PN-ACE-731
101030

The Hashemite Kingdom of Jordan

Ministry of Water and Irrigation

Report 3114-95-36-05

Water Quality Improvement and Conservation Project

Irrigation Management & Water Quality in the Central Jordan Valley (Baseline Survey)

Water & Environment Research & Study Center - University of Jordan

Development Alternatives, Inc.

USAID

The Technical Assistance Team Includes

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United States Agency for International Development
Contract No 278-0288-00-C-4026-00

April 1995

PREFACE/ACKNOWLEDGMENT

Prior to the start of the Water Quality Improvement and Conservation (WQIC) Project, USAID Jordan requested the Irrigation Support to Asia and Near East Project (ISPAN) to establish an agricultural baseline for the WQIC Project The University of Jordan was subcontracted by ISPAN to determine pre-project conditions in the Central Jordan Valley Measurements were to be made of (1) On-farm irrigation management efficiency, (2) Irrigation diagnostic survey, (3) Economics of agricultural production, (4) Agricultural economic diagnostic survey, (5) Conveyance system efficiency, (6) Irrigation water quality, and (7) Soil investigation Studies (2), (3), and (6) were completed before the USAID centrally funded ISPAN project ended its activities in 1994

A report covering the findings of the winter cropping season was presented to USAID in November 1994 Research investigations for the on-farm irrigation management efficiency, economics of agricultural production, and irrigation water quality continued for the spring and summer seasons The University of Jordan was contracted by the WQIC Project, implemented by Development Alternatives Inc , to continue the study The University of Jordan continued the field research by taking field measurements and conducting lab analysis for the above activities until the end of September, 1994 The aim of this extension was to have data on irrigation, water, and agricultural inputs to cover one year of data for perennial crops

This report presents the main findings during the summer season for the three studies It also compares the results from the winter season with those of the summer season and summarize the results for the whole 1993/1994 cropping season

The study team[1] wishes to acknowledge the USAID Mission in Amman for recognizing the need for the study and providing the financial support

The contributions of Ross Hagan to the study and comments on the report are highly appreciated The assistance and support of Hani Al-Rashid, Muhammad Hanbali are also appreciated Thanks are also extended to Muhammad Jitan, Muhammad Hamdan, May Muzaffar, Suhair Saa'deh, and Osama Hijazi for their assistance in field and laboratory work

[1] The study team consisted of Muhammad Shatanawi, Manar Fayyad, Muhammad Samir El-Habbab, Ibrahim Ghawi, Odeh Al-Jayousi, and Ali Al-Shrouf

EXECUTIVE SUMMARY

Field research was conducted during the growing season of 1993/1994 to measure on-farm irrigation management efficiency (IME) and to evaluate the economics of agricultural production for typical crop and irrigation situations in the Central Jordan Valley and Zarqa Triangle In addition, investigations on irrigation water quality was carried out

On-Farm Irrigation Management Efficiency

In the Central Jordan Valley, approximately one-half the farms are served by conventional surface systems and the other half use drip irrigation systems, including approximately six percent in plastic houses

Based on the weighted means of the data for the 1993/94 growing season, the management of drip irrigation in plastic houses is less efficient than expected The following is a summary of IME for the yearly growing season

On-Farm Irrigation Management Efficiency during the growing season 1993/1994

Irrigation Method	Irrigation Management Efficiency (IME) %
Conventional Surface	76
Drip in Open Field	70
Drip in Plastic Houses	47

Drip irrigation in plastic houses is the least efficient of the three system types Although IME under surface irrigation is high, there is no statistical difference between IMEs under drip in open fields and IME under conventional surface irrigation

Two main conclusions can be drawn

- The on-farm IME of drip irrigation in plastic houses is very low High-tech systems operate at 70 percent efficiency or less, offering much scope and opportunity to improve their performance The IME of a drip irrigation system in the open field can reach a value of 80 percent in practice Improvement in the on-farm irrigation management efficiency will enable farmers to increase their cropping intensity and will save water for irrigation of additional lands

- The conventional wisdom, that surface irrigation methods are inefficient when compared with drip irrigation methods, is incorrect Drip irrigation has the potential to be very efficient However, realization of the potential can occur only if systems are well designed and maintained and if irrigation scheduling is in accordance with

crop-water requirements If management is lax, and it has been, drip irrigation methods become very inefficient

Distribution uniformity values were in the average of 75 percent This indicates the potential for many farmers to use water efficiently, the physical system is not a constraint, provided that they are informed about crop-water requirements and the systems are well managed Improvement of distribution uniformity values, in combination with improved management of the irrigation systems, can lead to substantial savings in water, fertilizer, and energy

The Jordan Valley Authority (JVA) has been generous with winter water allocation to farmers to ease their transition to drip irrigation systems, which have the potential to use water more efficiently than surface irrigation In addition, water was given on demand and in quantities adequate for leaching purposes The JVA generosity is due in part to the shortage of storage facilities for the winter flow

In an environment where water is practically free, where large investments have been made in drip systems and plastic houses, and where there are few limitations on when farmers can take water or on the amounts they take, farmers do not employ water-conservation strategies On the contrary, farmers seek to reduce risk by over watering their crops This is particularly true for drip irrigation in plastic houses, where investments of more than JD 12,000 per hectare are required

Jordan has invested heavily in pressurized conveyance and delivery systems that permit farmers to convert to potentially efficient on-farm drip irrigation methods However, parallel investments have not been made to upgrade older drip systems or to train farmers new to drip systems in how to operate and maintain these technologies Additional attention should be paid to improving the management of on-farm systems and thereby increasing their efficiency Unless Jordan commits to further investment in on-farm water management, the benefits to the country from conveyance and delivery improvements cannot be fully realized

Economics of Agricultural Production

Farmers using drip irrigation realize large economic gains from their production systems The economic returns to water use (JD/m^3) in plastic house production systems were better than from production using open-field drip irrigation, which were in turn superior to the returns from conventional surface irrigation The economic returns to water use in plastic houses are almost 50 times those of surface systems and more than 15 times those of open field drip systems

The costs of production and marketing for surface irrigated crops were much lower than for drip irrigated crops, whose costs, in turn, were low relative to those in plastic houses

Investments in plastic houses and drip systems result in high levels of productivity and high returns Although expenditures for plastic house production are many times higher than for regular drip systems, plastic house production yields very high returns, on average more than ten times those received from surface irrigation production

Irrigation Methods	Economic Returns to Water Use (JD/m^3)*	
	Summer	Winter
Drip in Plastic House	0 486	1 26
Drip in Open field	0 06	0 078
Conventional surface	0 109	0 028

* Tomato was the only crop to use drip irrigation in the summer season

The analysis of production and marketing data show that investment in high-tech irrigation systems is highly profitable Farmers on average earn more with drip systems than with surface irrigation systems The use of productive inputs is greater with drip systems than with surface irrigation, resulting in higher yields and greater returns to capital

Water is a negligible cost component for production of annual crops in the central Jordan Valley Average returns to water use for the three types of irrigation were far greater than the current price of water For plastic house drip systems, economic returns to water use were more than 200 times the water price For crops under surface irrigation, water accounted for less than five percent of total cost, for crops using drip irrigation, less than two percent, and for plastic house production, water constituted less than one-half of one percent of total costs

It is useful to compare these figures with the price of water The Jordan Valley Authority currently charges JD 0 006/m^3 of water Only much higher water prices will result in water conservation Using water pricing as a policy tool to effect water conservation is only one reason to raise prices A second reason is to obtain additional funding for the operating water entity — the JVA At a minimum, water prices should be set at levels that fully recover the operations and maintenance costs of the JVA

There is common interest in seeking to increase the use of drip irrigation methods in the Jordan Valley If farmers convert to drip irrigation and if these systems are operated correctly, Jordan's economy stands to make large economic gain

Irrigation Water Quality

The following conclusions are based on a comparison of the results of water quality tests with guidelines for water to be used for irrigation, salt tolerance of agricultural crops, and the influence of water quality on the potential clogging of drip irrigation systems

High concentrations of nitrogen were detected in the drainage water due to excess fertilizer use In addition, excess fertilizer use can result in increased vegetative growth at the expense of fruiting

The concentrations of all trace elements were found to be low and within guidelines for irrigation water However, long-term use of irrigation water suggests that the accumulation of these elements in soil should be monitored regularly

RSS reports show that pesticide residues in the sampled waters were below established maximum guidelines Nevertheless, observed pesticide application practices are dangerous

Fecal coliform counts in King Abdullah Canal (KAC) water after mixing with Zarqa River water exceed 1,000 MPN/100 ml, which is the maximum value suggested by the World Health Organization (WHO) for unrestricted irrigation

Treated effluent from Khirbet As-Samra (Zarqa River water) can be used for irrigation with restrictions

Sprinkler irrigation (uncommon) and microjet applications of irrigation water may wet foliage and cause problems for crop production due to high concentrations of sodium and chloride in mixed KAC waters

Clogging of drip emitters can be caused by high calcium and magnesium contents in KAC waters High bacterial counts and nutrients that promote algal growth may also contribute to clogging Periodic chlorination of drip lines is therefore recommended

Mixing KAC water with Zarqa River water has adversely affected KAC's water KAC water, before mixing, can be used for all irrigation methods without any restriction

Salt water springs at Abu Zeighan increase the salinity of water in the Zarqa River, especially after rainfall This will affect plants which are salt and chloride sensitive

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ACRONYMS/TERMS

ADF	Agricultural Development Fund
BOD_5	Biological Oxygen Demand
CJV	Central Jordan Valley
D	Drip Irrigation
DA	Development Area
DAI	Development Alternatives, Inc
DU	Distribution Uniformity
du	dunum = 0 1 hectare
EC	Electrical Conductivity
FAO	Food and Agricultural Organization
fils	1 fil = JD 0 001
HT	High Technology, open field drip irrigation
IME	Irrigation Management Efficiency
IPC	International Pollution Control
ISPAN	Irrigation Support Project for Asia and Near East
JD	Jordanian dinar (1 JD = 1 43 US$)
JV	Jordan Valley
JVA	Jordan Valley Authority
KA	Khirbet As-Samra
KAC	King Abdullah Canal
KTD	King Talal Dam
KTR	King Talal Reservoir
MCM	Million Cubic Meter
MWI	Ministry of Water and Irrigation
PH	Plastic House
ppm	parts per million
S	Surface irrigation
SAR	Sodium Adsorption Ratio
T	plastic Tunnel
USAID	U S Agency for International Development
WERSC	Water and Environment Research and Study Center
WHO	World Health Organization
WQICP	Water Quality Improvement and Conservation Project
ZR	Zarqa River

INTRODUCTION

The Jordan Valley is part of the Great Rift Valley that extends from the Horn of Africa to northwestern Syria Within Jordan, the Rift Valley is a down-faulted valley The rift valley is divided into the Jordan River Valley, the southern Ghors and Wadi Araba The Jordan Valley is located at about 35 30″ east longitude and between 31 45″ to 32 40″ north longitude with altitudes below sea level ranging from 200 m near Yarmouk river to 406 m at the Dead Sea The Jordan Valley is bounded by the Yarmouk River in the north, the Dead Sea in the south, the Jordan River in the west and the Salt and Ajloun Escarpment in the east The Valley area is about 150 km in length and ranges from 4 km to 16 km in width

The climate of the Jordan Valley varies from subtropical in the north to tropical in the south The rainy period occurs during the winter months from October to March Rainfall varies from more than 350 mm in the north to less than 150 mm in the south near the Dead Sea Given these climatic conditions, the Jordan Valley is one of the few areas in the region that is ideal for winter irrigated agriculture Endowed with fertile, flat-lying soils, the Jordan Valley is the country's premier agricultural production area The mild winters in the valley, owing to its below-sea-level elevation, gives it great potential as a natural greenhouse for the production of off-season fruits and vegetables Agriculture in the valley includes a wide variety of crops, including high-value horticultural crops such as citrus, banana, and vegetable crops and field crops, such as alfalfa and wheat

According to a 1953 soil survey, irrigable land in the Jordan Valley totals 36,000 hectares Approximately 29,000 of these hectares are equipped with irrigation distribution networks Some 6,000 hectares at the southern end of the valley, however, are not supplied with water The net irrigated area of 23,000 hectares reflects the scarcity of water in the valley Even so, Jordan's agricultural sector consumes 70 percent of the country's developed water resources

The main sources of water in the central Jordan Valley are (i) releases from King Talal Reservoir to the Zarqa River, much of which is released from the reservoir is partially treated wastewater from the city of Amman and surroundings, (ii) a portion of Yarmouk River baseflow, and (iii) flow of side wadis Limited water resources motivated the Jordan Valley Authority to invest in pressurized systems for the conveyance of irrigation water Initiated in the late 1970s, this investment allows farmers to convert from conventional surface irrigation to modern drip and sprinkler methods, which can be highly efficient Many farmers converted to modern methods, particularly drip

Besides limited water availability, water quality problems are also constraints to realizing production from the full irrigable area of the valley Reclaimed wastewater is expected to provide about 30 percent of the water used in the central Jordan Valley and the Zarqa Triangle This portion of the middle section of the Jordan Valley covers an estimated 7,500 hectares, farmed by roughly 2,000 farmers Three-quarters of the irrigation water for this area comes from the Zarqa River The river drains the most populous and industrialized portion of the country, an area known as the Amman-Zarqa Basin Wastewater enters the river, is partially treated at Khirbet As-Samra, and is stored in the King Talal Reservoir to be used for agriculture in the valley below The volume of wastewater amounts to about 40 percent of the flow of the river

The distribution of water to farm units is managed by the Jordan Valley Authority under two delivery policies In the winter months, when water is normally available, deliveries are more flexible with water on demand During these months, the Jordan Valley Authority may encourage farmers to take water, free of charge, for leaching purposes In the summer months, when water is scarce, deliveries are on a rigid rotation schedule Management of irrigation water at the farm level is left to farmers Crops are cultivated using three main irrigation and production technologies surface irrigation in open field, drip irrigation in open fields, and drip irrigation in plastic greenhouses Irrigation technologies, and the type of delivery policy applied, affect farm-level system performance (irrigation efficiency) When water is made available on a flexible delivery schedule, on-farm irrigation efficiencies will be low relative to when a rigid rotation schedule is in effect

The USAID mission to Jordan requested the Irrigation Support Project for Asia and Near East (ISPAN) and the Water and Environment Research and Study Center (WERSC) of the University of Jordan to conduct a baseline study The financial support for the study was provided by the Agricultural Development Fund (ADF) A baseline monitoring program was carried out covering seven components, they were (1) on-farm irrigation management efficiency, (2) irrigation diagnostic survey, (3) economics of agricultural production, (4) agricultural economic diagnostic survey, (5) conveyance system efficiency, (6) irrigation water quality, and (7) soil investigation

Prior to this baseline study, information critical to planning project activities and tracking project progress was severely lacking Sufficient information was not available on agricultural and irrigation practices in the central Jordan Valley There was little documentation on the areas covered by the various methods of on-farm irrigation Nor was there accurate information available about the efficiency with which the various types of irrigation methods are used Comprehensive research on water quality in the Jordan Valley was also needed

The purpose of this study was to

- Document current agricultural and irrigation practices in the central Jordan Valley, and

- Provide a 1993/94 baseline against which to measure agricultural and irrigation changes as a result of WQIC Project

Except for water quality sampling, which began in April 1993, field studies for the baseline began in September 1993 Most baseline components were completed by the end of May 1994, and the findings for the first stage were presented in the winter cropping season report (Shatanawi et al, 1994)

The University of Jordan was contracted by the WQIC Project, implemented by Development Alternative Inc , (DAI) to complete the baseline monitoring program (June until the end of September, 1994) for the uncompleted components, namely on-farm IME, economics of production, and water quality This report presents the results of the summer cropping season, compares the summer and winter results, and summarizes the yearly finding of the study

ON-FARM IRRIGATION MANAGEMENT EFFICIENCY

Summary

Field research to study on-farm irrigation management efficiency (IME) covering the spring and summer seasons of 1994, was continued for perennial crops (fruit trees and alfalfa) and a few summer crops such as corn, okra, and molokhia The measured amounts of irrigation water and effective precipitation were compared with the calculated water requirements (actual evapotranspiration) to determine IME Results of the yearly IME shows that there are no significant differences between the values of IME under drip and surface irrigation methods in the open field conditions The results of the winter season show that IME values for drip irrigation in plastic houses are poor IME values for fruit trees were higher than those for vegetable and field crops

Farmers apply the same amount of water for a crop planted in a plastic house as for one planted in an open field This is one reason why IME in plastic houses is poor In addition, a lack of knowledge of irrigation management and large quantities of water available during winter encourages farmers to apply more water, thus reducing efficiency Restrictions on water deliveries during summer resulted in relatively higher values of IME

