, and clay in the soil determines its ability to hold moisture and nutrients. Soil samples need to be representative of the area. Making a composite by collecting small samples at evenly spaced intervals, across the actual roots growth . Figuring out the percentages of sand, silt, and clay in the sample, and measure the height of the total amount of sediment settled. This number represents 100 percent of the soil sample. To derive the percentages of sand, silt, and clay in the sample, measure the amount of each layer and divide by the amount of total sample. Transfer the results to the soil texture triangle to determine the soil type (Cahilly, 2000).

Water holding capacity is the amount of water in the soil between the field capacity and when the plant just starts to go into stress, Measuring the water holding capacity, depends on the type of soil, how effective the plant is at extracting water from the soil, and the wetted volume (Ley,et al,1994). The amount of soil's water available to plants is governed by the depth of soil that roots can explore (the root zone), and the nature of the soil material as shown in the table 3.2.

Table 3.2 Water holding capacity (mm/cm depth of soil) of main texture groups.

texture	**Field capacity**	**Wilting point**	**Available water**
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

Source: Soil, Department of Agriculture Bulletin of south Australia 462, 1960.

3.3.1 Measuring Soil Water Holding Capacity

Establishing the depth of the root zone, can be achieved either by observing the depth to which roots from the previous crop have extended, or by noting the depth to a restrictive layer. The roots of most annual field crops occur in the top 120 cm of soil, if there are no restrictive layers. Some perennial species may extend roots to 600 cm or more when the soil conditions are ideal and moisture is present (Ley,et al,1994).

Table 4.1 is used to calculate the water holding capacity of each soil layer in the root zone. For example, 25 cm of sandy clay loam with an available water of 1.5 mm water per cm of soil, can store 37.5 mm of available water. The water holding capacity of a soil is calculated by summing the capacity of each layer in the root zone (Ley,et al,1994).The nutrient holding capacity depends mainly on the soil structure type, where it has high abundance in clay soil, clays contain and hold an appreciable amount of plant nutrients (K, Fe, N, P,….) . Clay soils are characterized as being hard to work into good seed beds. These soils have slow drainage due to small seepage factor and can easily become excessively wet. Holding capacity is intermediate in slit soil, while the sand soil is very poor with nutrient holding capacity.

To determine the optimized quantity of water (water requirement for a crop) the water requirements for agricultural crops have been done by measuring plant water loss (evaptranspiration), the total amount of water lost during a specific period of time gives an estimate of the amount needed to be replaced by irrigation. A formula was developed which allows water loss to be calculated.

This formula (referred to as the *ETc* formula) is written as follows (Allen et al, 1998)

ETc = Kc *Eto equation (1)

Crop Evaptranspiration = Crop Coefficient multiplied by Reference Evaptranspiration

This formula states that the water loss from a crop (crop evaptranspiration, *ETc*) equals the amount of water that evaporates from a 0.12 m tall cool season grass growing in an open-field condition (reference evaptranspiration, *ETo*) multiplied by a factor determined for the crop (crop coefficient, *Kc*) (Allen et al, 1998).

The crop coefficient is a dimensionless number. It is a factor that relates actual crop water usage to reference crop evapotranspiration. The value of crop coefficient depends on several factors such as growth and development of the crop canopy. The pattern of Kc follows the canopy development(appendix:4 and appendix:5). Early in the growing season the values of kc are small for the annual crop, then starts to increase as the canopy develops. At some point the canopy development is sufficient so kc reaches the maximum value. This time is referred to as the effective covered date. After the effective covered date, kc is generally constant for a period of time even when the plant canopy continues to increase then the values decreases gradually at the last harvest season, (Allen et al, 1998). Crop coefficient values may also be affected by the cultivation patterns, such as protected agriculture in greenhouses, and mulches (appendix:6),(usually between 0.1 and 1.2) that is multiplied by the *ETo* value to arrive at a crop *ET (ETc)* estimate. The resulting *ETc* can be used to help an irrigation manager schedule when irrigation should occur, and how much water should be put back into the soil. (Allen et al, 1998).

Crop coefficients vary by crop, stage of growth of the crop, and by some cultural practices, see appendix 5. For example Citrus trees have smaller coefficients than peach trees (when the peach tree is at full cover). Coefficients for annual crops (row crops) will vary widely through the season, with a small coefficient in the early stages of the crop (when the crop is just a seedling) to a large coefficient when the crop is at full cover (the soil completely shaded). Almond orchards with cover crops between tree rows will have larger coefficients than almond orchards without cover crops. ***Kc*** values for agricultural crops typically changes during the seasons:

Low values are for early season (March/April) or late season (September/October), and high values for midseason (May/June/July).

Water requirement estimation, for cucumber plants require finding just *Eto*, which depends on the climate and varies from location to another. Weather stations are used to collect the climatic data for calculating *Eto,* including temperature, dew point temperature (relative humidity), wind speed, and solar radiation, see appendix 3.

Sufficient quantities of high quality water should be available to sustain vegetable farming. As the state's population continues to increase, less water will be available for agriculture sector. Increasing the water use efficiency is one of the major goals for future sustainable agriculture.

Vegetable crops require more water and more frequent irrigation than most agronomic crops (Dainello, 2001). Vegetable's water requirements vary largely for each growing season, depending on the vegetable grown type, production location, and environmental conditions. Little can be done to reduce water needs of any given vegetable. Plant water use is genetically controlled. Total volume of water supplied to meet crop needs and to produce is covered by water delivery systems and cultural practices.

Drip or trickle systems are the most efficient irrigation systems which are available today, and are best adapted to high value vegetable crops in the region. There are many advantages to drip such as water conservation by using water exactly where it is needed, which keeps paths and areas between plants dry. Drip irrigation delivers water slowly and evenly over a large area. Water lost to evaporation is negligible compared to overhead irrigation. Drip irrigation saves labour time. Opening a valve is much easier than standing at the end of a hose. The system can be controlled by hand or even by an automatic timer. They can also be used to apply fertilizers. A final advantage of drip irrigation is disease control (Shock, 2006) and the ability to place a precise quantity in the exact location where needed, is the biggest advantage. This ability enables drip systems to waste less water in the delivery process, compared to surface irrigation systems such as ditches, (which is almost diminished), furrows and /or pipes as a delivery vehicle, and sprinklers which apply water above the crop (Shock, 2006).

Water use efficiency can be increased through effective application scheduling; several devices and techniques are available to aid a vegetable grower in scheduling irrigation.

The effective method used to schedule irrigations depends mainly on evapotranspiration rate (ET), which is the measure of the amount of water used by a crop in a given period of time, plus water evaporating from the soil, and water vapor transpiring directly from the plant. Weather conditions which effect the soil and plant moisture losses are monitored, then a crop coefficient is determined.

Water quality, and water quantity are equally important for the growth and the yield of plant. Irrigation water for optimum vegetable growth should contain less than 400 ppm soluble salts, because most of vegetables can adapt to a salt concentration below this value (Dainello et al,1999.).

Soil and water analysis were conducted in addition to the soil texture. Salinity and measurement of the nutrient concentrations such as nitrogen, phosphorous, potassium, calcium, and magnesium have been done. Such set of analysis is needed to monitor crop's growth during the season, and to amend their fertilization program, as needed. Over fertilization can cause problems in crops, which can be easily prevented by managing nutrient levels in the field and crop.

Optimum crop growth and development is attained by timely application and accurate placement of fertilizers. Most vegetables absorb essential nutrients and water from the top 20 to 30 cm of the soil profile (Dainello et al,1999).

To have the proper decision about the constructive cucumber farming project, the study will focus on three major issues that need to be considered in selecting a field for growing cucumber. These issues are: site topography, soil type, water availability (quantity and quality) (Lorenz et al,1988).

Chapter 4

4: Methodology

4.1 Field investigation and data collection

The following should be investigated and implemented through the application of the research:

I: Site selection to determine:

a) Soil's sampling of different depths.

b) Determination of cucumber plants varieties.

c) Determination of water salinity, and other chemical component.

d) Irrigation methods in cucumber cultivation.

II: Sampling:

a. Soil sampling and soil mapping

b. Water sampling to measure, *TDS* chemical species concentration and *SAR*

III: laboratory work

a. Soil seaving (soil texture) and type.

b. Soil chemistry: Analysis of soil's chemistry in the irrigated site .

c. Physical Soil's properties

d. Water analysis..

e. Measuring *TDS*,EC,Na,K,Ca,…. and calculating *SAR* .

FAO has developed several tools to be used, as information systems, in the field of sustainable development of scarce fresh water resources. These tools include an information system with statistics on rural water use, software on crop water requirements also irrigation management , planning, and training material for people involved in irrigation, and drainage development (FAO AGL, 2006).

4.2 Limits of the study:

The experiment was conducted in the north side of Jericho area to the eastern site of Hisham palace, in a farm contains 12 greenhouses with an area of 2.5 donums each. Greenhouse number eight have been chosen randomly. The source of irrigation water to the farm is Al Nweima spring. An open canal is utilized to transport water, which is then stored in an agricultural pond, and then water distributed to greenhouses which uses drip irrigation system.

Aljawhar cucumber brand was transplanted in 5 December 2007 after planting seeds in a nursery for 15 days. The duration of the experiment was 130 days and the water delivery was executed according to the experiment's design and plan. This was applied through the winter season, from December 2007 thru March 2008.

4.3 Site of Experiment

A farm in Jericho area was selected to conduct this experiment .The experiment is located in a large area, planted with vegetables and considerable the most productive land for most kinds of vegetables in West Bank. The area of Jericho district is 35km ^{2}, while the area of the farm (greenhouse: Gh) was 2.5 donums.

The greenhouse looks like seven connected half cylinders arches; they are of 62.5 meters long, 40 meters wide and 4 meters high. The greenhouses have a framework made of galvanized iron pipes, and a polyethylene plastic skin of 180 micron, resistant against ultraviolet rays. The greenhouse is one of 12 greenhouses which were built parallel to each other, in tow rows with six greenhouses in each and of a space of 4 meters between one and other. The agronomic engineers of the site suggested that sufficient source of sunlight in the area, and the crucial matter of providing the heat were not used properly, and this clearly appear in the orientation design of the greenhouses from south to north. This orientation made the crop face the north cold wind during winter, and this effect had its impact on the growth and the yield of the first replicate which belongs to treatment (T3). Greenhouse has been known as a plant production system that can potentially enhance efficiency of water use by creating microclimate to enhance plant photosynthesis and to suppress excessive evapotranspiration. The water use efficiency (water use by irrigation per kilogram yield) is reportedly four to six times that in the open field (Howell,2001). Crop production in semiarid climate regions has been recognized as having a high potential, due to its high photosynthetically active radiation throughout the year.

Cucumber plants were transplanted in the site in December, 5, 2007 which has moderately deep roots and long taproots as well as shallow fibrous root systems. Most of the fibrous feeders are in the top 60 cm and the active roots are concentrated between 20 and 30 cm. Cucumber is a quick growing crop that produces a lot of succulent growth with life duration reaches to 130 days(Mao et al, 2003).

The study site is located at an elevation of about -360 m, and the contour coordinates as latitude & longitude 31 51`N and 35 27`E. The greenhouse was oriented from south to north. The site is covered with a soil layer that exceeded three meters, with good water and air drainage patterns. The ground surface of the field is one that is nearly flat with slight sloping to the east, well drained, and free of spots, rocks or trees.

4.4 Land Preparation

Cucumber has small size seeds, which are seeded in a special nursery to be transplanted after tow weeks. Consequently, proper transplant bed preparation is important. Optimum transplant beds have been prepared with mellow soils, comprised of fine size particles, free of clods, weeds and previous crop residue. Such transplant beds enable good soil to create surface contact which is required to allow uniform water absorption.

Deep moldboard plowing was done to a depth of 30 cm or more. Hence the field which has not been planted before for many years ago to any crop should be plowed. Deep plowing will promote complete decomposition of wild plant material to occur (Dainello et al, 2005**)**. Then deep chisel point plowing was conducted, which can improve or maintain the soil's physical condition by penetrating and fracturing compacted soil. This is desirable for the prevention of a plow pan or a compacted soil layer forming at the depth of the plow blade. Such formations can cause problems with respect to downward water percolation and normal root development. Transplanting cucumber directly over chisel marks permits roots to penetrate deeply into the soil profile. Beds were raised to ensure a good drainage of excessive moisture, early soil's warming, rapid drying of soil surface, improved soil aeration and less chance of soil borne diseases. This is especially true on heavier soil types such as clay loam similar to that of the project site. The soil moisture was insufficient for planting after bedding. Therefore, flooding pre-plant irrigate with excessive amount of water (eight hours of intensive irrigation with 4L./hour for each dripper in total volume 5760 L per each row of bedding) were implemented to replenish moisture up to the field capacity.

4.5 Transplanting

In 5th of December, 2007, transplanting took place by nursery of cucumbers of 15 days age. This method of transplanting of cucumber (Aljawhar brand) has advantages to enhance earlier harvest, to reduce impact of adverse environmental conditions during the early seedling growth, to reduce seed quantity which is needed for crop establishment, and to enhance plant stands and faster maturity.

Mulches :using of plastic mulch or any material applied to the soil surface of a plant bed to modify the microclimate just above or below the soil surface (Hochmuth, 1988). Mulch depending upon the material used and the time of the year. Mulches can successfully suppress weed growth, reduce soil's moisture loss(by decreasing evaporation) and the crop coefficient is reduced to about 15% (Allen,et al,1998), reduce fertilizer leaching, overcome unfavorable soil's temperature, manipulate insect populations, and manage disease problems (Lorenzo, et al, 2005). Also mulching increases yields, induces earliness, and improves quality of most vegetable crops (Hochmuth, 1988).

Mulch materials can be classified into organic or synthetic. In the experiment site synthetic mulch was used which had gained wide spread acceptance. Plastics are the most versatile mulches, and their application was fully mechanized .They also provided better weed control, enhanced soil warming, and served as an aid to fumigation. Two major disadvantages of plastic mulch are the cost of the materials, and the disposal of the used material, which must be removed from the field and disposed (Lorenzo, et al,2005). Plastic mulches were used, which are black on one side and white or silver on the other, have been introduced in the experimental site. Greatest reduction in moisture loss was accomplished by using plastics. However, important consideration with respect to soil moisture was the content at application, the size of the bed to be mulched and the soil type. When using these materials, a pre-plant irrigation to reach fully wet soil profile, prior to mulching was already done (flooding). Plastic mulches were used in conjunction with drip irrigation, where the drip line was applied prior to mulch application. Holes were punched in the plastic covering the bed with spacing 40 cm in both sides (between rows and through the row itself). These holes were used in replanting the cucumber nursery.

4.6 Materials and Methods

The irrigation system for the greenhouse consists of the followings, a) agricultural pond which is located at the upper level in the western side of the farm to supply water with suitable pressure, through 75 mm pvc pipeline, which will subdivided into two 50 mm pvc pipelines, one of these lines was chosen to construct the experiment.

b) Five valve stops and five flow meters are connected to the main pipeline. These five sub-lines are supply water to the five treatments (T1, T2, T3, T4, and T5) through tow -16 mm pipelines, along tow rows, connected to 188 drippers in each bed (replicate). Each treatment is consisting of three replicates which are chosen through completely randomized block design, and irrigated separately with special volume of water, controlled by flow meter valve, and determined according to the experiment design. These treatments are irrigated according to the experiment design through evapotranspiration estimation in the determination of water requirement for each trial treatment (T).

c) Reference evapotranspiration (Eto) for a hypothetical grass reference crop with an assumed crop height of 0.12 m with reference surface closely resembles an extensive surface of green, and can be computed from metrological data, as a function for the FAO Penman-Montieth method such as ; radiation, air temperature, air humidity and wind speed (Allen et al,1998).

Data are used to estimate the Eto values for grass. Taking the average value of the last five years, which are measured in Alkarama Station (similar to Jericho in climate, latitude and topography) (appendix:1), and hence determine the optimum water requirements for the cucumber crop. By taking into consideration Kc-values were adjusted for cucumber in greenhouses (Flávio ,et al,2003) and mulching effect which decrease the Kc values from 15 to 20% ,(Allen et al,1998) and choose the 85% Kc values through applying the equation to determine the water requirement . To adjust the Kc values related to greenhouses, as furnished by (Flávio et al, 2003) The applications of the mentioned equation to determine Kc values (appendix 7) suggest that the equation may be written in improper way, because while trying to sketch the diagram which represents the relation:

$$Kc = -0.024 + \frac{1.547}{(1+e^{(\frac{-DAT+52}{0.29131})})^{0.0054}}$$ Equation (2)

where DAT: day after transplantation values = 7, 8, 9, 10, 11 … 130

The graph has not fitted with normal Kc diagrams, so the equation may be modified to the following form (4)

$$Kc = \left[-0.024 + \frac{1.547}{(1+e^{(\frac{-DAT+52}{0.29131})})^{0.0054}}\right]^{-1}$$ Equation (3)

And the fitted diagram for Kc values (appendix 7) versus DAT is shown in the figure (4.1).

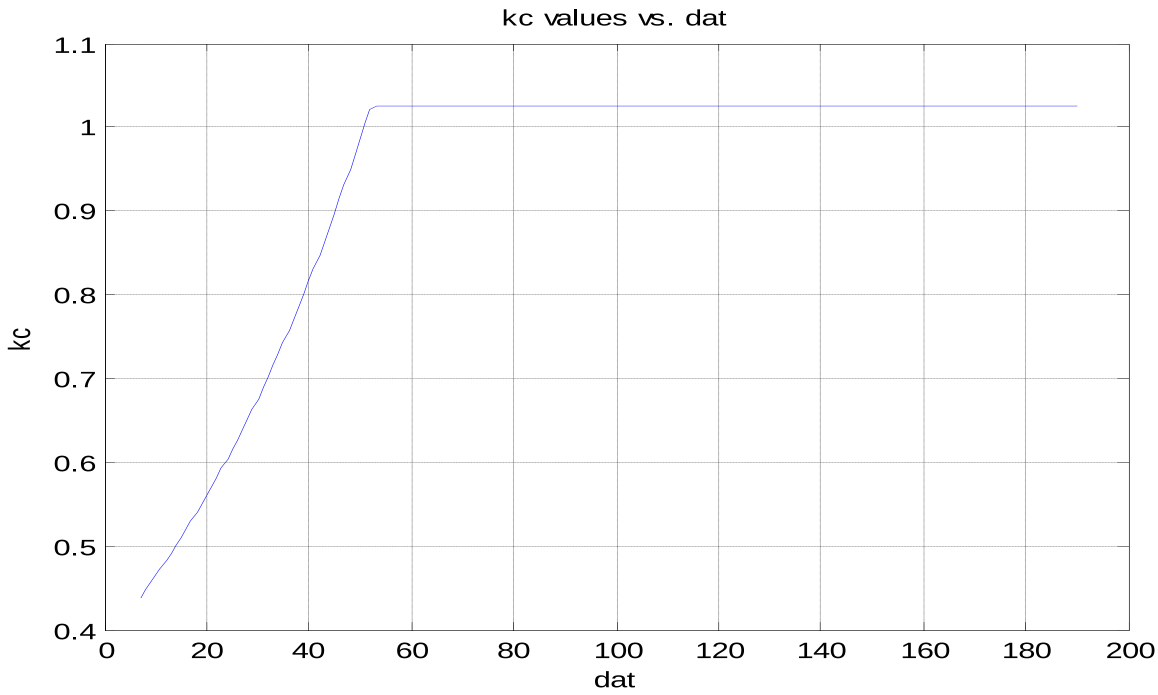

Figure (4.1): Kc curve adjusted for cucumber in greenhouses

Treatments: Five irrigation treatments were examined namely (T1,T2,T3,T4 and T5),where the experiment used the following percentages of the reference evapotranspiration Eto in each treatment. For T1 the value is 80% Eto, for T2 the value is 90% Eto, for T3 the value is 100% Eto, and for T4 the value is 110% Eto while T5 is the control treatment, which represented the farmer method of irrigation. Each treatment has an area of 0.1 donum and consists of three replicates. Each replicate has the area of 33.3 m^2, which were chosen randomly through the site of the experiment, and these treatments were irrigated with delivered water, by applying the equation of Allen et al, 1998:

Etc = Kc * Eto equation (4)

Where: Etc is crop evaptranspiration (mm/day),

Kc is crop coefficient (dimensionless) which is variable according to the plant stage,

Eto reference crop evaptranspiration (mm/day).

The Kc values are adjusted for the greenhouse (Flavio, et al,2003) and reduced by 15% due to the mulch effect (Allen,et al,1998).

4.7 Size of experimental plot:

The greenhouse constructed on 2500 meter square (2.5 donums). It was divided into seven half cylinders, and each arch consist of four beds. Through the extension of the experiment, fifteen beds have been chosen randomly to represent experimental replicates. The area of each bed is 33.3 meter square with plant's density about 2.5 plants per square meter.

Irrigation: Researchers consider Cucumber as heavy water requirement(Abou-Hadid et al .,1990), this is due to the nature of the root zone, which needs successive watering period and need warm water, which must not be less than 20 ^{o}C , because cold water will cause chilling to roots and this will negatively effect the growth and the yield (Moon, et al.,2006). Unfortunately, during frost days that hit the area in January,11,2008 to January,17,2008 delivery irrigation was used ,and this negatively effected the crop growth .

The irrigation system from the source,(which is Al Nuweimeh spring) that supplies the area with water using open concrete canal which passes the agricultural fields for a distance of about four kilometers. Water is collected in agricultural pond with a capacity reaches to 1500 cubic meter. Storing water in pond increases the productivity and improves the water's use efficiency. The soil irrigation pond, with a plastic covers on the bottom lining with a layer of mud which originates from lisan soil formation, explains the increase of salinity of the pond water, compared to the spring water. The water conveyance systems from spring to farm comprise open earth or lined canals and earth buffer pools (usually plastic lined). The bad condition of the irrigation system is responsible for substantial losses of water due to seepage and evaporation. These losses are estimated at about 25% of the total discharged water. The drip irrigation increase the water used efficiency up to 90% (MEnA-PSAPP). Drip irrigation system can also increase agricultural productivity, and solves the problems of water losses, which are often as high as 35% compared to traditional irrigation methods such as furrow systems. Also drip irrigation has increased the average productivity of vegetable crops by 243%. More than 50% of the total cultivated area in the Jericho district is irrigated using ponds (MEnA-PSAPP).

Agricultural pond and drip irrigation have played an important role in the production improvement by allowing better control of irrigation process, crop management; improve used water efficiency, and the reduction of the time and effort needed for irrigation. Thus it increases the size of cultivated areas; improves the production of the planted area production, enhances the summer crops cultivation during winter season, and increases the farmer's income (MEnA-PSAPP). Drip irrigation is the slow, frequent application of water to the soil through drippers. As only a small area of the total field is wetted, drip irrigation is especially suited for situations where the water supply is limited. Drip tubing is used frequently to supply water under plastic mulches. Applying nutrients through the trickle system is very effective, and may reduce the total amounts of fertilizer needed, if it is managed well. The problem is still in the farmer's culture and qualification in dealing with fertilizers, and irrigation. The following schematic diagram represents the experiment design and the drip irrigation system in the site as shown in Figure (4.2).

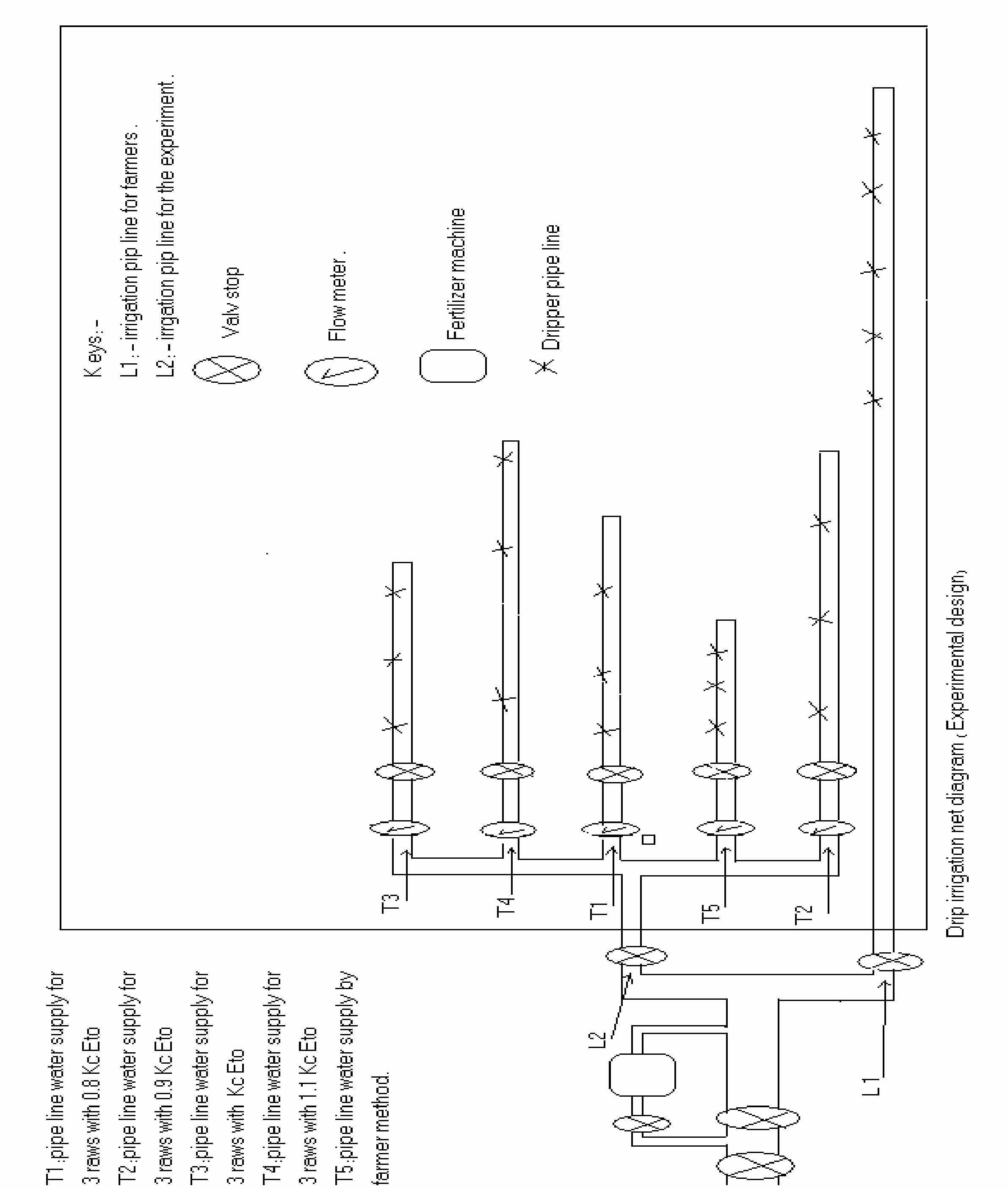

Figure (4.2): Schematic irrigation system used as a part of the executed experiment on the Location.