Background

The number of actual field studies to determine irrigation efficiency in the Jordan Valley are few A study of 214 valley farms in 1982/1983 (Shatanawi, 1986) revealed that the irrigation management efficiency of drip irrigation systems was about 60%, only marginally better than the efficiency for conventional surface systems A second study in 1987 (Tahboub, 1987) found irrigation efficiencies of 78, 66, and 67 for drip, surface and sprinkler irrigation, respectively

During the past ten years, irrigation methods have changed In the early 1980's, few farmers used drip irrigation, but by 1990, drip systems had covered 62% of the total irrigated area in Jordan and about 50% of the Jordan Valley Investments in modern irrigation systems, along with other associated technologies, has reached nearly 71 million JD In a policy study (Qassim et al, 1993), an overall irrigation efficiency of 62% was estimated, which means that 38% of the available water is lost It was postulated that if irrigation efficiency could be improved to 72% over the next fifteen years, about 60 million cubic meters of water could be saved for agriculture

As a part of the baseline survey (ISPAN, 1994), a rapid survey of the irrigation systems in the Valley in 1993 revealed that (1) few farmers know proper irrigation scheduling, (2) many drip irrigation systems are not operated to realize their design potential, and (3) excessive irrigation is due to a lack of knowledge of how much water to apply These observations suggest that there is much opportunity to improve water conservation The field research presented in this report supports these observations through direct measurements of efficiency of on-farm irrigation management The report presents an analysis of management issues related to the inefficient application of on-farm water This research gives attention to water as one component of the total cost for production and marketing of the major crops in the

valley This work will lead to recommendations related to on-farm management, and provides a strategy to improve water conservation

Methodology

Field investigations were carried out on 35 farms representing different irrigation methods, crops, and cultural practices that are typical of the Central Jordan Valley (CJV) The investigated farms were selected from development areas (DA) 21, 22, 23, 24, 25, 26, 27, 28 and 29 Only DA 21 receives high quality water from the Yarmouk River, while others receive water from KTR The selection criteria for farm units included in the study were (1) a range of irrigation methods, drip systems in both open field and plastic houses as well as conventional surface irrigation in open field, (2) a range of crop types, vegetables, field crops, and fruit trees, (3) distribution of farm units in the various development areas of CJV, and (4) pledges of cooperation from farm owners and managers

In the sampling process it was decided that judicious selection of a limited number of farms and a high level of accuracy in primary data collection was essential, rather than the collection of secondary information through a survey

For the purpose of measuring irrigation water, JVA installed in-line water meters (research meters) on the selected farms These meters were read and monitored by staff from the University of Jordan on an almost daily basis When any problem occurred with the meters, repairs were done the same day by JVA staff Taking meter readings started in September 1993 and continued until the end of May 1994 for the winter crops Monitoring for 15 farms with fruit trees and alfalfa continued until the end of May 1994

Effective precipitation was calculated using the SCS formula and rainfall data from the Deir Alla meteorological station Effective precipitation was adjusted for tunnel and plastic mulch cultivation Reference crop evaporation was calculated with the Penman-Monteith equation using 1993/1994 data from the Deir Alla station Actual ET was calculated by adjusting reference ET with the crop coefficient value Values for crop coefficient (Kc) were computed using the methods outlined in FAO irrigation and Drainage paper number 24 Details of the procedure and data used for the calculation of ET are presented in Annex A

Irrigation water applied plus effective precipitation were compared with crop evapotranspiration to compute on-farm irrigation management efficiency On-farm IME is the ratio of water that should have been used by a crop (calculated crop evapotranspiration) to the total amount of water applied

$$\text{IME}\,(\%) = \frac{\text{Crop Evapotranspiration}}{\text{Irrigation Water} + \text{Effective Precipitation}} * 100$$

Results

In this report, results of the summer season are presented and compared with the results of the winter season The winter season results showed that IME values were 70%, 56%, and

42% for conventional surface irrigation, drip irrigation in open field, and drip irrigation in plastic houses, respectively

To obtain summer and yearly IME, monitoring of 15 farms representing an area of 464 dunums was conducted Table 2 1 shows IME values and some statistical parameters of different irrigation methods for winter, summer, and the annual average For each crop IME calculations on an annual basis are shown in Annex B

The IME for fruit trees and alfalfa that were harvested in summer is much higher than those in winter There is little improvement in efficiency of drip irrigation in plastic houses because most plastic house cultivation ended in May 1994, at the end of the winter season It is worth mentioning that the area planted with summer crops represents about 66% of the total area under this study Therefore, more weight should be given to summer results There is an improvement in IME values from winter results over the combined results (annual average) by 6% for surface irrigation and 24% for drip irrigation Annual average IME of 76% for surface irrigation shows that the surface systems are excellent and a 70% efficiency for drip irrigation is reasonably good This indicates that farmers are aware of water scarcity during summer, thus, they are more conservative in the amount of irrigation water used Water in the summer is limited so they cannot obtain the amount of water they requested Flood water is available during winter and JVA is generous in giving water, since there are insufficient storage facilities, to farmers for soil moisture storage and leaching purposes Therefore, IME during winter was relatively low

To compare the IME values between drip and surface irrigation, a statistical analysis, described in Annex C, was made using a confidence level of 90% For a difference to be significant, **Z** must satisfy one of two criteria

$$Z \leq -1\ 645 \quad \text{or} \quad Z \geq 1\ 645$$

Table 2 2 shows that there is no significant difference between the annual average of the two open-field methods of irrigation However, the statistical analysis shows significant differences between drip irrigation in plastic houses and drip irrigation in the open field, and between drip irrigation in plastic houses and conventional surface irrigation

To determine if there is a significant difference between the IME values in winter season, a test hypothesis was conducted The tests showed that at a confidence interval of 90% (Table 2 2) there is significant difference between surface and drip irrigation in plastic houses, surface, and open field drip irrigation, and open field drip and drip in plastic houses

In the summer season, results showed that IME values were 82%, 80%, and 61% for conventional surface irrigation, drip irrigation in open field, and drip irrigation in plastic houses, respectively Statistical analysis showed that no significant difference exists between any systems at a confidence interval of 90% Thus, no conclusion can be drawn (Table 2 2)

Table 2 1 Weighted irrigation management efficiency (IME) for different irrigation practices in winter season, summer season, and yearly average, 1993/1994 growing season

Irrigation Method	Winter Season			Summer Season			Annual (Yearly)		
	IME (%)	Standard Deviation	Number of Readings	IME (%)	Standard Deviation	Number of Readings	IME (%)	Standard Deviation	Number of Readings
Conventional Surface	70	19 84	27	82	10 75	6	76	22 49	29
Drip in Open Field	56	23 50	45	80	24 71	13	70	24 68	53
Drip in Plastic Houses	42	15 85	12	61	38 70	2	47	17 31	12

Table 2 2 Z-values comparing different combinations of irrigation systems for winter summer, and annual, 1993/1994 growing season

Combinations of Irrigation Systems	Z-Value		
	Winter Season	Summer Season	Annual
Conventional Surface - Drip in open field	2 68*	0 218	1 056
Drip in open field- Drip in plastic house	2 40*	0 665	3 92*
Conventional Surface- Drip in plastic house	4 66*	0 706	4 504*

* Significantly different at the 90% confidence interval

Table 2 3 shows that when the summer season is compared with the results of the winter season, IMEs for surface irrigation and drip irrigation in open field are significantly different However, no significant differences were found between IMEs for drip irrigation in plastic houses

Table 2 3 Z-values for the comparison of winter and summer season, 1993/1994 growing season

Irrigation Method	IME (%)		Z-Value
	Winter	Summer	
Conventional Surface	70	82	1 98*
Drip in open field	56	80	3 07*
Drip in plastic houses	42	61	0 67

* Significantly different at the 90% confidence interval

Table 2 4 compares IME values for tree and alfalfa summer crops Measurements to determine the IME values were taken from 15 farms covering an area of about 446 dunums No explanation could be given for the low IME value for bananas The calculated annual ET of bananas reaches 1500 mm using Penman-Monteith and FAO Kc values The general feeling among banana growers and many officials from JVA is that bananas require about 2500 mm of water This feeling may be true A long-term study in Hawaii (Wu, 1985) shows that bananas do not have a convex yield vs water curve The relationship is pretty much a straight line to at least 2500 mm of ET (1 8 of Epan) The IME values for other fruit trees and alfalfa are excellent, these results indicate that some farmers may have planted in excess of their license and are "stretching" their irrigation water to cover the entire planted area or that there is concern and awareness about water conservation The latter reason can be verified or disproven by balancing water orders placed against water amounts received

Table 2 4 On-farm irrigation management efficiency (IME) of fruit trees and alfalfa, 1993-1994 growing season

Crop	Area (dunum)	No of Farms	IME
Citrus (Drip)	62	2	71
Citrus (Surface)	94	3	81
Grapes (Drip)	67	4	90
Apples (Drip)	93	2	83
Peaches (Drip)	60	1	100
Bananas (Drip)	41	2	44
Alfalfa (Surface)	29	1	85
Weighted Average	446	15	79

In general, IME in the open field (surface and drip) is acceptable for the whole year, which means that there is a positive attitude from the farmers and JVA about water management and water conservation The primarily concern is water losses from drip irrigation in plastic house The area under irrigation is quite small, but the low value for IME for plastic houses (42%) needs further investigation It may be concluded that water losses in plastic houses are due to a lack of knowledge of how much water to apply and crop water requirement Farmers do not realize that irrigation requirements under plastic houses are about 35% less than those under open field conditions Field observations and site visits to growers using plastic houses showed that the moisture content was always near saturation In many cases, runoff was observed at the end of the plastic houses and, in some cases, algae growth was noticed

ECONOMICS OF AGRICULTURAL PRODUCTION

Introduction

The same 31 farms selected for the winter cropping season were visited at two week intervals in the summer season to collect economic information on the costs of production and returns Only six vegetable crops were produced in the summer season tomatoes, onions, molokhia, green beans, okra, and eggplant Wheat was the only field crop in the sample The collection of data on the fruit trees chosen in the winter season continued The fruits were peaches, apples, grapes, banana, and citrus

Costs of Production and Marketing

Costs of production and marketing are shown in Table 3 1 and Figure 3 1 Molokhia or tomato are the only vegetable crops produced under plastic houses or tunnels in the summer season Tomato was also produced under open-field practices, either using drip or surface irrigation Two varieties of onion are produced, the local variety which cannot be stored for a long period of time and the storable variety

Covered production of the two crops showed higher costs than for surface irrigated fields The costs for tomatoes grown under plastic tunnels was JD 587/du, while it was JD 234/du and JD 136/du when grown in open fields with drip and surface irrigation, respectively The cost of production under plastic houses in the winter season was about JD 1 04 thousand per dunum This crop was not produced under plastic tunnels or open fields using drip or surface irrigation in the summer season

Onion, green beans, and eggplant were grown under surface irrigation in the summer season The costs of production for these crops were JD 162/du, JD 143/du, and JD 95/du, respectively, in the summer season The costs for producing the same crops in the winter season under surface irrigation were about JD 82/du, JD 125/du, and JD 727, respectively (Figure 3 2)

Marketing costs were the highest cost item for all vegetable crops except eggplant, molokhia under surface irrigation, and dry onion

As in the winter cropping season the costs of production and marketing in the summer season for crops in plastic houses or tunnels were very high relative to the other two forms of irrigated production For example, the total cost of tomato production and marketing was about JD 600/du, which is 2 5 times and 4 times the cost of producing it under open field with drip and surface irrigation, respectively

Water cost was the highest for molokhia produced under plastic houses (about JD 7 44/du), followed by eggplant (JD 6 11/du) The vegetable crop lowest in water cost was green beans (JD 3 23/du) (Figure 3 3)

The cost of producing wheat was very low (about JD 7 8/du) Both seed and marketing costs constituted about 21% of the total cost

Table 3 1 Breakdown of Production and Marketing Costs for Vegetables Crops using different Technologies (JD/du)

Crop	Techn.	JD %	Land Prep.	Labor	Seed	Fertiliz.	Pesticide	Marketing Cost	Land Rent	Water	Other	Total Cost
Tomato	Plastic	JD	123	114	34 9	56	24 2	223	8 3	4 5	0	587
		%	20 9	19 4	5 9	9 5	4 1	38	1 4	0 8	0	100
	Drip	JD	20 4	30 2	16 7	21 4	20 9	109	10	4 6	0	234
		%	8 7	12 9	7 1	9 2	9	46	4 3	2	0	100
	Surface	JD	5 8	20	20	16 1	8 2	53 0	9	3 9	0	136
		%	4 2	14 7	14 8	11 8	6	38 9	6 7	2 9	0	100
Onions	Local	JD	4 7	28 7	20 4	14 7	19 7	58 3	10	5 2	0	162
		%	2 9	17 7	12 6	9 1	12 1	36	6 4	3 2	0	100
	Storable	JD	2 6	17 8	53 8	3 8	6 7	39 2	19 3	3 6	0	146 7
		%	1 8	12 1	36 7	2 6	4 6	26 7	13 1	2 4	0	100
Molokhia	Plastic	JD	5	12 9	25 4	17 5	13 2	49 7	0	7 4	0	131
		%	3 8	9 8	19 3	13 4	10 1	37 9	0	5 7	0	100
	Surface	JD	6 3	10 3	9 1	4 4	2 8	10 0	9 2	3 4	0	55 8
		%	11 3	18 5	16 3	7 9	5	18 1	16 7	6 2	0	100
G Beans	Surface	JD	3 0	29 8	36 0	14 2	10 2	33 4	12 8	3 2	0	142 6
		%	2 1	20 9	25 3	10	7 2	23 5	9	2 3	0	100
Okra	Surface	JD	8 0	3 0	8 0	0	6 2	1 0	0	3 7	0	30
		%	26 7	10	26 7	0	20 8	3 3	0	12 5	0	100
Eggpl	Surface	JD	1 5	12 0	35 0	8 0	8 5	24 0	0	6 1	0	95 1
		%	1 6	12 7	36 8	8 4	8 9	25 2	0	6 4	0	100
Wheat	Surface	JD	1 9	0 3	2 1	0	0	2 0	0	1 5	0	7 8
		%	24 7	3 2	27 2	0	0	26 2	0	18 0	0	100

Figure 3 1 Comparison of Total Costs (per dunum) of Production and Marketing of Vegetable Crops and Wheat in Summer Season

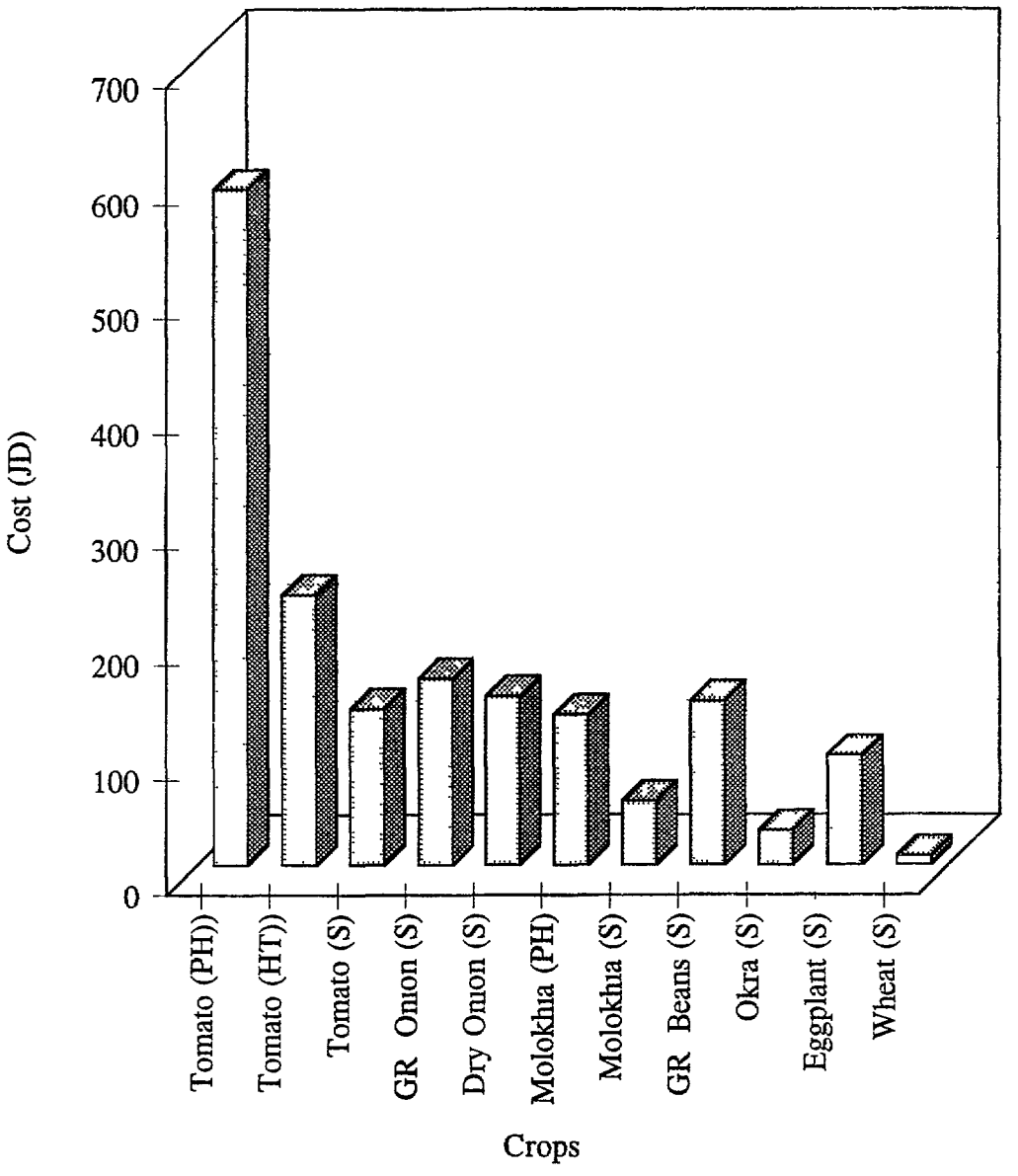


Figure 3 2 Comparison of Total Costs (per dunum) for Vegetables, Winter and Summer Season