Many times the farmer used fertilizer and pesticides as random practice (type, weight and occasion), which will effect the quality of the product, soil and groundwater. Drip is the most ideally suited to high value crops such as the vegetables (Dainello,2001). Properly managed systems enable the production of maximum yields with a minimum quantity of water**.** The most effective means of reducing water cost is to reduce the volume of water needed to produce a crop. The increased water use efficiency of drip enables a significant reduction in the total volume required to satisfy crop needs. To deal with limited water resources, vegetable producers are forced to either reduce acreage or sacrifice crop yield. The reduced water volume required to produce a crop with drip affords the opportunity to optimally irrigate a crop or to expand irrigational acreage. And it must be remembered that plant water requirements cannot be reduced with any type of irrigation system, but rather. The volume of water needed to be delivered to a crop can be reduced, because the efficiency of the system is higher. The distance between bedding is 1.5 meter; two pipe lines (16 mm) are available for each planting bed. Each pipe line (row) contains 94 drippers (4 litter per hour), and the dripper delivers water at a distance of 2 cm from the plant base,(each bedding contains 188 plants) and each bedding is considered as one replicate, with area 33.3 m^2,and each treatment contains three replicates of area 100 m^2 .

Spacing between plants in the bedding, for the same row, is 40 cm and the spacing between the adjacent rows in the bedding is also 40 cm, while the drippers discharge 4 L /h.

4.8 Irrigation Scheduling

Irrigation scheduling is the decision of when and how much water to apply to a field. Its purpose is to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level. Irrigation scheduling saves water and energy. All irrigation scheduling procedures consist of monitoring indicators that determine the need for irrigation. The purpose of irrigation scheduling in this experiment is to determine the exact amount of water needed to the field, and the exact timing of application. The amount of applied water is determined by using reference evapotranspiration estimation to determine the irrigation need, and how much water to be applied in any situation. This is to keep the soil's moisture content above a critical level. Irrigation scheduling offers several advantages such as enables the farmer to schedule water rotation among the various fields to minimize crop water stress and maximize yields. It reduces the farmer's cost of water, and labor through less irrigation, thereby making maximum use of soil moisture storage. It lowers fertilizer costs by holding surface runoff, and deep percolation (leaching) to a minimum. It increases net returns by increasing crop yields, and crop quality. It minimizes water-logging problems by reducing the drainage requirements, and finally it assists in controlling root zone salinity problems, through controlled leaching. A common and widely used irrigation criterion is soil moisture status, which depends on the estimation of the soil's moisture content, by measured reference evaptranspiration (Eto).The measured values for reference (Eto) have been taking place in Alkarama agricultural station, by using the Eto reference value data for previous five years, and then calculate the average value for each day in certain month.

4.9 Fertilizer Injector

Fertilizer, especially nitrogen compounds, is applied through the drip irrigation system by using injection device which must be selected for proper operation of the greenhouse's water system pressure. It must have the ability to inject the proper amount of fertilizer using the irrigation water flow rate.

Irrigation water flow rate will distribute fertilizer to every plant in the greenhouse. The injector was connected to the main irrigation supply line, so that the fertilizer can be selectively routed to each greenhouse section. To let each treatment have the same quantity of fertilizer, and prevent the leaching process of fertilizers, through excessive amount of water deliver through irrigation. This takes place by estimating the time needed for injection compared to the time needed for treatment one (T1), which will have the least amount of water delivery through the irrigation process. The farmer used his estimation methods in applying the amount of fertilizers needed. Thus random amounts have been used, and unfortunately this will have negative impact on both plants growth, in case of shortage, and the environment (soil and water) by increasing the salinity in the case of excess amounts. In addition if the farmer use proper amount of fertilizer, the intensive use of water delivery will leach fertilizers to a depth out of the range of the cucumber root zone, and the benefit of fertilizers will decrease (if not vanish).

Chapter:5

Results and discussion

5.1 Soil and water analysis:

Soil type refers to the physical makeup of the soil. Basically, soil is composed of decomposed mineral matter (sand, silt, and clay), and decomposed organic matters (plant or/and animal residues). The soil site conditions of cucumber farm consist of a deep, friable, well drained, sandy loam. Cucumbers were grown on soils that have good water infiltration rates, and good moisture-holding capacity. Hence cucumber can be grown in different types of soil. The soil type is not as important as soil management for cucumber production, especially soil preparation, and fertilizers. Soil leveling and the use of high beds to facilitate drainage may be necessary in the case of the heavier soils. (Seelig, 1972). Soil should not be compacted and the pH should not be acidic medium. Cucumbers are very sensitive to cold, and moderately sensitive to salinity. Salinity must not exceed 2.5mmho/cm,as per National Engineering Handbook, 1993 .Plants as well as the fruit can be injured by even a slight frost (Lorenz et al, 1988).Unfortunately the cucumber crop had suffered from frost for more than five days, (from 11/1/2008 to 17/1/2008) which severely affected the crop growth. Cucumber can be grown well in the optimum temperature- between 18°C and 30°C (Yamaguchi, 1983.). Temperatures above 30°C or below 12°C slow the growth and maturity of the crop. Cucumbers require a constant supply of moisture during the growing season. Moisture fluctuation, especially soil water depletion, will cause growth deformity, which can reduce both the yield and the quality of the crop.

Soil's analysis was performed for two samples, which were analyzed for tow different depths. Depths ranged between 0 - 25 cm, and 25 – 50 cm.

a) The depth between 0 and 25 cm : The soil analysis at this depth, indicates that the soil is slightly alkaline, with low value of electrical conductivity (Ec).Also chemicals have concentrations within suitable range for cucumber cultivations, and, the Sodium Adsorption Ratio (SAR) is slightly low which can be defined as the proportion of sodium Na^{+} ions compared to the concentration of calcium Ca^{+2} plus magnesium Mg^{+2} is slightly low, as tabulated in table 5.1 below .

The table (5.1) The results of the first soil analysis, depth ranging from 0 to 25cm

pH	Ec	CaCO3	Cl^{-}	SAR	Ca^{+2}	Mg^{+2}	Na^{+}	$NO3^{-}$	P^{-3}
unit less	ds/m	%	%	unit less	ml/L	ml/L	ml/L	ml/L	ml/L
7.48	3.91	49.0	4.76	2.26	2366.53	368.65	448.68	29.46	22.85

b) The depth between 25 and 50 cm: The soil analysis results were tabulated in table (5.2) shows different results from the previous one. It is more alkaline and has more concentrations of chloride , and magnesium. This refer to an increase of salinity due to the soil of lisan formation in this area, with low concentrations of calcium, sodium, nitrogen and phosphorous. These chemicals are responsible, mainly sodium, for decreasing the electrical conductivity (Ec) at this depth.

Table (5.2) Results of the second soil analysis, (Depth ranging from 25 to 50 cm).

pH	Ec	CaCO3	Cl^{-}	SAR	Ca^{+2}	Mg^{+2}	Na^{+}	$NO3^{-}$	P^{-3}
Unit less	ds/m	%	%	Unit less	ml/L	ml/L	ml/L	ml/L	ml/L
7.65	3.05	48.7	5.29	2.26	2150.2	386.24	183.99	14.52	14.52

The pH value is slightly higher than that of the optimum pH for cucumber (6 – 7). But cucumbers can also grow well in alkaline soils of pH = 8.5, but never grow in acidic soil with pH less than 5.5.

The Ec is an indicator of salts in the soil. There is a difference in values related to the layers. The upper layer shows higher Ec value due to the high evaporation and its higher absorbance to fertilizers than the bottom layer, due to filtration process, during water percolation through soil.

The chemical concentration is variable according to the depth, but N- NO3, P, and Na have higher concentrations in the upper layer due fertilizers.

Some soil properties of the site were measured and calculated for the tow depths .For example: Soil's moisture content (percentage of weight by weight :w/w) at field capacity, which can be defined as the amount of water held in a soil after gravitational water has drained away. It ranges from between 29.90% to 31.15 % (w/w).

Also, and permanent wilting point, which refers to the water content of the soil where the plant is no longer able to extract it and therefore the plant wilts (Cass,1999).The wilting ratio ranges from 22.75% to 23.05% (w/w).

The available water holding capacity, which expresses the amount of water that can be held in the root zone between the wilting point of the plants and the field capacity, ranged between 13.96% and 15.83% (mm).Some physical and chemical properties of the studied site are listed in table (5.3) .

The bulk density, which is the mass of dry soil per unit bulk volume, was between 1.58 and 1.63 g cm $^{-3}$.Higher bulk density of the soils will decrease the yield of cucumber, due to the highly compaction of the soil's particles which will limit the roots ability to extract water and penetration (Farias-Larios,et al,1994). Soil organic matters which can be defined as all of the organic matters in the soil - exclusive of the undecayed material - was ranged between 2.215 and 2.33 %. The previous parameters of the soil, decreased from the upper to the lower layers. Fine particles soils, and good drainage ability are soil characteristics that support the plant growth, and its yield.

Table (5.3) Selected properties of the investigated at the site

Soil depth (cm)	Field capacity FC% (w/w)	Wilting point WP% (w/w)	Water holding capacity (available) AWC (mm)	Bulk density BD (g/Cm3)	Organic matter OM (%)
0–25	31.15	22.75	15.83	1.63	2.33
25–30	29.90	23.05	13.96	1.58	2.21

The soil texture is a soil property used to describe the relative proportion of different grain sizes of mineral particles in a soil. The textural chart is used to describe the soil texture is shown in figure (5.1). Particles are grouped according to their size into what are called soil separates (clay, silt, and sand).

It is a measurement of the proportion of mineral particles of different sizes that are found in the same sample of soil (sand, silt, clay), at both depths which can be classified as clay loam. The soil's proportions were found to be different. For depth between 0 and 25 cm, it was found that numerical proportion (% by wt.) of sand, silt and clay in the soil is as follows: Clay 36.12%, silt 26.48% and sand 37.4% (clay loam).

For the depths between 25 and 50 cm analysis resulted in clay 44.34%, silt 21.64% and sand 38.02 %,(clay).

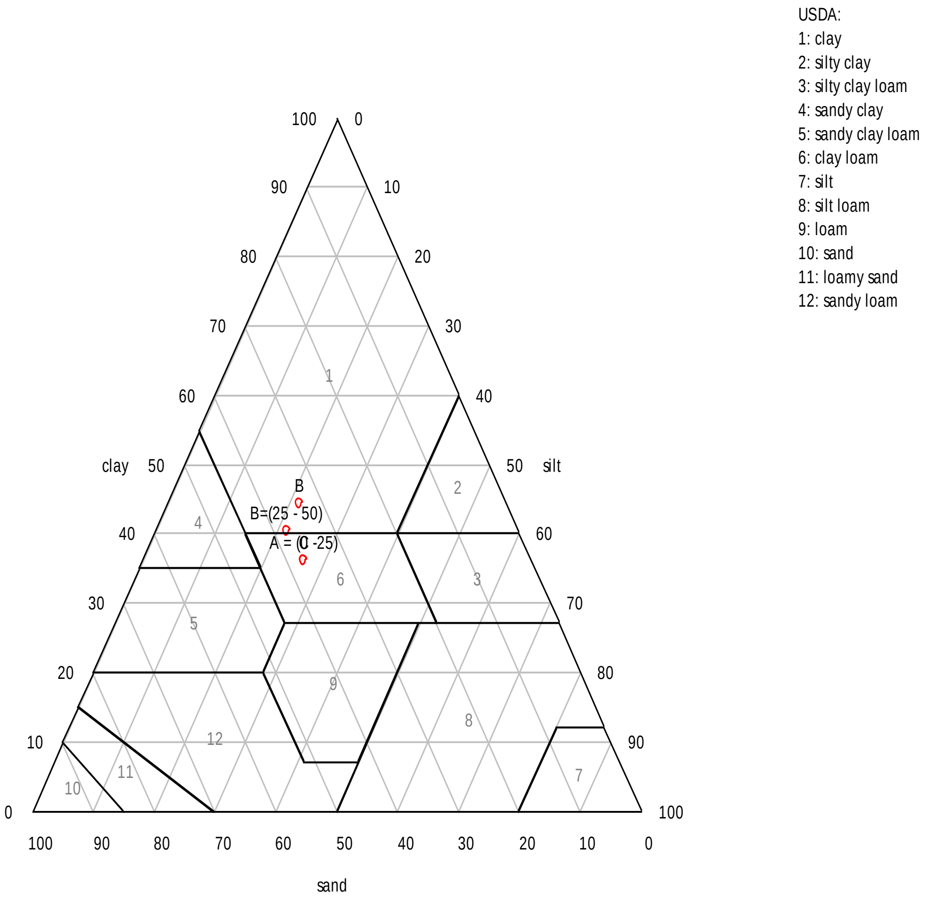

Figure (5.1): Soil texture chart,

Water Analysis:

Source of water is Al Nuweimeh spring. This water is stored in an agricultural pond. The spring in the Jericho area is influenced by structural features. The rate of discharge is about 84L/sec and 2,646,750 m^3/yr. The spring has relatively stable discharge, and it is not affected directly by the rainfall. The faulting system of the aquifer is important in controlling the flow of the spring. It belongs to Dyuk group springs (Dyuk, Shosha and Nuweimeh) (Abed Rabbo et al, 1999).