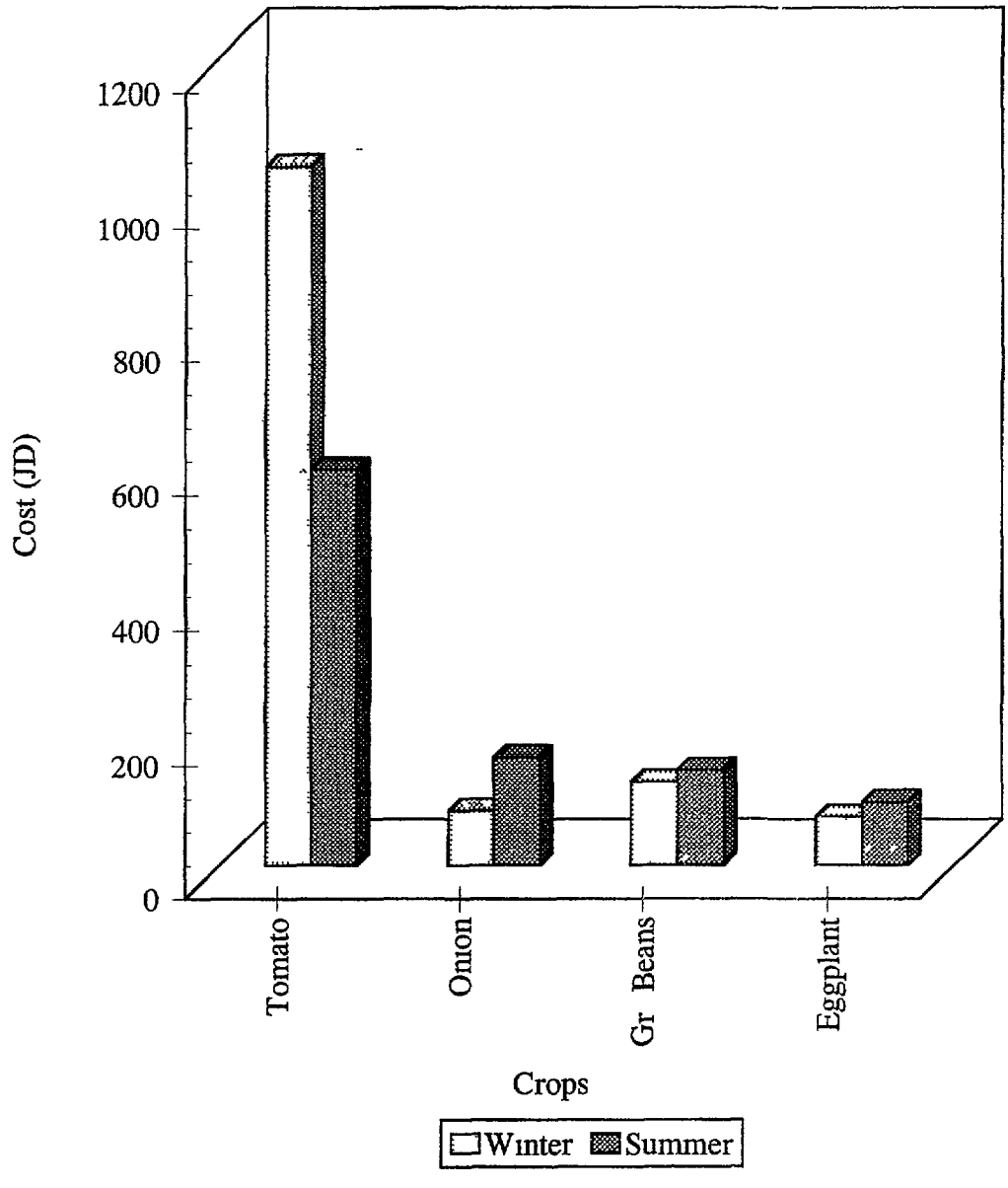
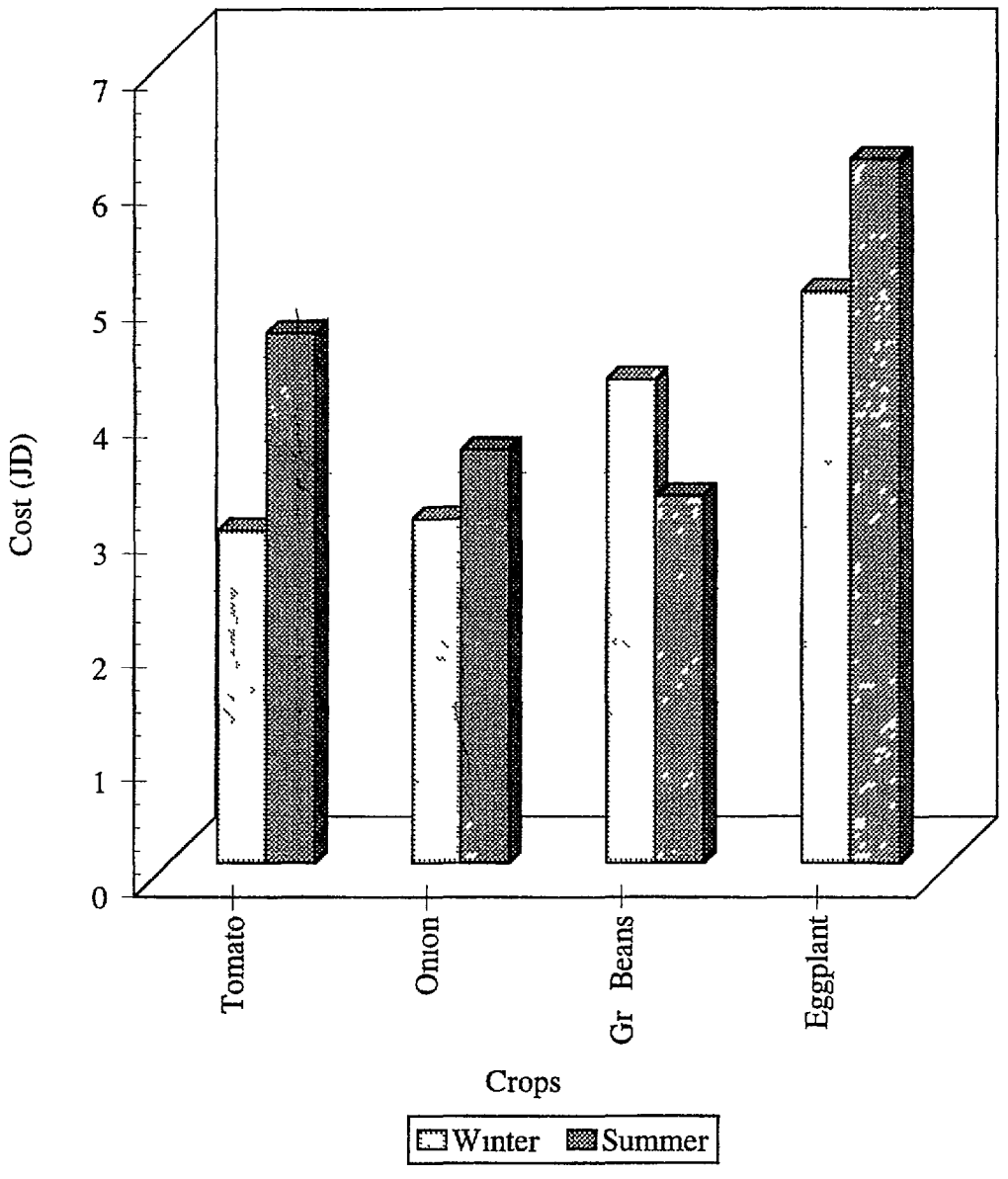


Figure 3 3 Comparison of Water Costs (per dunum) between Winter and Summer Crop Seasons



Five fruit crops were produced by the farmers in the sample, they are peach (70 du), apple (20 du), seedless or ordinary grapes (255 du), banana(34 du), and citrus trees (835 du) (Table 3 2)

The percentage of labor cost to the total cost was the highest in peaches (37 7%), apple (31 5%),and seedless grapes (30 3%) The highest costs for bananas were the pesticides (25 9%), in citrus were the marketing costs (50 5%), and in ordinary grapes were the fertilizer costs (32 4%) (Figure 3 4)

Costs of production and marketing are shown in Table 3 2 and Figure 3 5 Seedless grapes ranked first in these costs (about JD 274/du), followed by peaches (JD 274/du) Production and marketing costs were lowest for apples (JD 162/du)

Water costs were the highest for bananas (about JD 33 8/du), followed by citrus (JD 7 8/du) The lowest was normal grapes (about JD 4 6/du) (Figure 3 6) Figure 3 7 shows the cost factors for seedless grapes

Returns to Crop Production

The relative total returns and gross margins for vegetables and wheat to production in the summer season are shown in Table 3 3 and Figure 3 8

Tomato was the most profitable crop, and as with production and marketing costs, tomato produced under plastic tunnel using drip irrigation provides the highest returns and gross margins (JD 1286/du and JD 698/du, respectively), while the open field production with surface irrigation were the lowest (JD 144/du and JD 8/du respectively) High returns to crops grown in plastic tunnels results from extremely high average yield (4 539 tons/du compared to 1 219 tons/du for surface irrigation)

Average total returns for the vegetable crops using surface irrigation ranged from JD 31/du for okra to JD 337/du for storable onion Gross margins for these crops averaged about JD 91 5/du with a range of JD -18/du for eggplant to JD 356 7/du for local onions The loss in eggplants was caused by their low prices in the spring season

Table 3 4 summarizes the total costs, total returns, and gross margins for the vegetables grown in the two seasons (i e winter and summer) The total returns in the summer season were higher than in the winter season for onion, green beans and eggplants, while the opposite was true for tomatoes Tomatoes were produced under plastic houses in the winter season and under plastic tunnels in the summer season Figure 3 9

The gross margins for eggplant in both seasons were negative but the loss in the winter season was higher (JD -31 4/du) than in the summer (JD -18 1/du) Gross margins for the other crops followed the same pattern as the total revenues Figure 3 10

Table 3 2 Breakdown of Production and Marketing Costs for Fruits (JD/du)

Crop	Techn.	JD %	Labor	Fertilizer	Pesticide	Marketing Cost	Water	Others	Total Cost
Peach	surface	JD	103 2	49 3	30 3	84 8	6 2	0	273 8
		%	37 7	18	11	31	2 3	0	100
Apple	surface	JD	50 8	49 8	31 8	15 6	5 9	7 8	161 6
		%	31 5	30 8	19 6	9 7	3 6	4 8	100
Grapes Seedless	Seedless	JD	83 8	61 0	39 2	82 0	5 3	5 0	276 3
		%	30 3	22 1	14 2	29 7	1 9	1 8	100
Grapes Ordinary	Ordinary	JD	56 7	66 7	33 3	44 7	4 6	0	206 0
		%	27 5	32 4	16 2	21 7	2 2	0	100
Banana	Surface	JD	26 5	43 8	50 0	38 7	33 8	0	192 7
		%	13 7	22 8	25 9	20 1	17 5	0	100
Citrus	Surface	JD	75 3	27 1	7 1	119 4	7 8	0	236 5
		%	31 8	11 4	3	50 5	3 3	0	100

Figure 3 4 Breakdown of Production and Marketing Costs (%) for Tomato under different Production Technologies

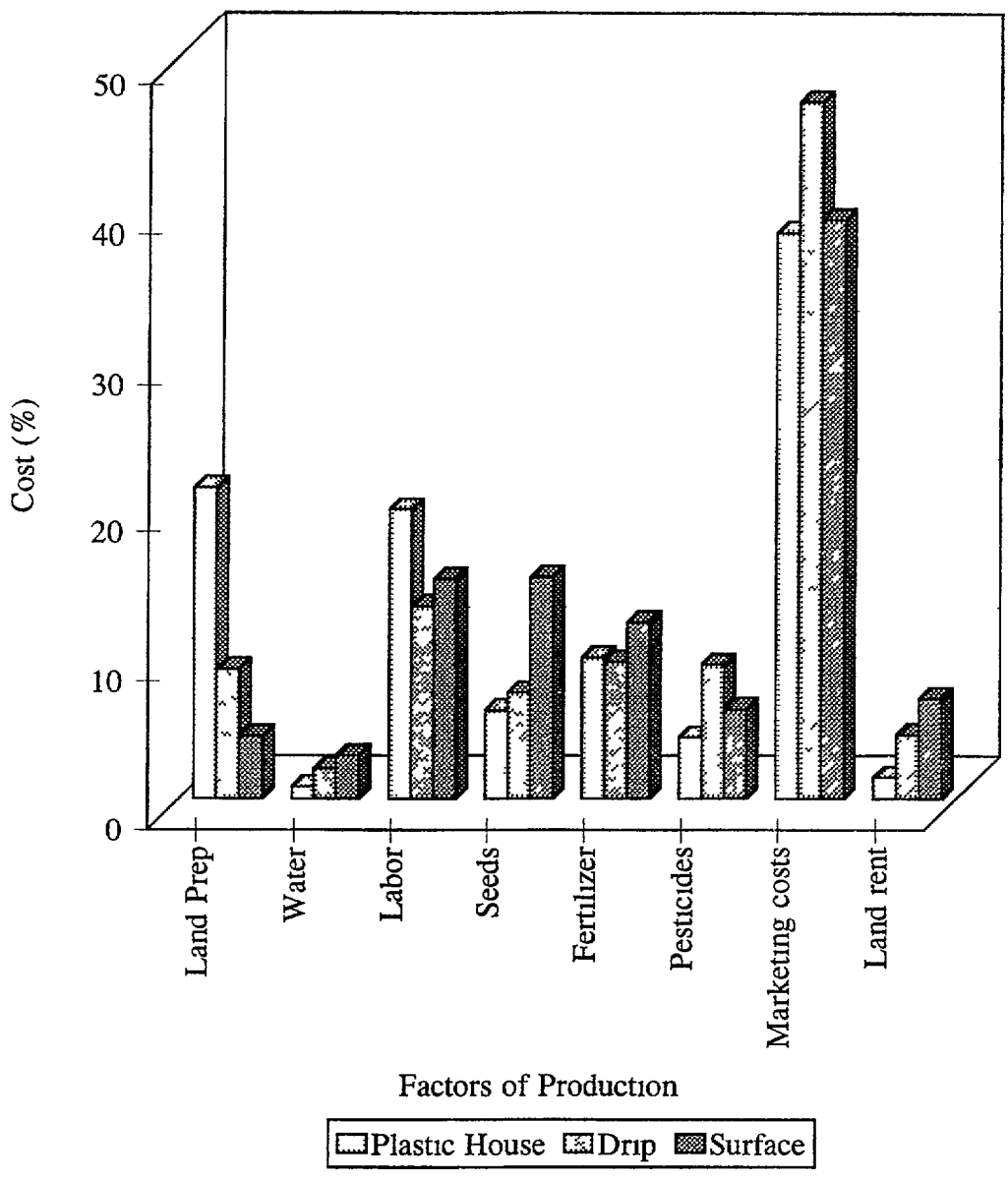


Figure 3 5 Total Cost for Production and Marketing (per dunum) Fruit, Summer Season