Two water samples have been collected to be analyzed. The first from the source (spring), and the second from the dripper inside the site. Water analysis calculated by the farmer, present in table (5.4) bellow.

Table (5.4) Results of spring water analysis

pH	Ec	Cl^-	SAR	Ca^{+2}	Mg^{+2}	Na^+	$HCO3^-$
Unit less	μs/m	ml/L	Unit less	ml/L	ml/L	ml/L	ml/L
7.95	618	62.07	0.92	19.2	11.8	22.03	54.9

Other water sample was collected from the dripper inside the greenhouse, and analyzed. The results of the analysis are shown in table (5.5) below.

Table (5.5): Results of site water analysis.

pH	SAR	Ec	Cl^-	HCO3	Ca^{+2}	Mg^{+2}	Na^+
7.02	0.9826	μs/m	ml/L	ml/L	ml/L	ml/L	ml/L
		635	77.99	183.06	32.87	43.74	52.00
		TDS	SSP	K^+	NH4	$SO4^{-2}$	$NO3^-$
		mg/l	%	mg/l	mg/l	mg/l	mg/l
		338.63	31.30	6.00	0.71	51.00	19.50

Comparing both results show differences in results. For example, the pH value in the farmer analysis is higher (more basic), while the pH of water is still in the range accepted for the cucumber plantation (6.0 – 8.5) (Peterson, 1999),(for further reading see appendix 10 and 11).

The electrical conductivity (Ec) showed a slight difference between analyzed samples. The second resulted in higher value due to the increased concentration of some chemicals.

However , Ec values are still in the acceptance range (0 – 3 ds/m). Hence, both values classified the irrigation water as of good quality .

Sodium adsorption ratio (SAR) value for farmer analysis is less than that in the second analysis and this can be explained due to the mud lining of the pond, which is from the lisan soil formation with high concentrations of evaporate minerals. This explains the high concentration of these chemicals in the second analysis, In spite of this difference, the SAR value is still in the acceptance range (0 – 15) (Peterson, 1999).This will classified water irrigation as low in sodium, and can be used for irrigation for almost all soils ,with little danger. The bicarbonate level is essentially a measure of the minerals in the water that act as bases. These bases neutralize acids in the substrate solution, and cause the pH of the substrate solution to increase over time. These bases could be thought of as a "lime" in the water. Therefore, the bicarbonate level can also be thought of as water's acid neutralization potential. The bicarbonate or alkalinity level is the property of water that has the greatest effect on the pH of substrate solution. When considering a water source for irrigation purposes, it is far more important to determine the alkalinity level than the pH (Evans, 2003).

The higher the water alkalinity level, the more water applied, and the longer the crop duration, the greater the potential pH increases. The use of basic fertilizers will cause the pH to increase over time, hence cucumber can grow in alkaline medium (Peterson, 1999).

Total dissolved salts (TDS),which has the soluble sodium percentage with the value of 338.63 mg/l which is in the acceptance range (0 – 2000 mg/l) and a grouping the irrigation water as medium salinity (Peterson,1999). Soluble sodium percentage (SSP) which is defined as the percentage of the ratio of the concentrations summation of Na^+ and K^+ to the concentrations summation of Na^+,K^+,Ca^{+2},and Mg^{+2}, has the value of 31.3%, so water can be classified as of good quality for irrigation.

5.2 Plant growth and water requirement:

The irrigation was applied from December 12, 2007, through January 17, 2008. For initial and development stages, (see appendix 3). Small cucumber plant's size coupled with low evapotranspiration resulted from the cold weather, lowered the demand for irrigation water. The water requirement for the plants will increase due to the growth of the cucumber plants and the meteorological factors (like temperature, and humidity).This will cause Eto to increases moderately. After the cucumber fruit appearance on the stems, more cucumber plants blossomed, and more fruits appeared. The first product has been harvested in January 23, 2008. Plants needed more water to meet the needs for more succulent fruits, and higher soil evaporation that resulted from higher temperatures. Thus, water requirement increased dramatically.

The experiment was designed to control the amount of water delivered to each treatment. These treatments T1, T2, T3, and T4 were irrigated according to the changes in the reference Evapotranspiration value (Eto) by the percents of 80%, 90%, 100% and 110% respectively.

For T1, the crop evapotranspiration (Etc) was equal to the crop coefficient multiplied by 0.8 Eto

Etc = Kc * 0.8Eto equation (5)

For T2 ,the crop evaptranspiration (Etc) was equal to the crop coefficient multiplied by 0.9 Eto

Etc = Kc * 0.9Eto equation (6)

For T3, the crop evaptranspiration (Etc) is equal to the crop coefficient multiplied by Eto

Etc = Kc * Eto equation (7)

And for T4, the crop evaptranspiration (Etc) is equal to the crop coefficient multiplied by 1.1 Eto

Etc = Kc * 1.1Eto equation (8)

While T5 was irrigated by the farmer's method and considered as the control treatment for the experiment.

5.3 Water Use Efficiency (WUE)

Water use efficiency (WUE) is defined as the ratio between crop yield and the amount of water applied to grow that yield from irrigation and has the unit of Kg/m^3 .

$$WUE = \frac{\text{Crop yield (usually the economic yield)}}{\text{Water used to produce the yield}}$$ equation (9)

and this value used in the case of water scarcity and WUE were calculated as fresh fruit cucumber yield divided by Etc and irrigation water applied volume, respectively.

$$WUE = \frac{Ya}{Ets}$$ equation (10)

Where:

WUE is the water use efficiency as kilogram per cubic meter (Kg/CM).

Ya is the cucumber crop yield in kilogram per donum (kg/donum).

Etc is evapotranspiration of cucumber calculated according to:

Etc = Eto * Kc

Where Etc measured in cubic meter per donum (CM/donum). (Stanhill, 1986). This can be applied in the case of T1, T2, T3, And T4. Irrigation water use efficiency (IWUE) is obtained as the fruit weight from per unit irrigation water (IW) used in producing the crop.

$$\text{IWUE} = \frac{Y_a}{\text{IW}} \quad \text{equation(11)}$$

Where Ya is the cucumber yield. This equation can be is utilized in the case of T5 (the farmer treatment), because the farmer delivered water without using Etc, and the total water applied to the treatment T5 had been delivered through irrigation processes.

ET_c and IW were similar in T3. However, the IW values were found to be much higher than ET_c values in the case of T5. Thus, it could be concluded that the water extracted by the crops from the soil, in this treatment, was much less than the water applied. If the crop yield (appendix:8) is expressed in kilogram, and water use is expressed in cubic meter, then WUE has units of kg/ m^3 .The simple calculation can prove that; the treatment with least water consumption has the highest water use efficiency, and this trend is summarizing in table (5.6) and figure(5.4).

Table (5.6) water use efficiency, and the different treatments, with there yields and water consumption

Treatments	T1	T2	T3	T4	T5
Yield (Kg/donum)	8980	9470	9130	10170	10040
Water volume consumed (m^3/dunum)	130	145	162	178	281
WUE (kg/m3)	69.1	65.3	56.3	57.3	35.7

In general the treatment with the least water consumption has the highest water use efficiency, and the treatments, general trend (according to the experiment results) can be classified in the following order according to the yield: T4 > T5 > T2 > T3 > T1.

Based on the water consumption, treatments have the following order:

T5 > T4 > T3 > T2 > T1.

While the treatments order according to the water use efficiency is as follows:

T1 > T2 > T4 > T3 > T5.

The previous trends can be summarized in the following histogram, figure (5.2), which facilitates the comparison between different treatments according to the water consumption, yield and water use efficiency (WUE).

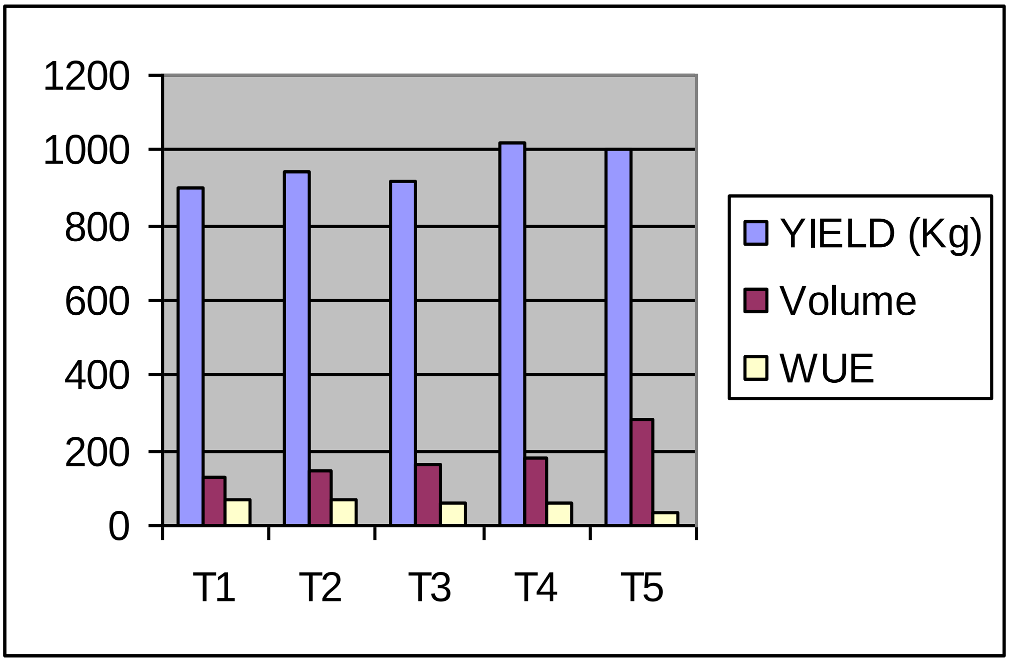

Figure (5.2): water use efficiency, water volume consumption and yield of cucumber from five treatments, in the year of 2008.

The figure (5.2) shows that the treatment 5 (T5) is the biggest consumer of water and has the least value of water use efficiency. While T4 has the biggest production, and T1 has the least production, but it has the biggest water use efficiency.

Farmers cultivate their farms as a source of income, and they may completely depend on the farm's production. So, the results of the research can satisfying the farmers trend to have the largest crop with least drop (water delivered), in order to have the highest benefit(value of production) with least water consumption.

5.4 Cucumber Results

Cucumber plants have moderately deep roots, and long taproots as well as shallow fibrous root systems, but they do not seem to be as extensive as others in this family. It needs sufficient amount of water to sustain the cucumber quick growth, with life duration of about 130 days. The crop must be supplied with plenty of moisture for its vigorous growth. Irrigation is important for both plant and fruit growth. The objective of the experiment is to optimize the water volume delivered in irrigation. Water used according to the experiment design for each treatment controlled by valve and flow meter. The irrigation started from December, 12, 2007 through March, 2008.This time was divided to 31 irrigation intervals. The volume of water that had been delivered through the duration of the experiment is illustrated in table (5.7) bellow:

Table (5.7): volume of water consumed (m^3) by the treatments

Treatment	T1	T2	T3	T4	T5
Volume (m^3)	13	14.5	16.2	17.8	28.1
Cubic meter/donum	130	145	162	178	281
Saving percent %	53.9	48.4	42.8	36.6	0.00

Based on the tabulated results, the treatments can be ordered according to the volume of water consumed, during the experiment execution, as: T5 > T4 > T3 > T2 > T1, and the water saving (percent) of the treatments has the following trend: T1 > T2> T3 > T4.The sole purposes of farming is an economical factor .Therefore, farmer needs to follow the most productive method of cultivation, without scarifying the water savings factor. It can be noted that (T4) has the highest amount of production with water savings 36.6%.