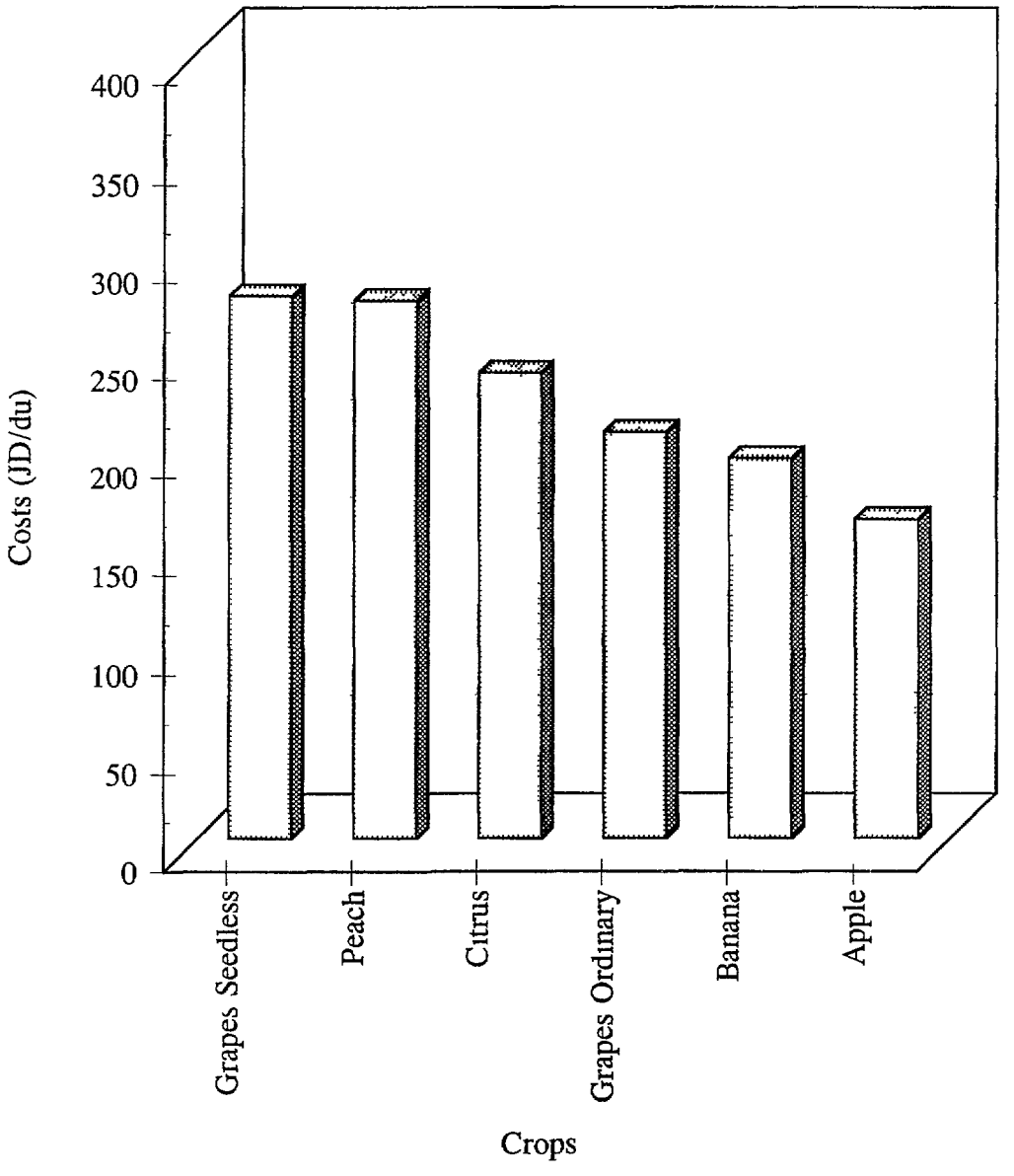


Figure 3 6 Comparison of Water Costs (per dunum) for Summer Season Fruits

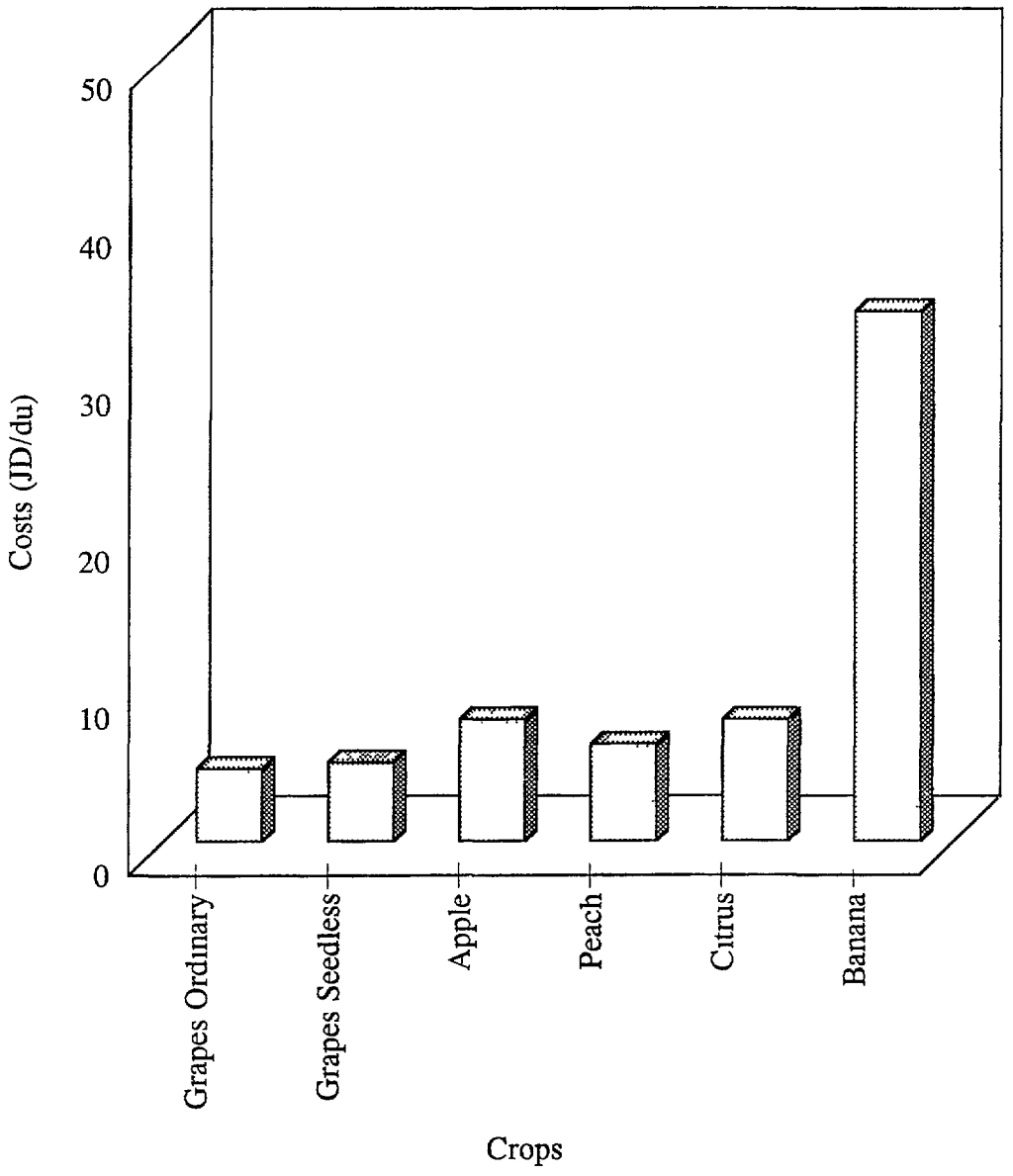


Figure 3 7 Breakdown of Production Costs (per dunum) for Seedless Grapes

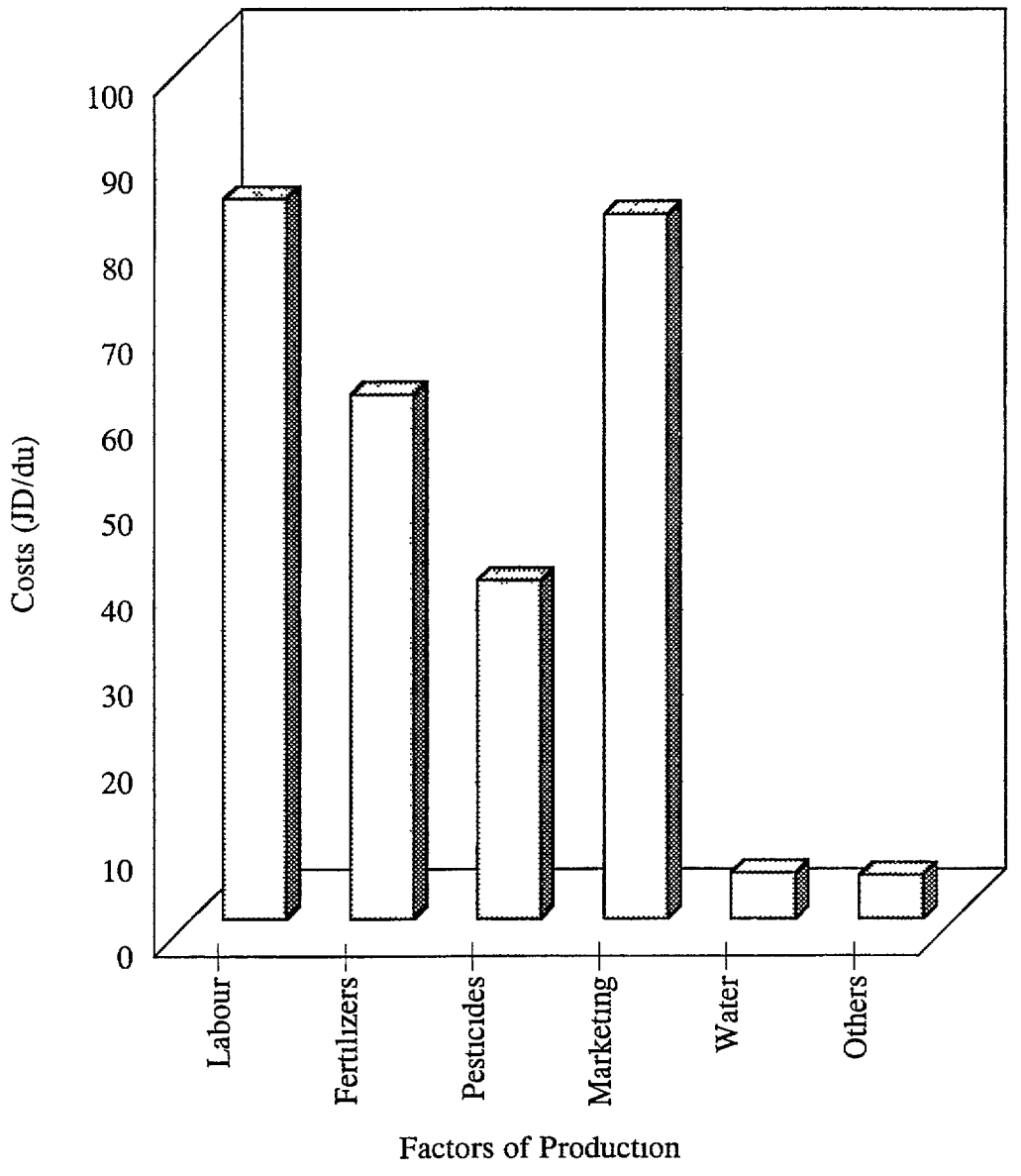


Table 3 3 Total Return and Gross Margins for Vegetables and Wheat by Irrigation Technology, Summer Season (JD/du)

Crop	Techn.	Yield Ton/ha	Total Cost	Total Return	Gross Margins	Return to Capital
Tomato	Plastic	4 539	587 3	1285 7	698 4	1 19
	Drip	2 479	233 5	280 2	46 7	0 20
	Surface	1 219	136 0	144 1	8 1	0 06
Onions	Local	4 063	162 0	518 7	356 7	2 20
	Storable	2 813	146 7	337 2	190 5	1 30
Molokhia	Plastic	1 448	131 1	400 0	268 9	2 05
	Surface	1 491	55 8	91 7	35 9	0 64
G Beans	Surface	0 533	142 6	209 0	66 4	0 47
Okra	Surface	0 1	30 0	31 0	1 0	0 03
Eggpl	Surface	0 7	95 1	77 0	-18 1	-0 19
Wheat	Surface	0 109	7 8	17 2	9 3	1 19

Figure 3 8 Comparison of Total Returns and Gross Margins (per dunum) for Vegetables and Wheat, Summer Season

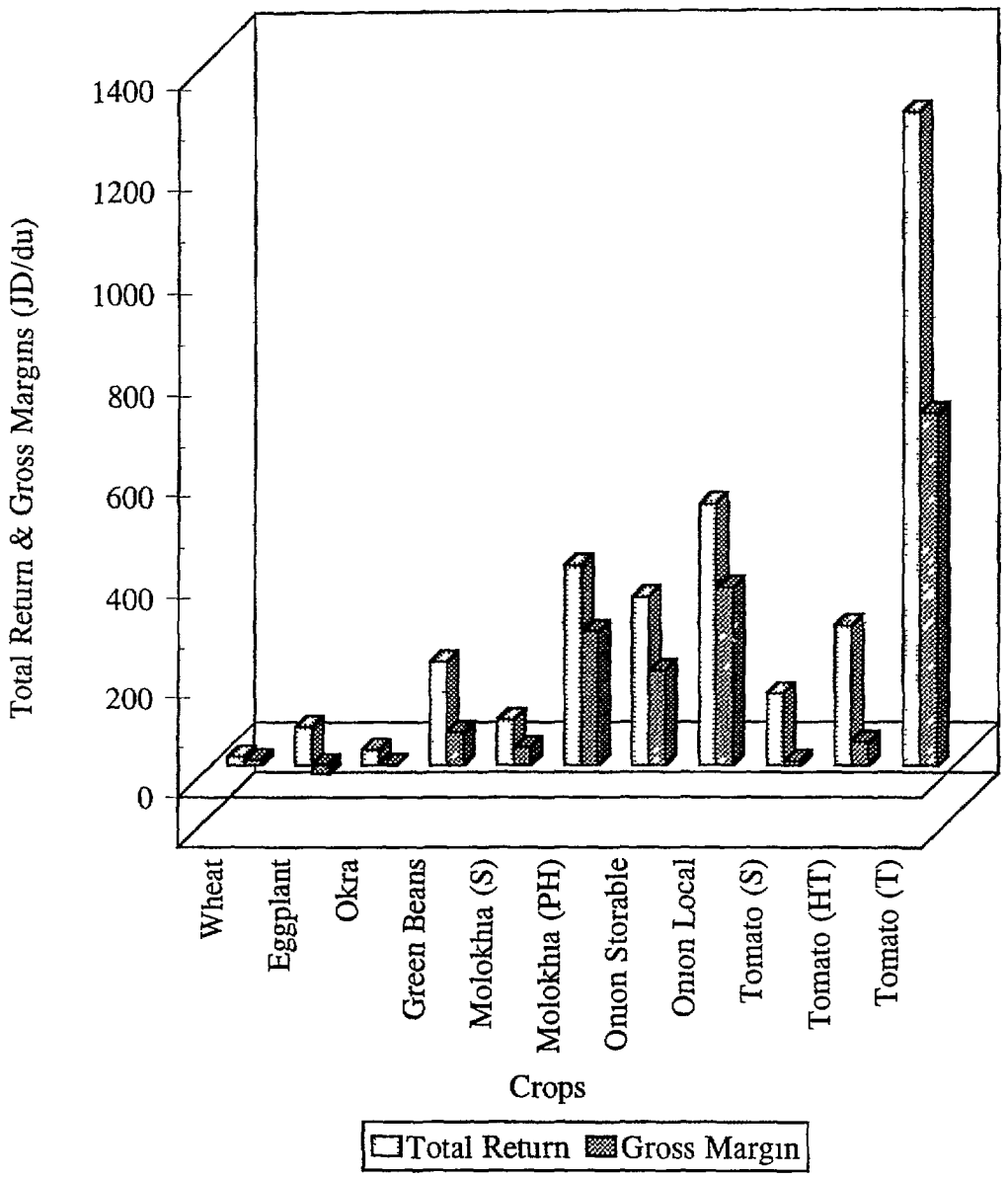


Table 3 4 Comparison of Total Costs, Total Revenues, and Gross Margins for Vegetables, Winter and Summer Seasons (JD/du)

Crop	Total Costs		Total Returns		Gross Margins		Return to Capital		Return to Water	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Tomato	1042 3	587 3	2607 1	1285 7	1564 8	698 4	1 5	1 2	3 24	0 93
Onion	82 1	162 0	185 7	518 7	103 7	356 7	1 3	2 2	0 21	0 41
Gr beans	124 6	142 6	158 5	209 0	32 9	66 4	0 3	0 5	0 05	0 12
Eggplant	72 7	95 1	41 3	77 0	-31 4	-18 1	-0 4	-0 2	-0 04	-0 11

Figure 3 9 Comparison of Total Returns (per dunum) for Vegetables, Winter and Summer Seasons