For Jericho district, the production of cucumber was 7632 tons and the total area cultivated by cucumber was 2398 donums, with about 538 donums in greenhouse. The average yield was 9 tons per donum in west bank including Jericho area, while the value of the total cucumber production in Jericho area was 3.643 million $(477.3 $/ ton), (PCBS, 2007) .By simple calculation according to the results of the research, farmers can expand the greenhouses area by 194 donums and increase the production by 1746 tons, with total value as 0.83 million $ in each season by using the same amount of water by applying the water deliveries in case of T4.

The results from the available data support the prediction that a large amount of water is wasted by following the farmer's irrigation method (T5). This will be clearer by comparing with other treatments such as (T4), which indicates that the water saving is about 36.6%. In general the water saving percent can range from 53.9% in the case of T1 to 36.6% in the case of T4.

Cucumber consumed water during the season in different intervals due to differences in the Eto and Kc values. So there is fluctuation but in the increasing trend in the irrigation operation. Figure (5.3) represents the case of (T 3) which is a good example.

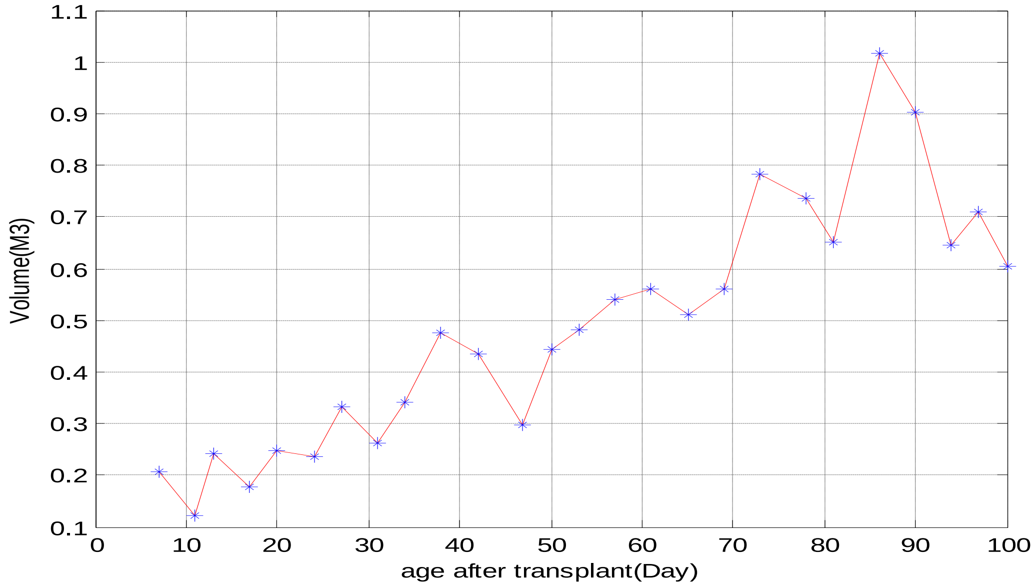

Figure (5.3): Water volume consumption in m^3 by treatment (T3) with respect to plant age.

The fluctuation in the curve of figure (5.3) can be explained due to the differences in the average Eto, temperature, irrigated interval and the growth stage of the plant.

Figure (5.4) represents the accumulation of water consumption by each treatment. The linear relationship can be modulated through linear equation, to be fit correctly with these data, and figure.

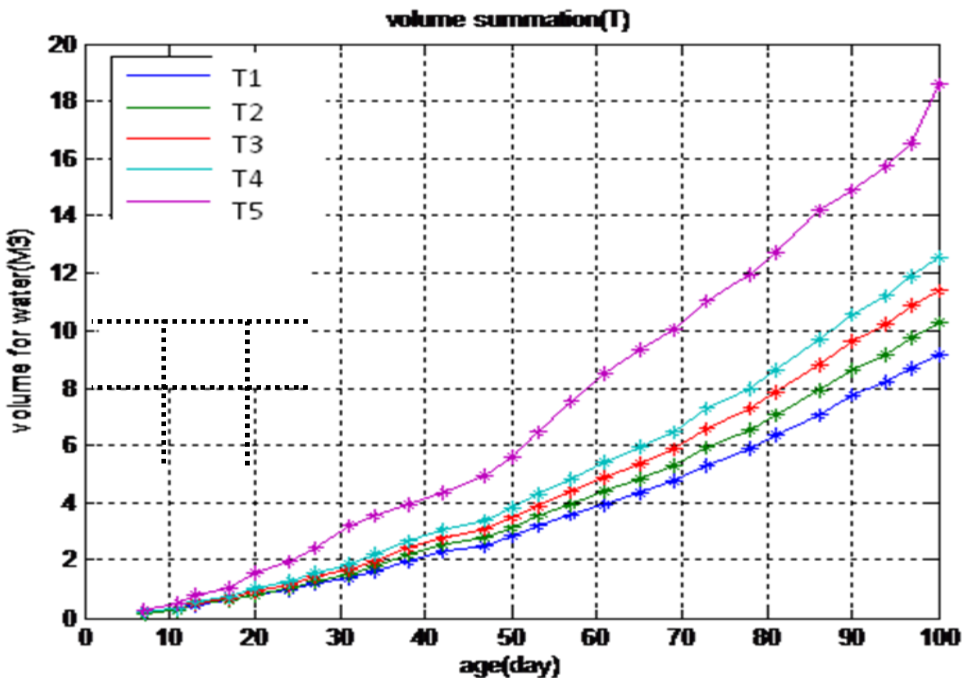

Figure (5.4): Accumulation of water consumption for different treatments with respect to plant ages.

Water consumption vrs. age for each of the five treatments can be represented for the whole growth period as shown in the diagram. It is clearly that T5 consumed more water than others, while the other treatment can be arranged in water consumption order according to the increasing in the percent of Eto, for each treatment. By using the MATLAB program, the data is more fitted to the second order polynomial in the form:

$$\mathbf{Y = a\,X^2 + b\,X + c} \qquad \text{equation (12)}$$

Where Y is water volume accumulation in cubic meter, X is plant age in days and the equation parameters (a, b, and c) for each treatments are shown in table (5.8).

Table (5.8): Parameters of the second order polynomial, expressing the relation between water volume (m^{3}) and the plant's age (days).

Parameters for equations of treatments	a	b	c
Treatment 1 (T1)	0.0007	0.0233	0.0010
Treatment 2 (T2)	0.0008	0.0250	- 0.0158
Treatment 3 (T3)	0.0009	0.0278	-0.0175
Treatment 4 (T4)	0.0009	0.0306	-0.0194
Treatment 5 (T5)	0.0011	0.0738	- 0.4057

The cucumber yield fluctuates during the harvest stage within the replicates(R) of each treatment, or comparing between treatments themselves. Table (5.9) shows the yield of the replicates of each treatment.

Table (5.9): Variation in the replicates yield for each treatment, and the variation in yields between treatments.

Treatment	T1			T2			T3			T4			T5		
replicate	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
Yield (kg)	300	295	303	292	353	302	271	307	335	316	330	371	302	358	344
Average R	299.3			315.7			304.3			339			334.7		
∑ yield (kg)	898			947			913			1017			1004		

From table (5.9), replicate one (R1) in treatment three T3 has the least yield, and this can be explained according to its order in the experiment (the first replicate) in the green house, and severely effected by the cold north wind. According to the agronomic engineers of the site, the sufficient source of sunlight in the area, and the crucial matter of providing the heat were not used properly .This clearly appear in the orientation design of the greenhouses from south to north. Finally farmers delay the usage of ventilation. This orientation made the crop face the cold north wind during winter. This effect has been noticed on the growth and yield of the first replicate, which belongs to treatment T3.This, may be the reason for the ranking of T3 after T2 in the productivity.

Tabulated values in table 5.9 foeR1, R2, and R3 of the five treatments are presented in figure (5.5) below.

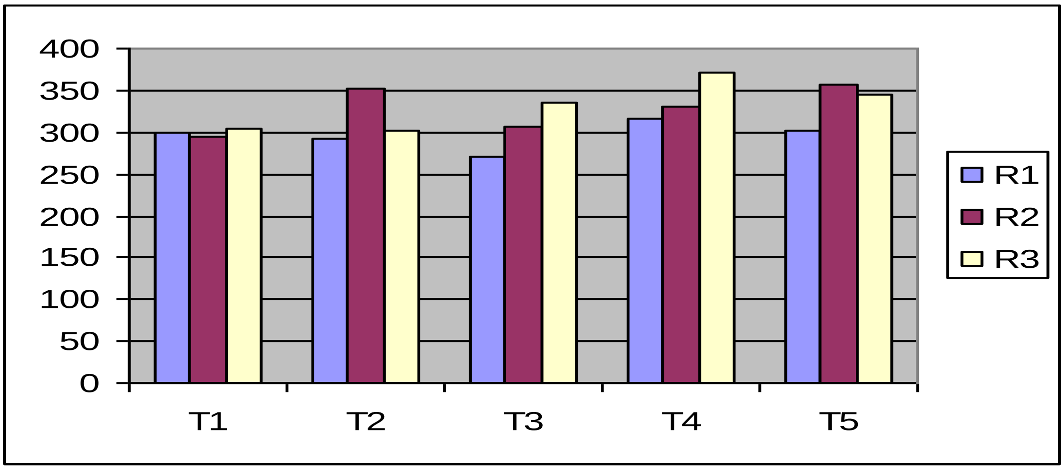

Figure (5.5) the yields of replicate for five treatments.

It can be noticed that R3 of treatment T4 has the highest yield. The largest yield was obtained from treatment (T4) and the smallest yield was from treatment (T1).In general the harvested yield has fluctuation, and not constant. For example the least harvested case for (T2) was the second harvest in January 26, 2008 of 6.425 kg and the highest harvest for the same treatment was the 14th in March, 9, 2008 of 68.110 kg. The fluctuation in the collected harvest was a dependent on number of days after the preceding collection, in addition to the weather conditions, and the plant growth stage (age).

The variation in the average production replicates was in the range of 40 kg .This indicates that the variation is so small. This needs to be taken into consideration in the case of water scarcity or high price of water. The main controlling factor in this condition was the financial value of both water cost and cucumber fruit price .These may be helpful to the farmer in his search for profitable agricultural activities. The fluctuation of yield for each treatment, as mentioned above, depends on the number of days after the preceding collection, the weather conditions (temperature), and the plant growth stage (age).

The following figure (5.6) shows the fluctuation of yield within the harvest season

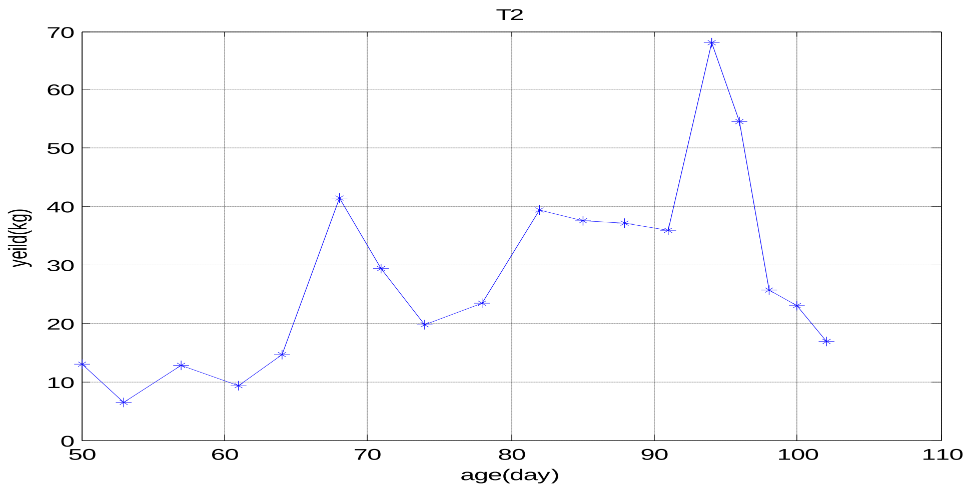

Figure (5.6): fluctuation of yield with increasing trend in treatment (T2).

The yield of each treatment was variable and fluctuation and depends on many factors related to many conditions, such as: The age of plant and its growth during development stage and harvested stage by increasing trends till to the last season stage, it will drop gradually. The time spend after the preceding harvest case by increasing trend but it may effect the fruit quality, hence customers looking for fruit quality such as the shape and size. Weather is another factor specially temperature with direct proportion, in addition the replicate ranking in the experiment execution, for example R1 in T3 ranking the first with least production. Finally, the amount of water consumed during irrigation was with direct proportion with production. The accumulation of yield was steadily increasing for all treatments. Figure (5.7) shows the steady increase along the harvest duration, for all treatments.