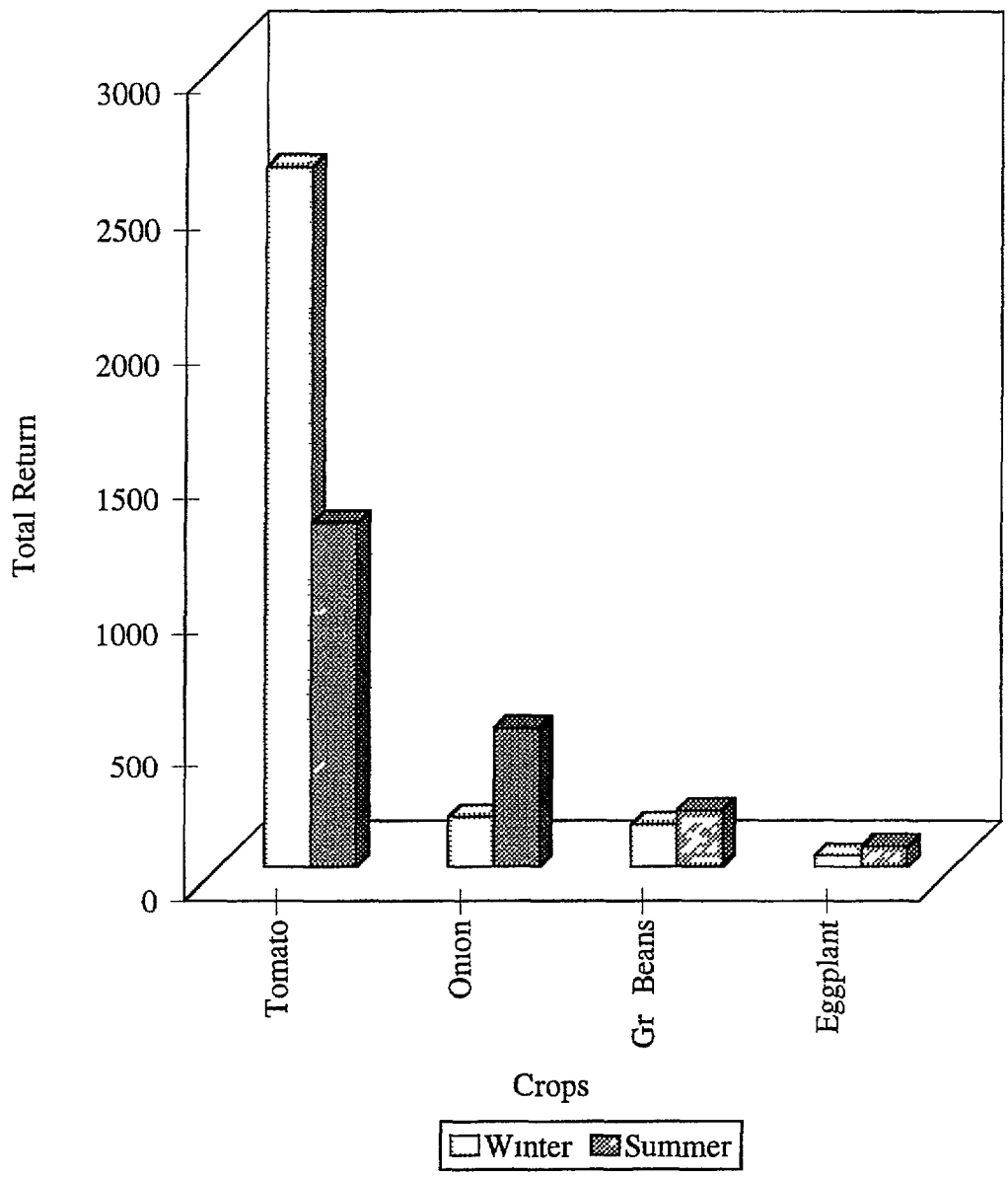
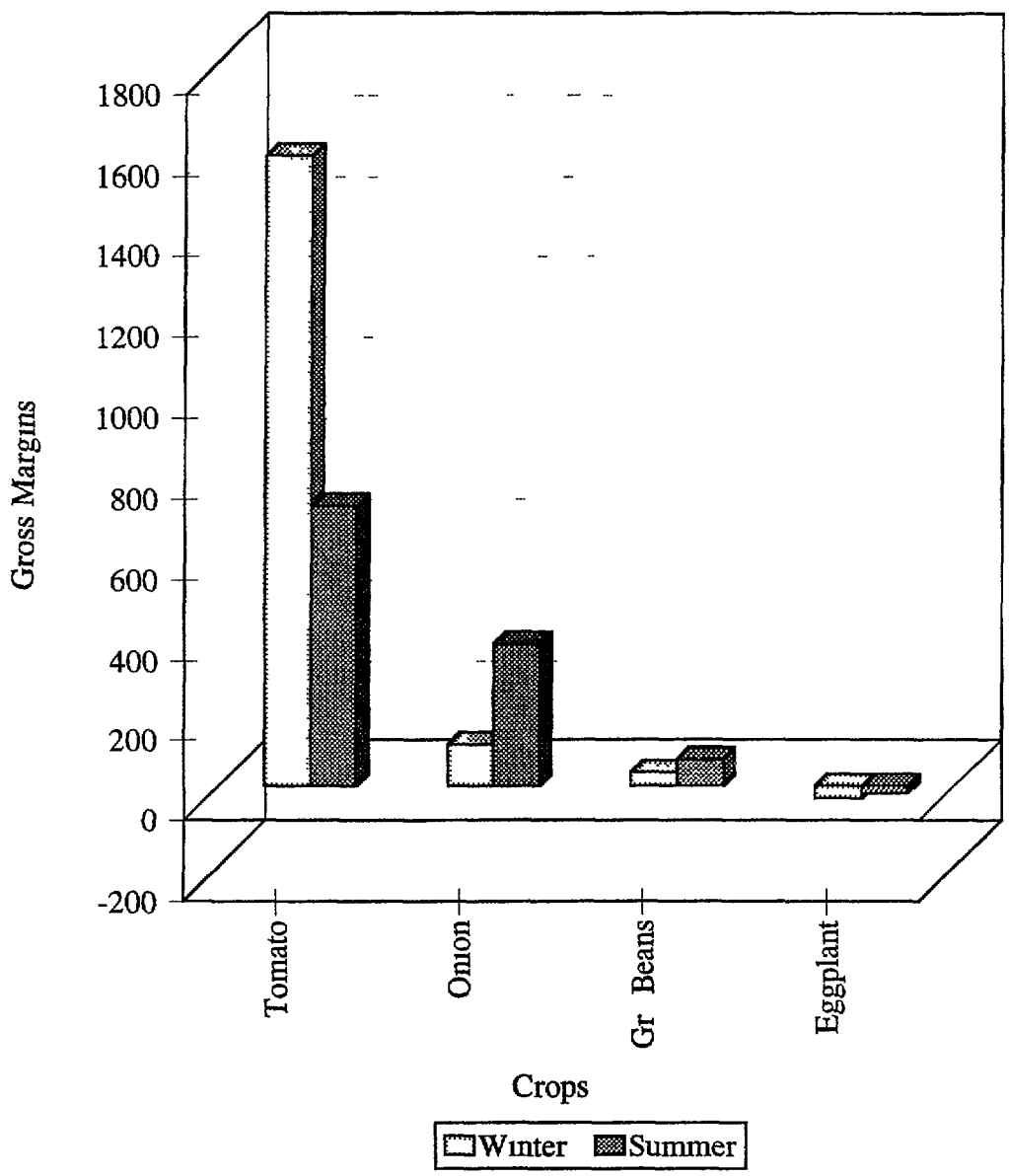


Figure 3 10 Comparison of Gross Margins for Vegetables, Winter and Summer Seasons



The returns to capital, defined as gross margins divided by operational costs, for each crop are shown in Table 3 3 According to different technologies, tomatoes in plastic tunnels provide the highest return to capital (1 19 JD/JD), while it was (0 2 JD/JD) and (0 06 JD/JD) for drip and surface irrigation, respectively The highest return to capital was for molokhia produced under plastic houses (2 5 JD/JD), followed by local onion (2 2 JD/JD) The lowest positive return to capital was for okra (0 03 JD/JD), Figure 3 11

Seedless grapes was the most profitable fruit crop for the Central Jordan Valley The net gross margin for this crop was about JD 4 6 thousand per hectare, which is almost five times the return for normal grapes The second most profitable crop was citrus (about JD 459/du), followed by peach (about JD 239/du) The net loss in apples was JD 99/du This loss was due to a warm winter, which caused low productivity, accompanied by low quality, which adversely affected prices, Table 3 5 and Figure 3 12

Returns to capital were the highest for citrus (1 72 JD/JD), followed by seedless grapes (1 66 JD/JD) The returns to capital for the rest of the fruit crops (except for apple where it was negative) were less than one, Figure 3 13

Table 3 4 and Figure 3 14 show that the returns to capital for tomatoes grown in the winter season were about 1 5 JD/JD, while in the summer season returns were about 1 2 JD/JD The returns to capital for onion and green beans in the winter season were 1 3 JD/JD and 0 3 JD/JD, respectively, they were 2 2 JD/JD and 0 5 JD/JD in the summer season, respectively The return to capital for eggplant in both seasons was negative

Economic Returns to Water Use

Table 3 6 shows that the highest economic returns to water were for tomato under surface irrigation (JD 1 01/m^3) The economic return to water for molokhia grown in plastic houses was low (JD 0 22/m^3), while it was three and a half times the return for the same crop using surface irrigation, Figure 3 15

Table 3 7 and 3 8 compare summer season and winter season results for costs of production and the economic return to water Results show that the economic returns to water were higher in the summer season than in the winter season for vegetables produced in both seasons with the same technology, Figure 3 16 and Table 3 8

Although bananas were the highest in water consumption, the economic returns to that water were only JD 0 02/m^3

The economic returns to water for tomato under plastic houses were the highest in the summer season (JD 0 93/m^3), followed by seedless grapes (JD 0 52/m^3)

Figure 3 11 Returns to Capital (per dunum) for Vegetables and Wheat, Summer Season

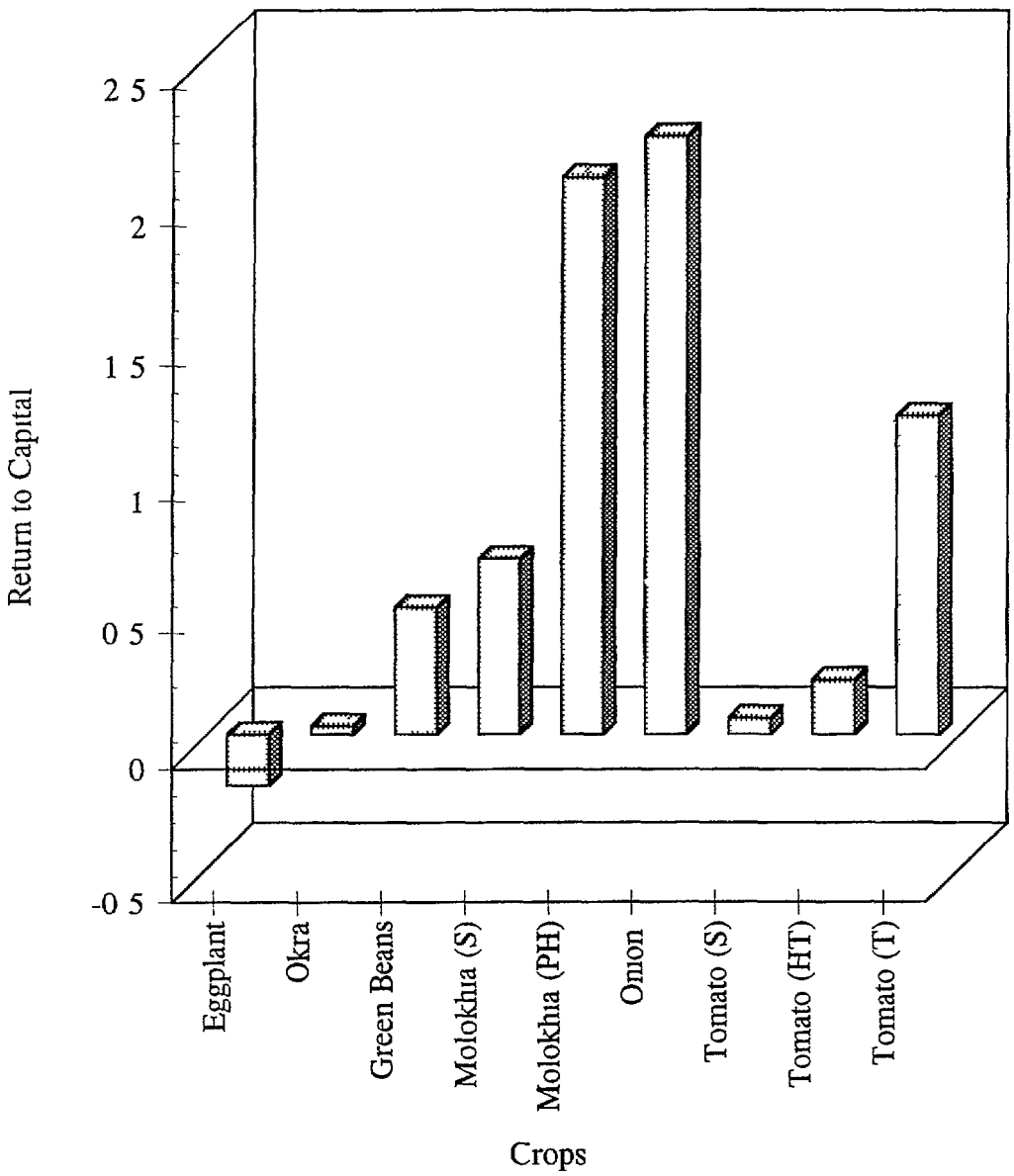


Table 3 5 Total Returns and Gross Margins for Fruits (JD/du)

Crop	Techn	yield (Ton/du)	Total Cost	Total Return	Gross Margins	Returns to Capital
Peach	Surface	1 1	273 8	513 1	239 3	0 87
Apples	Surface	0 1	161 6	62 4	-99 2	-0 61
Grapes Seedless	Surface	0 8	276 2	735 7	459 4	1 66
Grapes Ordinary	Surface	0 5	205 9	298 5	92 4	0 45
Banana	Surface	8 8	192 7	308 8	116 1	0 60
Citrus	Surface	0 3	236 5	642 8	406 3	1 72

Figure 3 12 Comparison of Total Return and Gross Margins (per dunum) for Fruits, 1993