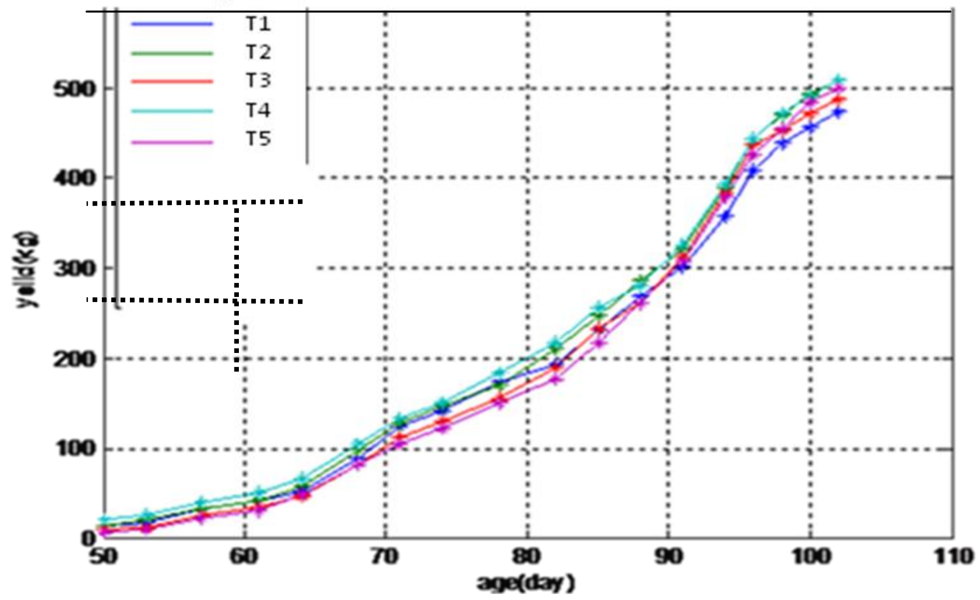

Figure (5.7): Accumulation of yields for the five treatments (second order function).

The curves in figure (5.7) are more fitted to the second order functions, by using MATLAB program, and the general equation can be written as

$Y = a X^2 + b X + c$ equation (13)

where Y is the yield accumulation, X is plant age (in days), and the equation parameters a, b, and c are found fore each treatment T in table (5.10).

Table (5.10): parameters for the second order polynomial in the case of yield accumulation

Parameters for equations of treatments	a	b	c
Treatment 1 (T1)	0.1511	-13.9057	331.6029
Treatment 2 (T2)	0.1708	-16.1803	398.1636
Treatment 3 (T3)	0.1787	-17.5836	444.1529
Treatment 4 (T4)	0.1639	- 15.2957	377.9152
Treatment 5 (T5)	0.1962	- 20.1715	531.7823

There was symmetry between curves, which are representing the water consumption, and the yield for all treatments. Figure (5.8) represents that, which shows yields of different treatments verses water consumption during the crop life. It is clear that the yield of each treatment increases along the harvest season, and reach the zenith phase at the same time for the same harvest. this may be explained due to the nature of the plant physiology ,plant age or the climate conditions, especially the temperature rise, during the days of fruit maturity. Table (5.11) and figure (5.8) demonstrate the zenith phase for each treatment, and the water volume consumed until that stage.

Table (5.11): comparison between different treatments in the zenith stage yields and the volume of water consumed through date March, 7, 2008

treatment	T1	T2	T3	T4	T5
Zenith phase yield (kg)	56.465	68.110	72.180	65.975	72.325
Water consumed (m^3)	7.724	8.639	9.602	10.561	14.640

The zenith stage can be achieved during the crop life at the same time regardless of the water volume which had been delivered. Then yield tends to decrease gradually, as the crop age becomes older, and this is a natural fact related to the nature of the crop life cycle.

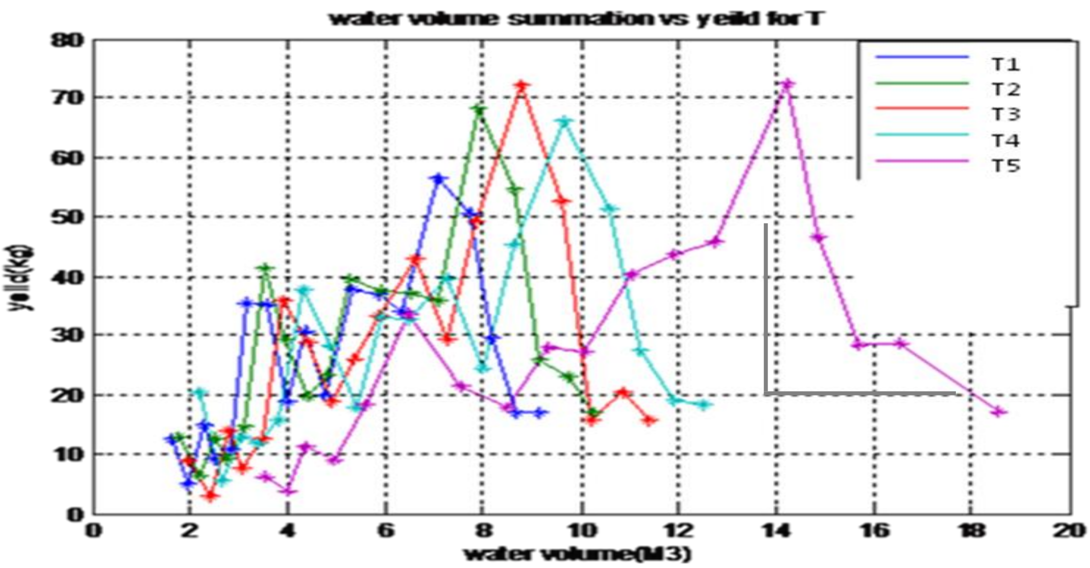

Figure (5.8): yields of different treatments with respect to consumed water accumulation.

As the results indicate in the above figure curve , T4 is the most favorable to the farmer, who is looking for the highest production, which had less water consumption compared to the production of the farmer's treatment. This fact about T4 and other treatments can be illustrated and summarized in the figure (5.9).

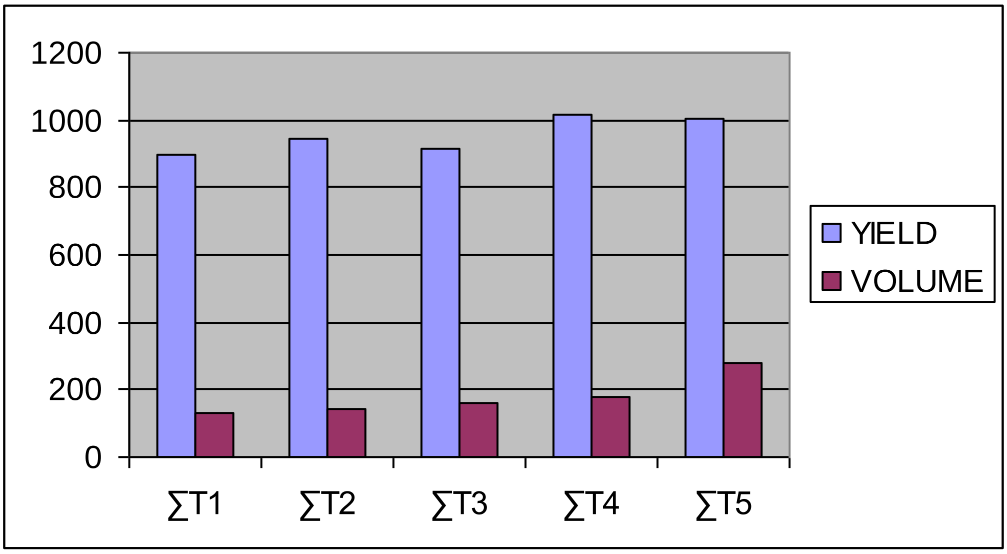

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Figure (5.9): comparison between different treatments in yields verses water consumption.

The total volume of consumed water by each treatment, and the total harvested yield for each treatment can be summarized in above figure (5.9). The results indicate that the most water consumers is treatment T5, which belongs to the farmer, and the least consumer is treatment T1. The most yield production is T4, and the least production is T1. But in the case of critical situation of water scarcity, or high pricing of water, T1 will promote more satisfaction.

Farmer may looking to the production regardless to water consumed, so T4 will be more satisfaction from economically side and saving water by percent of more than36%. But in general farmer can save water by percent rage from 36% to 53 %, with production adapted to average cucumber production in West Bank and Jericho area.

5.5 Conclusion and recommendation

The results indicate that farmer can save at least 36% of water, and then expand the size of the cultivated land and slightly more production by using proper method in the cultivation process such as good quality of water, using protection cultivation (greenhouse) with proper design and management, using drip irrigation system, using plastic mulch which can decrease soil's moisture loss of 10% to 50%, and finally using the method of reference evapotranspiration estimation of water requirement to cucumber.

For Jericho district, the production of cucumber was 7632 tons and the total area cultivated by cucumber was 2398 donums, with about 538 donums in greenhouse. The average yield was 9 tons per donum in the greenhouses. The value of the total cucumber production was 3.643 million $(477.3 $/ ton), (PCBS, 2007) .By simple calculation based on the results of the research, farmers can expand the greenhouses area by additional 194 donums, and increase the production by 1746 tons. The gained value of 0.83 million $ each season, can be achieved by using the same amount of water in the case of T4.But T1 production (8980 Kg/donum) was very close to the average value of cucumber production in West Bank (9000 kg/donum), so farmer can save water by more than 50% and cultivated double area by the same amount of water consumed, and this will double the production and double the gained value of the total cucumber production and may exceeded 7 million $ per year.

This method can improve the irrigation scheduling. This has several advantages, it enables the farmer to schedule water rotation among various fields to minimize crop water stress, and maximize yields. Also reduces the farmer's cost of water and labor by having less irrigation. This can be achieved by maximizing the use of soil moisture storage, and lowering fertilizer's costs, by holding surface runoff, and deep percolation (leaching) to a minimum. It increases the net return by increasing crop yields, and crop quality. It results in additional returns by using the "saved" water to irrigate other crops that otherwise may not be irrigated during water-short periods.

Water pricing and stiff regulations related to water consumption, coupled with enhancing farmer's knowledge and better water management education to the farmers, can help following new water saving techniques The applying irrigation water price may help in saving water that may lead to expanding in irrigated cultivation area and changing crop irrigation pattern, but there is no set of irrigation water price and farmers used water without any care to conserve water.

An effective farming management is necessary to achieve suitable production of cucumber, and protection of the environment. The qualified farmer who can deliver proper amount of water and the proper amount of fertilizers will achieved water savings, good benefits of yield, and protect the environment.

It is clearly that more researches can be conducted by using the same experiment, but for different conditions such as: Different soil texture, different water quality, different sites, different seasons, and different variety of cucumber, and other similar vegetables. Also the irrigation system enhancing used to supply water to crops. Further researches may be done using the same application of the experiment design but using Kc values, measured according to the FAO values for both open field and greenhouses cases. Finally other researches can also done by using one of the following methods of irrigation scheduling : gravimetric soil moisture sample ,tensiometers, electrical resistance blocks and water budget approach on cucumber under the same conditions to optimize the water requirement for cucumber or any other crop.

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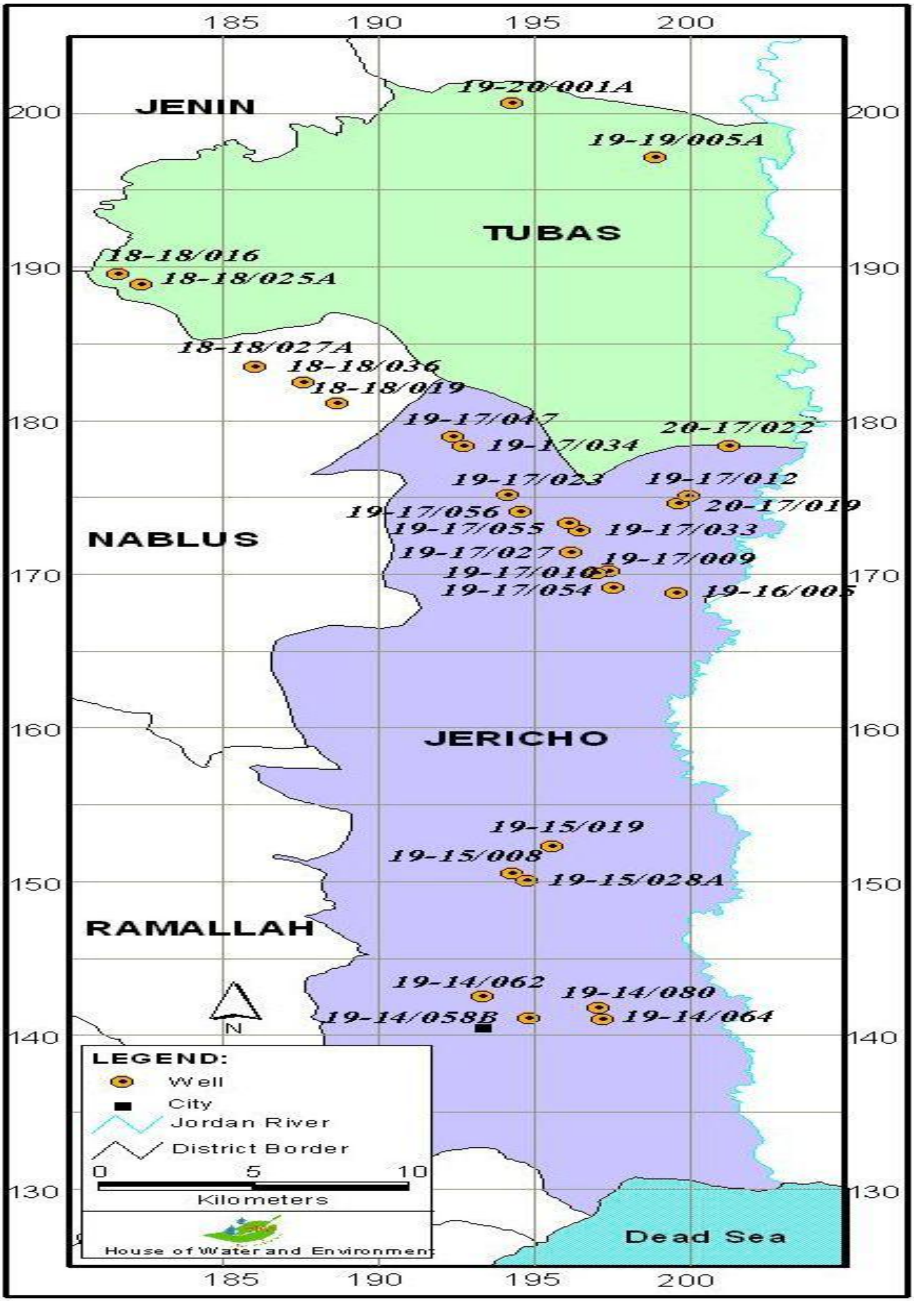
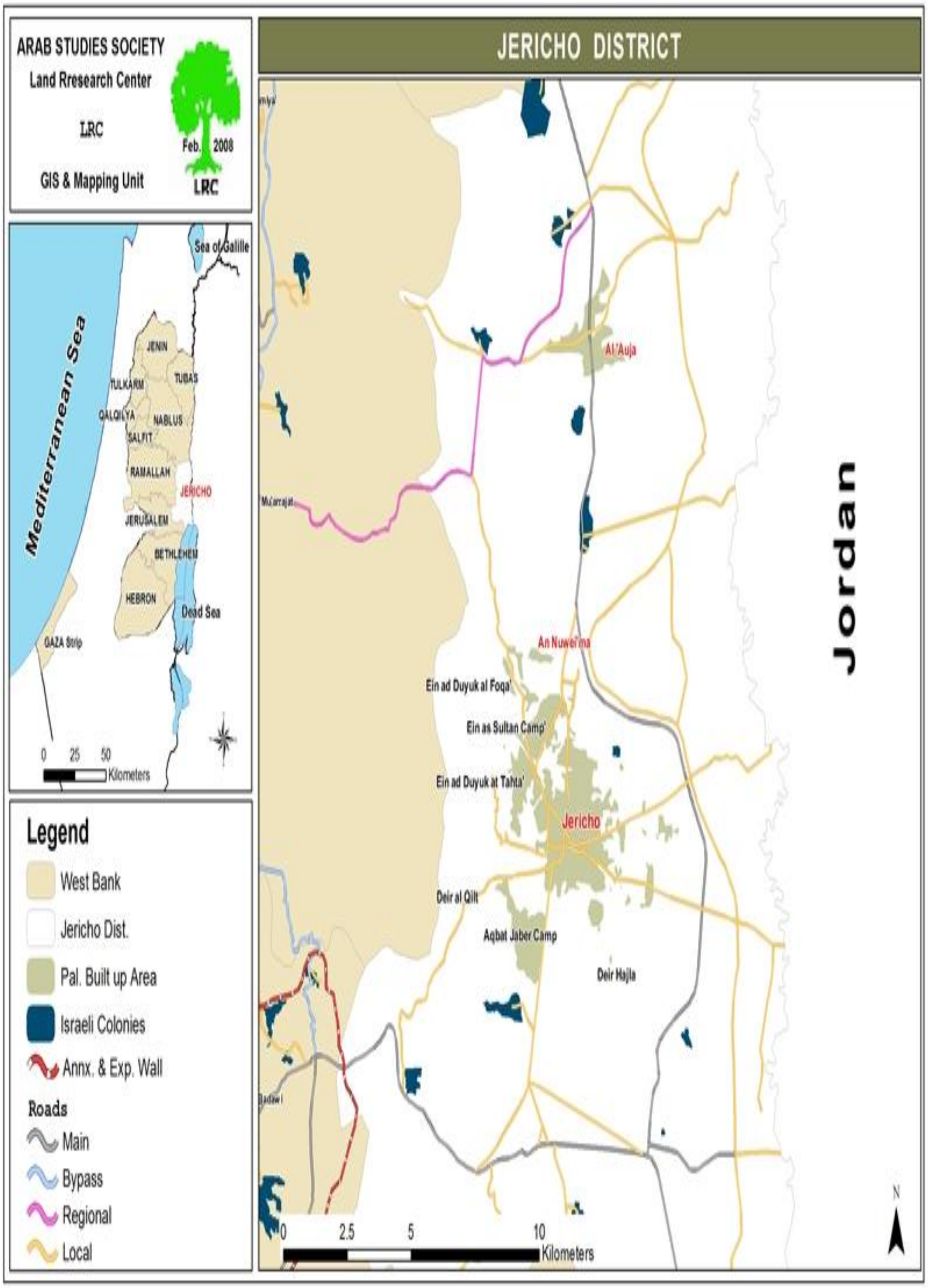
Appendix: 1

Wells distribution in the study area (Jericho) (House of water and Environment)



Appendix : 2

Springs in the study area (Arab Studies Society, Land Research Center)



Appendix 3

Average reference evapotranspiration values (NCARTT)

Average reference Evapotranspiration (Eto) measured through years 2002 to 2007 in December, January, February and March months.

The average values of daily reference evapotranspiration mm/day (Eto)				
Day in month	December	January	February	March
1	1.4576	1.160	1.58	2.4094
2	1.2874	1.138	1.379	2.6504
3	1.5596	1.200	1.49	2.3188
4	1.3572	1.172	1.575	2.2974
5	1.264	1.230	1.622	2.4738
6	1.3344	1.118	1.48	2.5768
7	1.337	1.091	1.45	2.3208
8	1.2396	0.924	1.425	2.6104
9	1.8608	0.991	1.353	2.0936
10	1.1304	1.095	1.262	2.1854
11	1.2062	1.201	1.421	2.6948
12	1.1502	1.037	1.262	2.2592
13	1.2934	1.114	1.481	2.2652
14	1.2916	1.116	1.759	1.9726
15	0.98	1.093	1.489	2.1602
16	1.2782	1.118	1.599	2.3274
17	1.2046	1.155	1.649	2.1646
18	1.3062	1.237	1.722	2.8468
19	1.2238	1.191	1.847	2.2372
20	1.0252	1.088	1.542	2.1786
21	1.08966	0.889	1.896	2.5164
22	1.1508	0.762	1.834	2.788
23	0.8778	1.525	1.92	2.6184
24	1.0840	1.586	2.217	2.5464
25	0.9316	1.450	1.724	2.6532
26	0.8514	1.705	1.321	2.8972
27	1.0942	1.392	1.77	2.9334
28	1.0874	1.258	2.144	2.8682
29	1.1248	1.283		2.8732
30	1.3868	1.231		3.2158
31	1.037	1.325		2.9872

Appendix:4

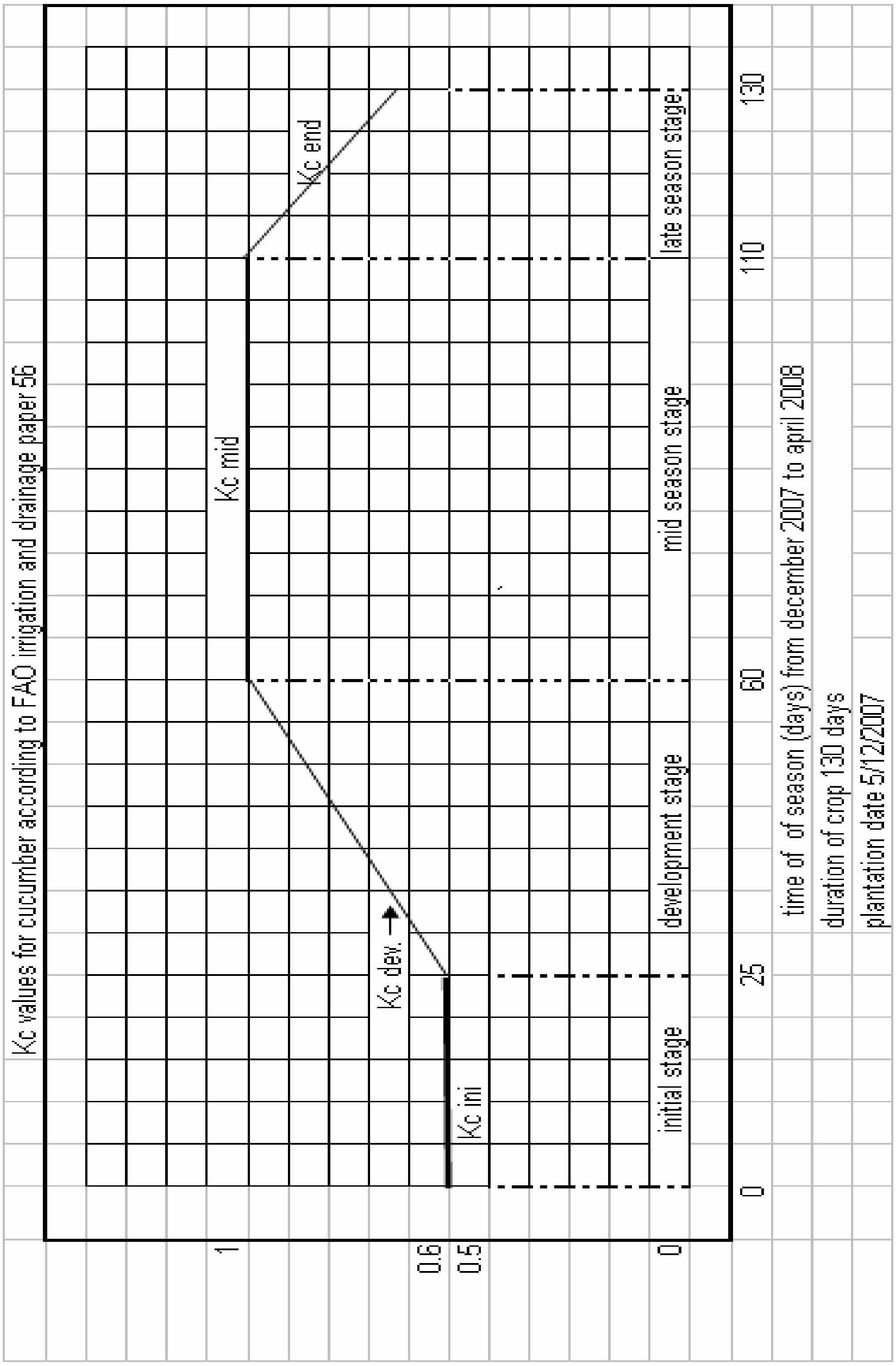
Irrigation cucumber calendar in Jericho area
From 21/11/2007 to 31/3/2008

date	age	stage	date	age	stage	date	age	stage
21/11/2007	**1**	**Initial stage**	**4**	**45**	**Developmental stage**	**17**	**89**	**Mid season stage**
22	**2**		**5**	**46**		**18**	**90**	
23	**3**		**6**	**47**		**19**	**91**	
24	**4**		**7**	**48**		**20**	**92**	
25	**5**		**8**	**49**		**21**	**93**	
26	**6**		**9**	**50**		**22**	**94**	
27	**7**		**10**	**51**		**23**	**95**	
28	**8**		**11**	**52**		**24**	**96**	
29	**9**		**12**	**53**		**25**	**97**	
30	**10**		**13**	**54**		**26**	**98**	
1/12/2007	**11**		**14**	**55**		**27**	**99**	
2	**12**		**15**	**56**		**28**	**100**	
3	**13**		**16**	**57**		**29**	**101**	
4	**14**		**17**	**58**		**1/3/2008**	**102**	
5	**15**		**18**	**59**		**2**	**103**	
6	**16**		**19**	**60**		**3**	**104**	
7	**17**		**20**	**61**	**Mid season stage**	**4**	**105**	
8	**18**		**21**	**62**		**5**	**106**	
9	**19**		**22**	**63**		**6**	**107**	
10	**20**		**23**	**64**		**7**	**108**	
11	**21**		**24**	**65**		**8**	**109**	
12	**22**		**25**	**66**		**9**	**110**	
13	**23**		**26**	**67**		**10**	**111**	
14	**24**		**27**	**68**		**11**	**112**	
15	**25**		**28**	**69**		**12**	**113**	
16	**26**	**Developmental stage**	**29**	**70**		**13**	**114**	
17	**27**		**30**	**71**		**14**	**115**	
18	**28**		**31**	**72**		**15**	**116**	
19	**29**		**1/2/2008**	**73**		**16**	**117**	
20	**30**		**2**	**74**		**17**	**118**	
21	**31**		**3**	**75**		**18**	**119**	
22	**32**		**4**	**76**		**19**	**120**	
23	**33**		**5**	**77**		**20**	**121**	Harvested stage
24	**34**		**6**	**78**		**21**	**122**	
25	**35**		**7**	**79**		**22**	**123**	
26	**36**		**8**	**80**		**23**	**124**	
27	**37**		**9**	**81**		**24**	**125**	
28	**38**		**10**	**82**		**25**	**126**	
29	**39**		**11**	**83**		**26**	**127**	
30	**40**		**12**	**84**		**27**	**128**	
31	**41**		**13**	**85**		**28**	**129**	
1/1/2008	**42**		**14**	**86**		**29**	**130**	
2	**43**		**15**	**87**		**30**	**131**	
3	**44**		**16**	**88**		**31**	**132**	