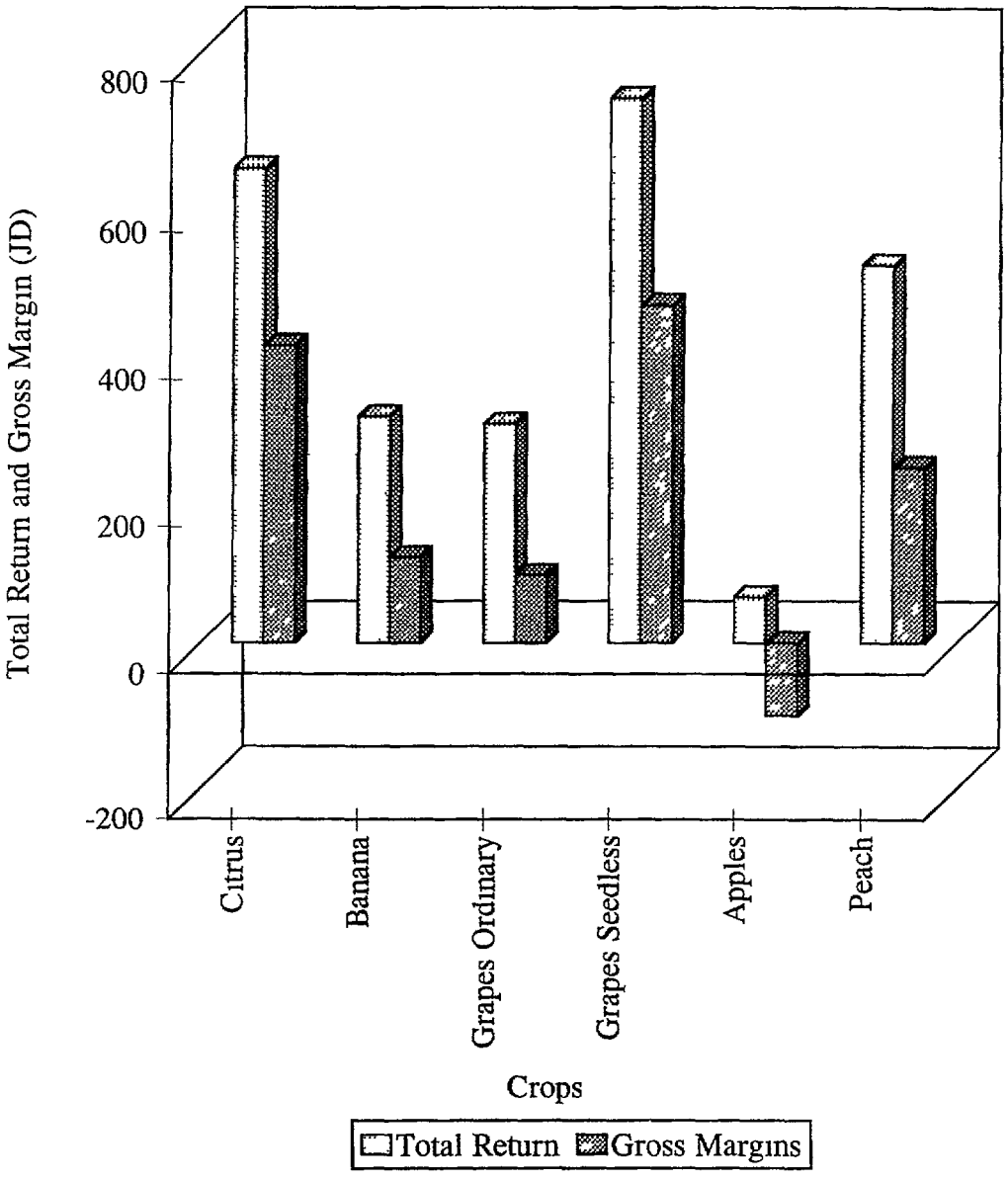


Figure 3 13 Returns to Capital for Fruits, 1993

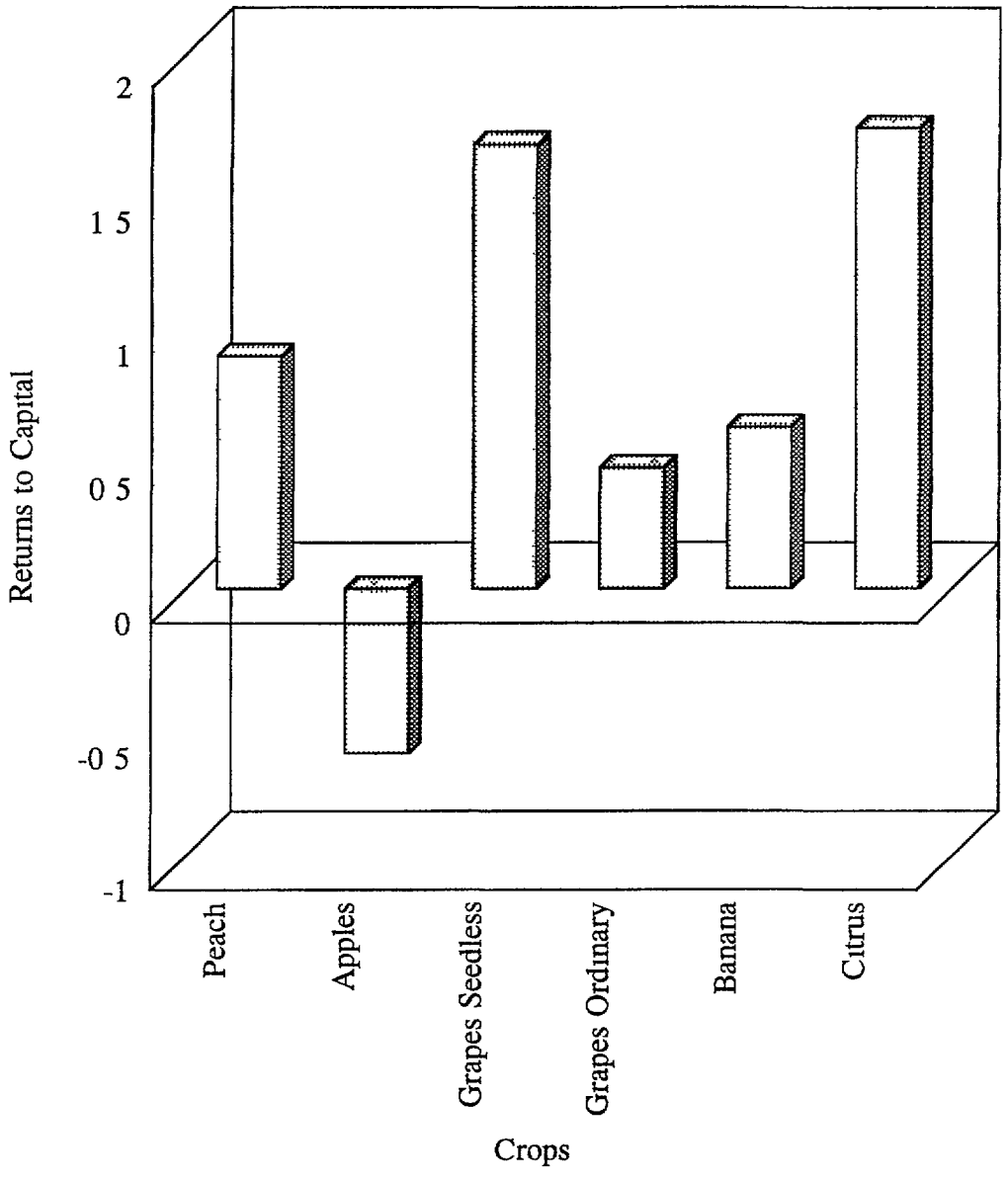


Figure 3 14 Comparison of Returns to Capital for Vegetables, Winter and Summer Seasons

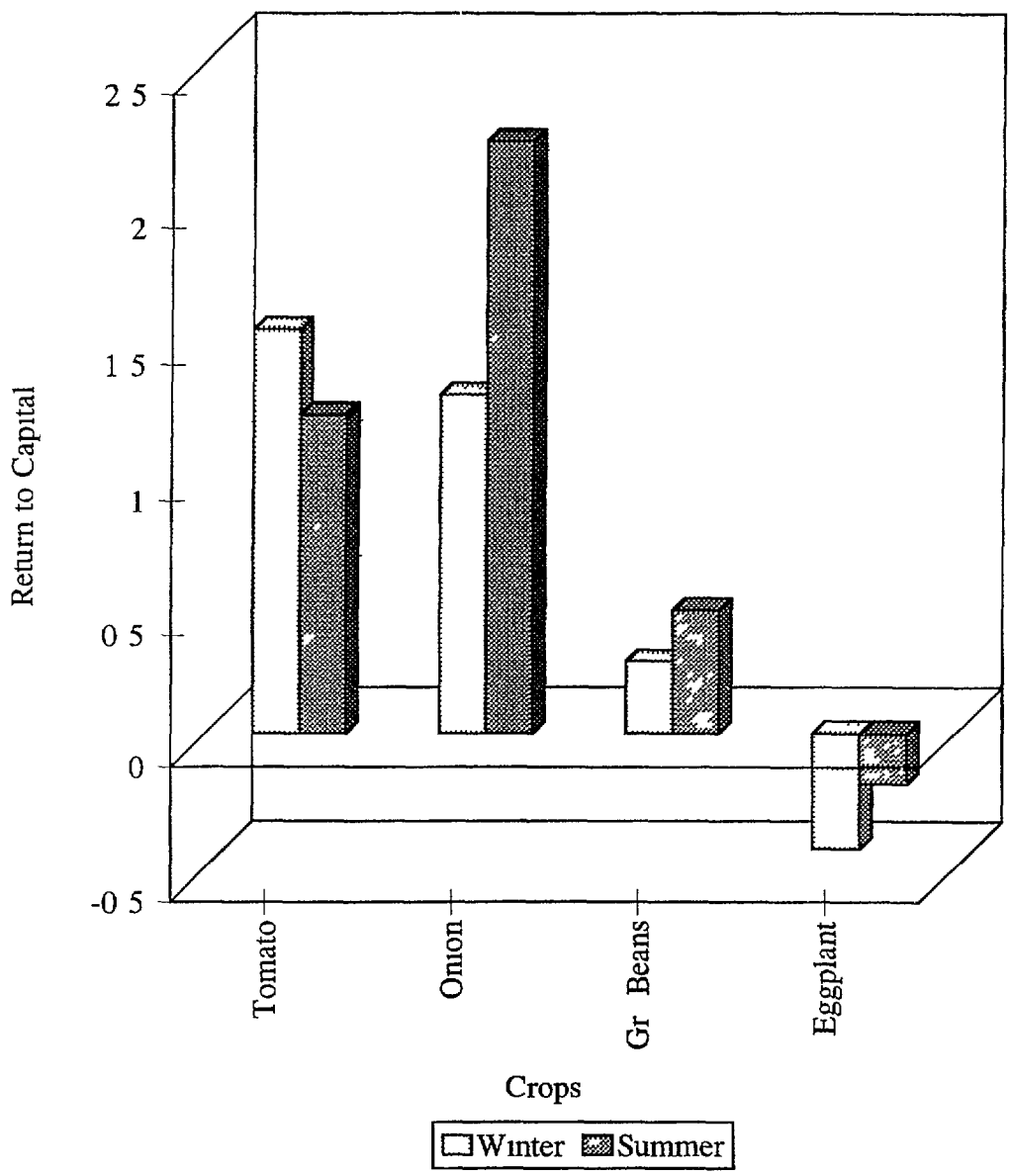


Table 3 6 Economic Returns to Water Consumption (per dunum)

Crop	Techn.	Water Consumption	Total Return	Economic Return to Water
Tomato	Plastic	752	698 4	0 93
	Drip	771	46 7	0 06
	Surface	650	8 1	0 01
Onions	Local	863	356 7	0 41
	Storable	610	190 5	0 31
Molokhia	Plastic	1240	268 9	0 22
	Surface	581	35 9	0 06
G Beans	Surface	538	66 4	0 12
Okra	Surface	624	1 0	0 001
Eggpi	Surface	1018	-18 1	0 02
Wheat	Surface	244	9 3	0 04
Peach	Surface	1028	239	0 23
Apples	Surface	980	-99	-0 10
Grapes (Seedless)	Surface	888	459	0 52
Grapes (Normal)	Surface	763	92	0 01
Banana	Surface	5629	116	0 02
Citrus	Surface	1296	406	0 31

Figure 3 15 Returns to Water Use for Vegetables and Fruits, Summer Season

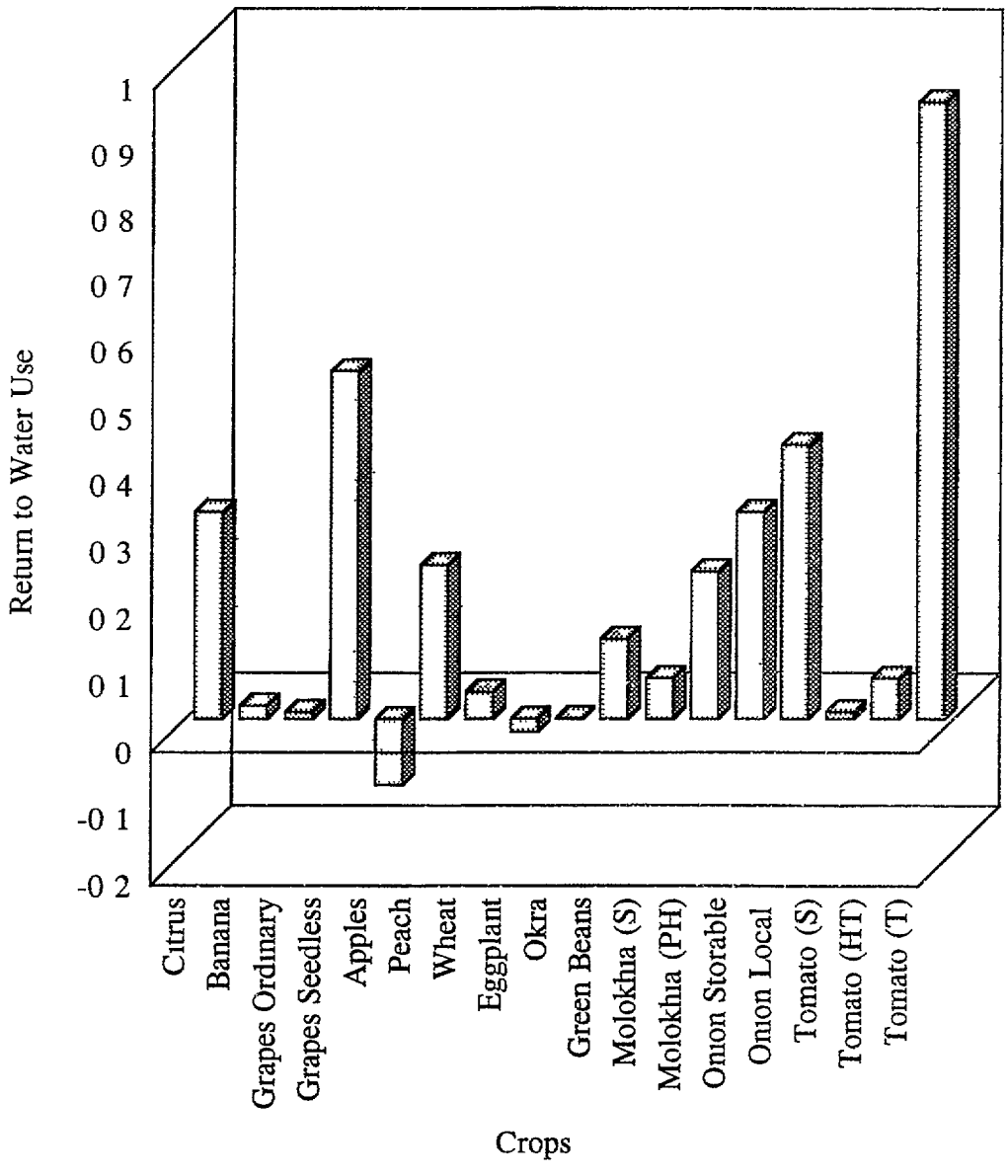


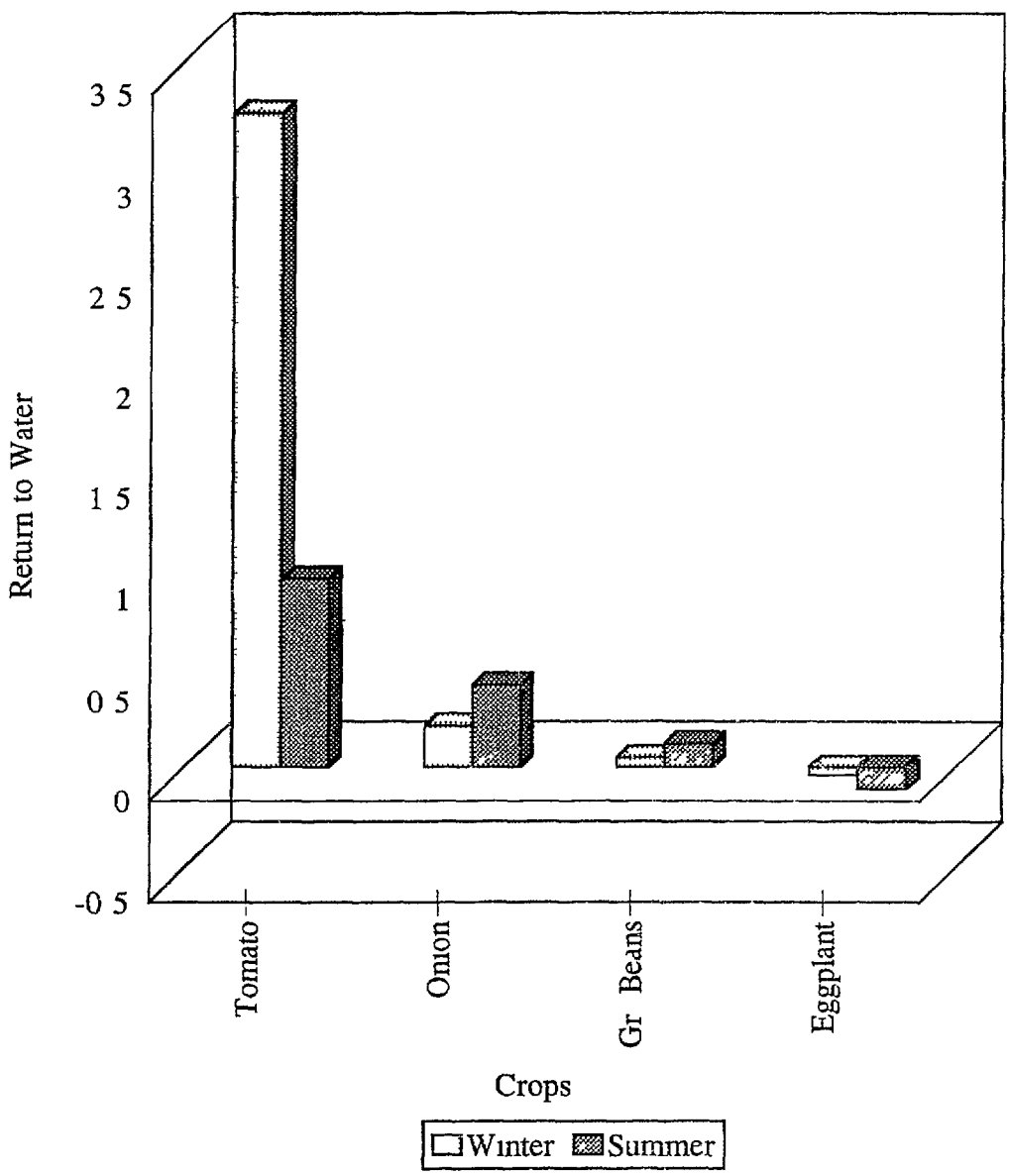
Table 3 7 Comparison of the Costs for Producing Vegetables, winter and summer seasons (JD/du)