Mohammad shakarnah

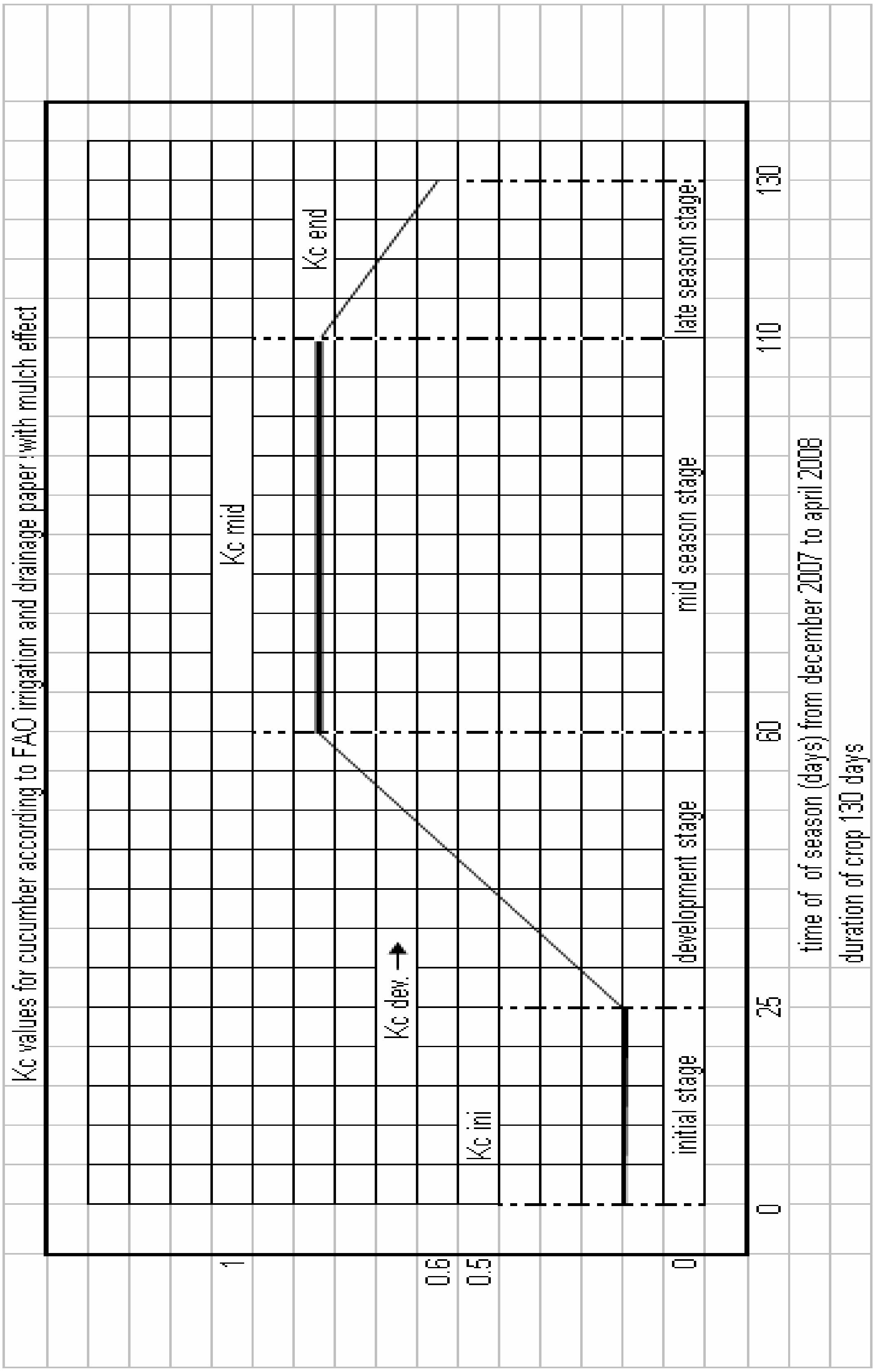
Appendix:5

Crop coefficient (Kc) for cucumber in open fields



Appendix: 6

Crop coefficient (Kc) for cucumber in protection fields



Appendix : 7

Adjusted Crop Coefficients (Kc) for cucumber according to age in days in greenhouse
Age measures by Days after Transplanted (DAT)

age	Kc	age	Kc	age	Kc	age	Kc
7	0.438810981	38	0.785975507	69	1.024590164	100	1.024590164
8	0.447109159	39	0.80096366	70	1.024590164	101	1.024590164
9	0.455565958	40	0.816243125	71	1.024590164	102	1.024590164
10	0.464184476	41	0.831819775	72	1.024590164	103	1.024590164
11	0.472967872	42	0.847699612	73	1.024590164	104	1.024590164
12	0.48191937	43	0.863888764	74	1.024590164	105	1.024590164
13	0.49104226	44	0.880393496	75	1.024590164	106	1.024590164
14	0.5003399	45	0.897220204	76	1.024590164	107	1.024590164
15	0.509815715	46	0.914375429	77	1.024590164	108	1.024590164
16	0.519473201	47	0.93186585	78	1.024590164	109	1.024590164
17	0.529315925	48	0.949698288	79	1.024590164	110	1.024590164
18	0.539347529	49	0.967879558	80	1.024590164	111	1.024590164
19	0.549571728	50	0.986411628	81	1.024590164	112	1.024590164
20	0.559992315	51	1.005141596	82	1.024590164	113	1.024590164
21	0.570613161	52	1.020668529	83	1.024590164	114	1.024590164
22	0.581438215	53	1.024409986	84	1.024590164	115	1.024590164
23	0.592471511	54	1.024584254	85	1.024590164	116	1.024590164
24	0.603717166	55	1.024589973	86	1.024590164	117	1.024590164
25	0.615179381	56	1.024590158	87	1.024590164	118	1.024590164
26	0.626862445	57	1.024590164	88	1.024590164	119	1.024590164
27	0.638770738	58	1.024590164	89	1.024590164	120	1.024590164
28	0.650908731	59	1.024590164	90	1.024590164	121	1.024590164
29	0.663280987	60	1.024590164	91	1.024590164	122	1.024590164
30	0.675892167	61	1.024590164	92	1.024590164	123	1.024590164
31	0.688747029	62	1.024590164	93	1.024590164	124	1.024590164
32	0.701850431	63	1.024590164	94	1.024590164	125	1.024590164
33	0.715207335	64	1.024590164	95	1.024590164	126	1.024590164
34	0.728822807	65	1.024590164	96	1.024590164	127	1.024590164
35	0.74270202	66	1.024590164	97	1.024590164	128	1.024590164
36	0.756850257	67	1.024590164	98	1.024590164	129	1.024590164
37	0.771272916	68	1.024590164	99	1.024590164	130	1.024590164

Appendix :8

The yield (kg) of each treatment (T) in the experiment

No.	yield of T1	yield of T2	yield of T3	yield of T4	yield of T5
1	12.475	13.02	9.07	20.57	6.165
2	4.99	6.425	3.02	5.57	3.77
3	14.95	12.85	13.95	12.925	11.4
4	9.3	9.32	7.54	11.72	8.96
5	10.9	14.65	12.5	15.7	18.35
6	35.33	41.4	35.92	37.78	33.62
7	35.235	29.38	28.87	28.485	21.42
8	18.89	19.73	18.715	17.84	17.805
9	30.805	23.335	26.185	33.17	27.995
10	19.945	39.475	33.24	32.55	27.195
11	37.865	37.54	42.9	39.58	40.34
12	36.75	37.18	29.435	24.54	43.645
13	33.98	35.935	49.27	45.26	45.78
14	56.465	68.11	72.18	65.975	72.325
15	50.695	54.595	52.445	51.415	46.605
16	29.62	25.755	15.75	27.39	28.42
17	17.025	23.055	20.575	24.125	28.755
18	17.02	16.89	15.905	18.38	17.08
19	32.935	37.875	38.21	35.07	39.315
20	40.13	43.34	46.79	54.465	58.12
21	38.46	29.75	33.5	42.7	44.36
22	46.6	45.79	44.86	58.115	48.48
23	32.99	39.335	34.75	43.325	38.7
24	53.63	58.15	51.365	62.485	60.955
25	28.35	27.53	29.72	32.07	34.18
26	28.43	34.9	34.62	35.1	36.875
27	30.99	33.06	28.22	45.53	51.07
28	47.16	47.69	40.255	43.12	43.46
29	46.77	40.76	43.635	49.68	51.465
Total	898.7	946.8	913.4	1017.6	1004.6

Appendix :9

Cucumber yield according to treatments of the experiment

NO	T1	∑	T 2	∑	T 3	∑	T 4	∑	T 5	∑

Appendix :10

R.S. Ayers and D.W. Westcot,1994, Water quality for agriculture, FAO IRRIGATION AND DRAINAGE PAPER 29 Rev. 1Rome, 1985 © FAO

Desirable water quality parameters for greenhouse irrigation water		
pH	5.5 - 7.0	
Alkalinity	plugs/seedlings	1.0 - 1.3 $meq \cdot L^{-1}$
	bedding plants/4-inch containers	1.6 - 2.0 $meq \cdot L^{-1}$
	6-inch and larger potted crops	2.6 - 3.6 $meq \cdot L^{-1}$
Electrical Conductivity (E.C.)	seedlings/cuttings	0.6 $mS \cdot cm^{-1}$ or less
	established crops	1.2 - 1.5 $mS \cdot cm^{-1}$
	problematic water	2.0 $mS \cdot cm^{-1}$ or higher
Nitrates (NO_3^-)	5 ppm or less	
Ammonium (NH_4^+)	5 ppm or less	
P	5 ppm or less	
K	10 ppm or less	
Ca	50 - 120 ppm	
Mg	25 - 50 ppm	
SO_4^-	240 ppm or less	
S	100 ppm or less	
Na^+	50 ppm or less	
Mn	1 ppm or less	
Fe	5 ppm or less	
B	0.5 ppm or less	
Cu	0.2 ppm or less	
Zn	0.5 ppm or less	
Cl^-	100 ppm or less	
F^-	1 ppm or less	

Appendix :11

R.S. Ayers and D.W. Westcot,1994, Water quality for agriculture, FAO IRRIGATION AND DRAINAGE PAPER 29 Rev. 1Rome, 1985 © FAO

GUIDELINES FOR INTERPRETATIONS OF WATER QUALITY FOR IRRIGATION							
Potential Irrigation Problem				**Units**	**Degree of Restriction on Use**		
					None	**Slight to Moderate**	**Severe**
Salinity*(affects crop water availability)*[2]							
	EC_w			dS/m	< 0.7	0.7 – 3.0	> 3.0
	(or)						
	TDS			mg/l	< 450	450 – 2000	> 2000
Infiltration*(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*[3]							
SAR	= 0 – 3	**and EC_w**	=		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		=		> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12		=		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		=		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		=		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*							
	Sodium (Na)[4]						
	surface irrigation			SAR	< 3	3 – 9	> 9
	sprinkler irrigation			me/l	< 3	> 3	
	Chloride (Cl)[4]						
	surface irrigation			me/l	< 4	4 – 10	> 10
	sprinkler irrigation			me/l	< 3	> 3	
	Boron (B)[5]			mg/l	< 0.7	0.7 – 3.0	> 3.0
	Trace Elements (see Table 21)						
Miscellaneous Effects *(affects susceptible crops)*							
	Nitrogen (NO_3 - N)[6]			mg/l	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)						
	(overhead sprinkling only)			me/l	< 1.5	1.5 – 8.5	> 8.5
	pH				**Normal Range 6.5 – 8.4**		

Adapted from University of California Committee of Consultants 1974.