Crop	Irrigation Method	Production Costs		Marketing Costs		Water Costs		Labor Costs	
		Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Tomato	Plas Hous	459	-	332	-	29 0	-	244	-
	Plas Tunn	-	246	-	223	-	4 5	-	114
	Drip	-	89	-	109	-	4 6	-	30
	Surface	-	59	-	53	-	3 9	-	20
Eggplant	Plas Hous	411	-	449	-	3 8	-	517	-
	Surface	35	53	21	24	5 0	6 1	12	12
Cucumber	Plas Hous	475	-	404	-	5 3	-	227	-
Onion	Drip	95	-	52	-	3 0	-	30	-
	Surface	30	55	20	58	3 3	5 2	27	29
Gr Beans	Drip	97	-	38	-	1 9	-	34	-
	Surface	82	76	19	33	4 3	3 2	19	30
Potato	Drip	226	-	63	-	3 1	-	21	-
	Surface	153	-	35	-	1 5	-	26	-
Carrot	Surface	42	-	-	-	7 0	-	6	-
Garlic	Surface	41	-	18	-	4 7	-	51	-
Molokhia	Plas Hous	-	61	-	50	-	7 4	-	13
	Surface	-	32	-	10	-	3 5	-	10
Okra	Surface	-	22	-	1	-	3 7	-	3
Wheat	Surface	-	41	-	2	-	1 5	-	0 3

Table 3 8 Comparison of the Returns for Producing Vegetables, Winter and Summer Seasons (JD/du)

Crop	Irrigation Method	Total Returns		Gross Margins		Returns to Water		Returns to Capital	
		Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Tomato	Plas Hous	2607	-	1565	-	3 24	-	1 5	-
	Plas Tunn	-	1286	-	698	-	0 93	-	1 19
	Drip	-	280	-	47	-	0 06	-	0 20
	Surface	-	144	-	8	-	0 01	-	0 06
Eggplant	Plas Hous	2187	-	796	-	1 25	-	-	-
	Surface	41	77	-313	-181	-0 04	-0 11	-0 43	-0 19
Cucumber	Plas Hous	2107	-	996	-	1 14	-	0 9	-
Onion	Drip	417	-	235	-	0 46	-	1 29	-
	Surface	186	519	104	357	0 21	0 41	1 26	2 20
Gr Beans	Drip	315	-	143	-	0 43	-	0 83	-
	Surface	159	209	34	66	0 05	0 12	0 27	0 47
Potato	Drip	542	-	197	-	0 38	-	0 57	-
	Surface	269	-	54	-	0 21	-	0 74	-
Carrot	Surface	194	-	-	-	0 11	-	2 06	-
Garlic	Surface	123	-	9	-	0 01	-	0 08	-
Molokhia	Plas Hous	-	400	-	269	-	0 22	-	2 05
	Surface	-	92	-	36		0 06	-	0 64
Okra	Surface	-	31	-	1	-	0 002	-	0 03
Wheat	Surface	-	17	-	9	-	0 04	-	1 19

Figure 3 16 Comparison of the Returns to Water Use for Vegetables, Winter and Summer Seasons



WATER QUALITY INVESTIGATIONS

Background

This study is a continuation of the water quality investigations that were done in summer 1993 and winter 1994 A water quality baseline was constructed against which water quality changes, as a result of USAID's Water Quality Improvement and Conservation (WQIC) Project, that began in early 1994, can be measured

In this study sampling at a frequency of twice a month was continued during summer 1994 (May 7 to October 30, 1994) at the same sampling locations used in the previous study

The water quality parameters followed were the same as in the first report Tables 4 1 and 4 2 show the chemical characteristics of water quality samples collected from Khirbet As-Samra (KA) and along the Zarqa River before and after mixing with King Abdullah Canal water during the summer months Table 4 3 shows averages of the chemical characteristics for a few key parameters in winter and summer months

Results and Discussion

In general, values for all water quality parameters have increased in summer 1994 when compared with summer 1993 This may be due to lower precipitation in 1994 as compared with 1993

Salinity as measured by electrical conductivity, calcium, magnesium, sodium the sodium adsorption ratio (SAR), and chloride increased in summer 1994 when compared with summer 1993 This applies for all sampling locations before and after mixing Yarmouk River waters with Zarqa River waters

Nitrogen as nitrate was lower at all locations (except at the drainage ditches) in summer 1994 when compared with summer 1993 Due to lower precipitation in 1994 less water from Khirbet As-Samra flowed into King Talal Reservoir and also lesser quantities of Zarqa River waters were mixed with KAC waters and thus nitrate levels decreased at all locations in summer 1994 when compared with summer 1993 Only the drainage waters exhibit higher NO_3 levels in summer 1994 when compared with summer 1993, an indication of nitrogenous fertilizer overuse and its leaching by over irrigation

Measurements for trace metals made during this study (summer 1993 through summer 1994) were always lower than the FAO guideline values (Table 4 4) Accumulation of these elements in the environment must, however, be monitored over the long term

Table 4 5 shows the results for microbiological tests of water samples collected during summer 1994 It can be seen that total heterotrophic bacterial counts, total coliform, and fecal coliform counts did not change significantly The same restriction criteria on using these waters for irrigation applied in summer 1994 as in summer 1993

A comparison of average values obtained in winter with those for summer (Table 4 3) showed the expected trend of lower concentrations of the different parameters in winter than in summer Except for Tal Al-Thahab and Abu-Zeighan locations, the EC values were lower in winter than in summer This was also observed in the previous summer season and was attributed to higher flow of the salt springs during the rainy season Drainage water at locations A and B also showed higher EC values in winter than in summer, which reflects leaching due to rain and excess water applied during the wet season

As for the suitability of using this water for irrigation, the sodium adsorption ratio (SAR) together with EC indicates no restriction on using this water, the chloride content requires, however, severe restrictions, Tables 4 1, 4 2, and 4 3

Table 4 1 Chemical characteristics of water collected from Khirbet As-Samra and along the Zarqa River before mixing with the KAC, Summer months (May - October)

Parameter	Effluent from KA wastewater treatment plant *Range* *Average*	23 km before King Talal Dam *Range* *Average*	King Talal Dam Reservoir *Range* *Average*	13 km below KTD Reservoir (Tal Al Thahab) *Range* *Average*	Z R Above the Valley (Abu Zeighan Weir) *Range* *Average*
EC (dS/m)	2 3 2 7 2 4	2 4 2 7 2 6	1 8 2 3 2 2	1 9 2 36 2 13	1 96 5 33 3 07
pH	6 9 7 8 7 5	7 7 8 2 7 9	7 4 8 1 7 9	8 0 8 4 8 2	7 2 7 8 7 5
Ca (mg/l)	69 81 76	80 156 103	100 134 118	88 124 114	116 317 177
Mg (mg/l)	34 59 45	32 74 52	53-70 58	50 75 60	55 97 68
Na (mg/l)	236 269 251	237 466 298	203 281 244	13 279 216	229 927 434
K (mg/l)	40 45 43	32 44 38	21 44 31	20 32 28	24 60 40
Cl (mg/l)	351 358 355	404 469 433	303 498 396	317 568 382	326 1074 554
SAR	5 7	6 0	4 6	4 1	7 0
SO_4 (mg/l)	34 57 49	44-139 99	79 176 136	118 243 159	151 608 281
HCO_3 (mg/l)	825 1025 926	60 970 583	364 671 474	392 588 443	443 973 575
BOD_5 (mg/l)	140 230 183	190 400 338	70 270 113	4 40 23	2 40 20
NH_4 (mg/l)	100 131 108	53 138 82	0 11 18 2 6 43	0 6 21 7	0 2 6 8 2 2
NO_3 (mg/l)	17 78 28	13 28 22	6 66 43	17 53 32	20 64 38

* *KA results are yearly average*

Table 4 2 Chemical characteristics of water samples collected from the KAC before and after mixing with Zarqa River water, and from two drainage ditches, Summer months (May-October)

Parameter	KAC Before Mixing *Range* *Average*	KAC After Mixing *Range* *Average*	KAC DA 22 23 *Range* *Average*	KAC DA 24 25 *Range* *Average*	KAC DA 26 27 *Range* *Average*	Drainage Water A *Range* *Average*	Drainage Water B *Range* *Average*
EC (dS/m)	0 91 0 98 0 93	2 02 3 67 2 74	1 3 3 4 2 74	1 01 3 38 2 66	1 03 3 59 2 71	2 13 6 35 4 81	5 25 6 66 5 94
pH	8 1 8 5 8 32	7 58 8 81 7 92	7 6 8 3 7 96	7 6 8 2 7 9	7 62 8 43 7 99	7 6 8 1 7 96	6 6 6 8 6 7
Ca (mg/l)	50 80 63	84 220 152	83 218 160	67 212 162	83 182 149	141 303 211	220 357 309
Mg (mq/l)	27 70 39	43 112 61	37 74 62	27 74 57	26 74 58	175 236 192	127 160 141
Na (mg/l)	78 313 106	214 478 330	233 432 339	170 421 329	169 447 340	502 1498 722	807 933 846
K (mg/l)	4 32 11	26 56 35	15 203 49	22 66 37	28 46 37	90 150 102	100 122 114
Cl (mg/l)	108 482 148	112 700 464	174 637 472	140 626 477	149 667 494	637 965 747	1117 1404 1216
SAR	2 6	5 7	6 3	6 1	6 5	9 9	11 0
SO_4 (mg/l)	43 150 86	120 338 223	125 402 246	113 366 228	137 346 245	940 1288 1129	688 919 860
HCO_3 (mg/l)	248 364 297	206 769 473	223 685 491	232 643 512	335 635 494	433 714 545	624-885 769
BOD_5 (mg/l)	0 20 6	0 13 4 2	0 20 6	0 19 6	0 13 3	0 16 3 4	0 2 0
NH_4 (mg/l)	0 02 0 34 0 1	0 11 7 4 3 0	0 04-8 9 2 6	0 1 4 6 1 5	0 04 10 7 2 5	0 02 54 0 13	0 01 0 08 0 03
NO_3 (mg/l)	5 3 32 2 12 5	22 66 39	28 55 43	25 55 38	25 53 38	127 196 153	54 105 82

Table 4 3 Summary of the chemical characteristics of water samples collected from Khirbet As-Samra and along the Zarqa River before and after mixing with KAC, winter and summer months

Site	EC (dS/m)		pH		SAR		BOD_5 (mg/l)		Cl (mg/l)		NH_4 (mg/l)		NO_3 (mg/l)	
	W*	S*	W	S	W	S	W	S	W	S	W	S	W	S
Effluent from KA	2 6	2 4	7 5	7 5	5 7	5 7	183	183	355	355	108	108	28	28
23 km before King Talal Dam	2 1	2 5	7 7	7 8	5 0	5 4	106	225	345	412	77	79	33	26
King Talal Dam Reservoir	2 0	2 1	7 7	7 8	4 5	4 1	37	99	338	348	14	6 2	57	55
13 km below KTD Reservoir (Tal Al-Thahab)	2 1	1 9	8 0	8 0	4 1	3 7	28	22	327	323	6	7 5	57	42
Z R Above the Valley (Abu-Zeighan Weir)	3 7	2 5	7 4	7 5	5 8	5 4	14	20	728	467	3	2 1	55	46
KAC Before Mixing	0 9	0 9	8 2	8 2	2 1	2 4	6	12	106	126	0 3	0 2	15	12
KAC After Mixing	1 7	2 4	8 0	7 8	3 7	4 9	15	18	278	407	2 0	2 6	31	46
KAC DA 22,23	1 7	2 4	8 0	7 9	3 7	5 0	8	19	276	403	1 8	2 3	29	47
KAC DA 24,25	1 8	2 4	8 0	7 8	4 0	5 1	18	15	296	430	3 0	2 7	31	44
KAC DA 26,27	1 8	2 4	8 0	8 0	4 3	5 2	13	20	315	430	1 1	1 7	30	46
Drainage water A	5 1	4 2	7 9	7 9	6 4	7 4	5	15	1094	692	0 6	0 6	118	135
Drainage water B	4 9	4 5	7 0	7 2	10 1	8 7	4	20	1181	810	1 1	0 6	95	85

W* Average winter month values

S* Average summer month values

Table 4 4 Trace metal concentrations in the collected water samples Results show averages and suggested guideline values for trace elements in irrigation waters, Summer months (May-October 1994)

Sample location	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
Suggested Maximum Guidelines values[1]	*0 1*	*0 1*	*0 2*	*5 0*	*0 2*	*2 0*
23 km before KTD	0 004	0 007	0 006	0 5	0 05	0 04
KTD Reservoir	0 01	0 006	0 007	0 4	0 04	0 02
KTD Outfall	0 003	0 008	0 004	0 2	0 08	0 04
Tal Al-Thahab	0 005	0 01	0 009	0 5	0 05	0 09
Abu Zeighan	0 007	0 01	0 008	0 7	0 03	0 02
Yarmouk River (KAC before mixing)	0 005	0 01	0 006	0 9	0 01	0 02
KAC after Mixing	0 006	0 01	0 007	1 0	0 04	0 02
KAC DA 22,23	0 006	0 01	0 006	1 0	0 05	0 07
KAC DA 24,25	0 006	0 02	0 007	1 0	0 03	0 02
KAC DA 26,27	0 006	0 01	0 007	0 6	0 04	0 007
Drainage water A	0 009	0 01	0 01	1 0	0 01	0 02
Drainage water B	0 01	0 01	0 01	0 8	0 05	0 02

(1) Adapted from Ayers and Westcot (1985)

Table 4 5 Microbiological analysis of the collected water samples, Summer months (May - October, 1994)

Site	Total Heterotrophic Bacterial Counts (THBC) CFU/ml[1]	Total Coliform Counts TC (MPN/100 ml)[2]	Fecal Coliform Counts FC (MPN/100 ml)
Effluent of Khirbet As-Samra	$3\ 99 \times 10^6$	$4\ 77 \times 10^3$	$3\ 41 \times 10^3$
23 km before KTD	$3\ 92 \times 10^6$	$2\ 94 \times 10^4$	$4\ 72 \times 10^4$
KTD Reservoir	$3\ 46 \times 10^4$	$2\ 43 \times 10^3$	$2\ 67 \times 10^2$
KTD Outfall	$3\ 72 \times 10^4$	$4\ 74 \times 10^2$	$4\ 31 \times 10^1$
Tal Al Thahab	$5\ 03 \times 10^4$	$4\ 0 \times 10^3$	$3\ 53 \times 10^2$
Abu Zeighan	$3\ 54 \times 10^5$	$3\ 0 \times 10^3$	$3\ 41 \times 10^3$
Yarmouk River (KAC before mixing)	$3\ 93 \times 10^4$	$5\ 26 \times 10^3$	$3\ 44 \times 10^3$
KAC after mixing	$4\ 17 \times 10^5$	$2\ 64 \times 10^4$	$7\ 88 \times 10^4$
KAC DAs 22,23	$1\ 58 \times 10^5$	$4\ 53 \times 10^4$	$4\ 5 \times 10^4$
KAC DAs 24,25	$4\ 22 \times 10^5$	$2\ 97 \times 10^4$	$4\ 10 \times 10^4$
KAC DAs 26 27	$3\ 86 \times 10^5$	$3\ 9 \times 10^4$	$3\ 82 \times 10^3$
Drainage Water	$3\ 31 \times 10^5$	$5\ 16 \times 10^4$	$5\ 18 \times 10^4$
Drainage Water	$4\ 27 \times 10^4$	$3\ 79 \times 10^3$	$3\ 0 \times 10^3$

(1) CFU Colony Forming Unit per milliliter
(2) MPN/100 ml Most Probable Number in 100 ml

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ANNEXES

ANNEX A

METHODS AND DATA USED FOR CALCULATION OF EVAPOTRANSPIRATION AND ON-FARM IRRIGATION MANAGEMENT EFFICIENCY

Effective Precipitation

Precipitation data for 1993/94 were taken from the Deir Alla meteorological station in the Central Jordan Valley Effective precipitation was calculated using the method employed by the Soil Conservation Service, U S Department of Agriculture, using the formula

$$P_{eff} = P_{tot}(125\text{-}0\ 2\ P_{tot})/125 \qquad \text{for } P_{tot} < 250 \text{ mm}$$

Effective precipitation was further adjusted as follows

(1) For plastic houses, effective precipitation was considered to be zero

(2) For crops grown in tunnels, effective precipitation was considered to be zero during the time the tunnels were used

(3) For drip irrigation in open fields, where the crop was grown using a plastic mulch, effective precipitation was assumed to be 30 percent of the effective precipitation as calculated from the formula

Monthly values for precipitation and effective precipitation are given in Table A-1

Reference Crop Evapotranspiration

Reference crop evapotranspiration (ET_p) was calculated from the Penman-Monteith equation using 1993/94 data from the Deir Alla meteorological station Calculations were developed for a 10-12 centimeters high grass cover Daily and monthly values for ET_p are furnished in Table A-1

Crop Coefficients

Values for crop coefficients (Kc) were computed using methods detailed in FAO Irrigation and Drainage Paper No 24, "Crop Water Requirements " Table A-2 is a compilation of Kc values for each crop and farm in the baseline study

Table A-1 Monthly Precipitation, Effective Precipitation, and Reference Crop Evapotranspiration

Month	Monthly Precip (mm)	Effective Precip (mm)	Reference Crop Evapo-transpiration (ETp)	
			(mm per day)	(mm per month)
September, 93	0	0	5 1	153
October, 93	7	7	4 6	143
November, 93	8	8	2 4	72
December, 93	6	6	1 3	40
January, 94	92	79	2 2	68
February, 94	42	39	2 5	70
March, 94	24	23	3 1	96
April, 94	0	0	5 2	156
May, 94	0	0	6 4	199
June, 94	0	0	7 38	222
July, 94	0	0	7 3	226
August, 94	0	0	6 9	214
Total	179	162	-	1660

Precipitation data from Deir Alla
ETp calculations using Penman-Monteith Method and data from Deir Alla

Table A-2 Farms Crops, Crop Stage Duration, Initial Period Evapotranspiration, and Crop Coefficent (Kc) Values

Crop	Duration of Crops Stage (days)				Total	ETpi	Kci	Kc1	Kc2	Seasonal Kc
	1st	2nd	3rd	4th						
Grapes					365					0 65
Grapes					365					0 65
Citrus					365					0 75
Tomato	30	45	75	35	185	1 3	0 73	1 2	0 65	1 01
Potato	20	29	30	20	99	2 4	0 62	1 15	0 75	0 92
Squash	17	24	24	7	72	4 5	0 50	0 95	0 75	0 76
Eggplant	29	40	40	20	129	4 6	0 50	1 05	0 85	0 83
Beans	15	15	15	2	47	4	0 51	1	0 9	0 76
Tomato2	30	30	40	13	113	2 5	0 60	1 2	0 65	0 93
Grapes					365					0 65
Cabbage	25	35	30	18	108	2 4	0 60	1 05	0 9	0 86
Califlower	25	35	30	18	108	2 4	0 60	1 05	0 9	0 86
Squash	20	35	31	25	111	2	0 66	0 95	0 75	0 83
Potato	25	33	33	20	111	1 8	0 70	1 15	0 75	0 95
Tomato	35	40	45	26	146	2 2	0 64	1 2	0 65	0 94
Banana					365					0 90
Onion	15	30	55	35	135	1 3	0 73	1 05	0 8	0 95
Alfalfa			273		365					0 95
Wheat	19	25	60	30	134	2 2	0 64	1 15	0 2	0 92
Citrus					365					0 75
Onions	15	30	105	40	190	2	0 66	1 05	0 8	0 96
Alfalfa			273		365					0 95
Spinach1	20	23	29	5	77	4	0 51	1	0 95	0 80
Spinach2	20	20	16	5	61	2 4	0 60	1	0 95	0 80
Carrots1	25	35	42	20	122	5 1	0 45	1 1	0 8	0 85
Carrots2	30	40	61	20	151	4 6	0 45	1 1	0 8	0 86
Onion	15	30	85	42	172	2 4	0 60	1 05	0 8	0 94
Eggplant		1	40	20	61		0 41	1 05	0 85	1 01
Tomato	30	45	50	33	158	1 6	0 70	1 2	0 65	0 98
Br Beans	20	30	30	23	103	4 8	0 48	1	0 9	0 81
Fennel	25	41	56	40	162	2 4	0 60	1 1	0 2	0 85
Beans	20	30	50	20	120	2 2	0 64	1	0 9	0 89
Garlic	15	30	91	45	181	2 4	0 60	1 05	0 8	0 94
Wheat	20	33	64	40	157	1 3	0 73	1 15	0 2	0 93

Table A-2 Contiued

Crop	Duration of Crops Stage (days)				Total	ETpi	Kci	Kc1	Kc2	Seasonal Kc
	1st	2nd	3rd	4th						
Okra	25	30	30	17	102	5 6	0 46	1	0 9	0 78
Molokhia	25	30	32	20	107	5 2	0 45	1	0 95	0 79
Beans1	15	20	25	12	72	4 4	0 50	1	0 9	0 82
Potato	20	30	30	14	94	2 4	0 60	1 15	0 75	0 92
Onions	15	30	100	45	190	2 2	0 64	1 05	0 8	0 96
Beans2	20	30	36	17	103	2 5	0 60	1	0 9	0 86
Grapes					365					0 65
Citrus					365					0 75
Cucumber C	20	30	108	40	198	4 2	0 50	0 95	0 95	0 87
Molokhia C	33	20	20	19	92	6 4	0 41	1	0 95	0 72
Potato	25	33	47	31	136	2 2	0 64	1 15	0 75	0 95
Onion	15	30	78	40	163	2 4	0 60	1 05	0 8	0 94
Beans	20	30	54	20	124	2 2	0 64	1	0 9	0 89
Citrus					365					0 75
Citrus					365					0 75
Peaches					365					0 60
Apples					365					0 55
Eggplant C	30	40	85	33	188	4 4	0 50	1 05	0 85	0 89
Cucumber C	20	30	100	30	180	4 4	0 50	0 95	0 75	0 85
Tomato C	30	30	125	41	226	4 4	0 50	1 2	0 65	1 01
Alfalfa	35	40	65	49	189	2	0 66	1	0 95	0 80
Onion	15	30	99	45	189	2	0 66	1 05	0 8	0 96
Apples					365					0 55
Cucumber1 C	20	30	113	35	198	4 4	0 50	0 95	0 75	0 85
Cucumber2 C	20	30	128	35	213	4 4	0 50	0 95	0 75	0 86
Molokhia C										
Potato	30	40	67	30	167	4 4	0 50	1 15	0 75	0 92
Eggplant	10	40	52	20	122	6 5	0 42	1 05	0 85	0 88
Peppers	10	35	88	20	153	6 5	0 42	1 05	0 85	0 92
Tomato	30	45	70	28	173	1 3	0 73	1 2	0 65	1 01
Squash	15	35	30	22	102	5	0 46	0 95	0 75	0 77
Beans	15	25	28	10	78	3 5	0 54	1	0 9	0 83
Pepper	10	35	57	20	122	6 5	0 42	1 05	0 85	0 89
Potato1	25	33	30	20	108	4 4	0 50	1 15	0 75	0 86
Squash/tun	17	35	30	25	107	2	0 66	0 95	0 75	0 83

Table A-2 Continued

Crop	Duration of Crops Stage (days)				Total	ETpi	Kci	Kc1	Kc2	Seasonal Kc
	1st	2nd	3rd	4th						
Tomato1	30	43	49	30	152	2 2	0 64	1 2	0 65	0 96
Onion	19	35	110	45	209	2 4	0 60	1 05	0 8	0 94
Squash	25	36	36	25	122	5 1	0 45	0 95	0 75	0 75
Tomato2	20	36	36	24	116	2 5	0 61	1 2	0 65	0 95
Corn	20	31	31	11	93	3 5	0 53	1 15	1 05	0 91
Potato2	15	30	45	30	120	2 2	0 64	1 15	0 75	0 97
Beans	20	50	60	21	151	4 6	0 50	1	0 9	0 84
Peas	25	60	60	17	162	4 4	0 50	1 15	1 05	0 92
Potato	25	36	36	20	117	2 4	0 60	1 15	0 75	0 91
Peppers		11	60	20	91	6 5	0 42	1 05	0 85	0 99
Garlic	14	35	104	45	198	4 9	0 46	1 05	0 8	0 93
Onion	15	39	84	40	178	4 2	0 50	1 05	0 8	0 92
Potato	25	36	36	20	117	2 4	0 60	1 15	0 75	0 91
Cucumber C	25	50	65	25	165	4 2	0 50	0 95	0 75	0 80
Tomato	28	45	70	30	173	1 3	0 73	1 2	0 65	1 02
Eggp+Corn	30	41	41	20	132	2 3	0 63	1 05	0 85	0 87
Beans2	10	24	24	10	68	4 6	0 50	1	0 9	0 83
Corn	20	30	30	11	91	5 2	0 47	1 15	1 05	0 88
Molokhia C	22	30	40	15	107	5 2	0 47	1	0 95	0 81
Banana					365					0 90
Cabbage	25	40	45	12	122	4 6	0 50	1 05	0 9	0 84
Tomato1	30	40	76	15	161	2 2	0 64	1 20	0 65	1 00
Tomato2	18	28	28	19	93	3 3	0 56	1 20	0 65	0 92
Tomato C	25	40	40	25	130	1 3	0 73	1 2	0 65	0 98
Onion	15	34	79	40	168	1 3	0 73	1 05	0 8	0 96
Cucumber C	25	30	100	33	188	2	0 66	0 95	0 75	0 87
Tomato C	25	40	93	30	188	2	0 66	1 2	0 6	1 02

C = Plastic Houses (Covered)

(1) The growing season for each crop was taken from field observations For calculation of Kc, the duration of each crop stage was taken from FAO No 24 in combination with plant/harvest information shown in Table A-3

(2) The ET for the initial period, ET_{pi}, is the average daily ET_p for the month (or portion thereof) when the crop was planted

(3) Kci (Kc x initial period) is derived from ET_{pi} and Figure 6, FAO No 24

(4) For vegetables and field crops, seasonal Kc values were calculated from the equation

Kc = {Kci x initial period + ((Kci+Kcmid)/2) x Crop-development period + Kcmid x mid-season period + ((Kcmid+Kclate)/2) x late-season periods} / total-seasonal period All periods are number of days

(5) Kc for the permanent crops was calculated using methods detailed in the FAO Paper No 24

Crop	Table No	Remarks
Alfalfa	23	Except for new plantings
Banana	24	
Citrus	25	Assume clean cultivated and full cover, dry light winds
Grapes	27	Assume 30% cover, dry light winds
Peaches	26	50% cover
Apples	26	30-50% cover

Crop Evapotranspiration

Crop evapotranspiration, ET_c, was calculated using the formula

$$ET_c = Kc \times ET_p$$

Seasonal values for Kc were used together with ET_p values for the entire growing period to compute ET_c

ET_c and ET_p values for each crop are given in Annex B

Because of microclimate effects, especially high relative humidity, and a lack of ventilation (wind) , ET_c in plastic houses was assumed to be 65 percent of the calculated ET_p, per FAO No 24 Sensitivity analyses were made using ET (plastic houses) equal to 75 percent and 85 percent of calculated ET_p

Table A-3 Planting and Harvesting Dates for All Crops under study in the selected farms

Farm No.	Crop	Date of Planting	Date of Harvesting
	Grapes		
2	Grapes		
4	Citrus		
5	Tomato/tun	28-Nov-93	31-May-94
	Potato	25-Oct-93	31-Jan-94
	Squash	20-Oct-93	31-Dec-93
	Eggplant	25-Sep-93	31-Jan-94
	Beans	15-Oct-93	30-Nov-93
	Tomato2	05-Feb-94	28-May-94
6	Grapes		
7	Cabbage	05-Nov-93	20-Feb-94
	Califlower	05-Nov-93	20-Feb-94
	Squash/tun	20-Nov-93	10-Mar-94
	Potato	25-Nov-93	15-Mar-94
	Tomato	01-Jan-94	31-May-94
8	Banana		
9	Onion	02-Dec-93	15-Apr-94
	Alfalfa		
	Wheat	02-Jan-94	15-May-94
10	Citrus		
11	Onions	20-Nov-93	28-May-94
13	Alfalfa		
14	Spinach1	15-Oct-93	30-Dec-93
	Spinach2	01-Nov-93	30-Dec-93
	Carrots1	01-Sep-93	31-Dec-93
	Carrots2	01-Oct-93	28-Feb-94
	Onion	05-Nov-93	25-Apr-94
	Eggplant	before Sep	31-Oct-93
	Tomato	25-Dec-93	31-May-94
	Br Beans	20-Sep-93	31-Dec-93
	Fennel	10-Nov-93	20-Apr-94
	Beans	01-Jan-94	30-Apr-94
	Garlic	01-Nov-93	30-Apr-94
	Wheat	10-Dec-93	15-May-94
	Okra	20-Apr-94	30-Jun-94
	Molokhia	01-Apr-94	31-Jul-94
15	Beans1	20-Oct-93	30-Dec-93
	Potato	27-Oct-93	30-Jan-94
	Onions	20-Nov-93	28-May-94

Table A-3 Continued

Farm No.	Crop	Date of Planting	Date of Harvesting
	Beans2	15-Feb-94	28-May-94
16	Grapes		
17	Citrus		
18	Cucumber C	15-Oct-93	30-Apr-94
	Molokhia C	01-May-94	31-Jul-94
19	Potato	15-Nov-93	30-Mar-94
	Onion	04-Nov-93	15-Apr-94
	Beans	28-Dec-93	30-Apr-94
20	Citrus		
21	Citrus		
23	Peaches		
24	Apples		
25	Eggplant C	10-Oct-93	15-Apr-94
	Cucumber C	18-Oct-93	15-Apr-94
	Tomato C	18-Oct-93	31-May-94
	Alfalfa	24-Nov-93	31-May-94
	Onion	24-Nov-93	31-May-94
27	Apples		
28	Cucumber1 C	15-Oct-93	30-Apr-94
	Cucumber2 C	15-Oct-93	15-May-94
	Molokhia C	11-Apr-94	15-Jun-94
29	Potato	15-Oct-93	30-Mar-94
	Eggplant	before Sep	31-Dec-93
	Peppers	before Sep	31-Jan-94
	Tomato	10-Dec-93	31-May-94
	Squash	21-Sep-93	31-Dec-93
	Beans	15-Mar-94	31-May-94
30	Pepper	before Sep	31-Dec-93
	Potato1	16-Oct-93	31-Jan-94
	Squash/tun	29-Nov-93	15-Mar-94
	Tomato1	29-Dec-93	31-May-94
	Onion	04-Nov-93	31-May-94
	Squash	01-Sep-93	31-Dec-93
	Tomato2	05-Feb-94	31-May-94
	Corn	15-Mar-94	15-Jun-94
	Potato2	01-Jan-94	30-Apr-94
31	Beans	01-Oct-93	28-Feb-94
	Peas	10-Oct-93	20-Mar-94
	Potato	01-Nov-93	25-Feb-94

Table A-3 Continued

Farm No.	Crop	Date of Planting	Date of Harvesting
	Peppers	before Sep	30-Nov-93
	Garlic	20-Sep-93	05-Apr-94
	Onion	25-Oct-93	20-Apr-94
	Potato	01-Nov-93	25-Feb-94
	Cucumber C	23-Oct-93	05-Apr-94
	Tomato	10-Dec-93	31-May-94
	Eggp+Corn	20-Jan-94	31-May-94
	Beans2	25-Mar-94	31-May-94
	Corn	01-Apr-94	
	Molokhia C	10-Apr-94	
32	Banana		
33	Cabbage	01-Oct-93	30-Jan-94
	Tomato1	01-Jan-94	10-Jun-94
	Tomato2	10-Mar-94	10-Jun-94
34	Tomato	15-Dec-93	23-Apr-94
35	Onion	15-Dec-93	31-May-94
	Cucumber C	25-Nov-93	31-May-94
	Tomato C	25-Nov-93	31-May-94

C= Plastic Houses (Covered)

On-Farm Irrigation Management Efficiency

IME was computed from crop evapotranspiration, actual amount of water applied, and effective precipitation according to the following formula

$$IME = [ET_c/(\text{applied water} + \text{effective precipitation})] \times 100$$

For each crop, IME calculations are shown in Annex B

Average values for IME for each irrigation type (surface, drip, and plastic house drip) were computed as weighted averages

ANNEX B

DATA PERFORMA

Table B-1 Area, Water Application, Effective Precipitation, Reference Crop Evapotranspiration, Crop Evapotranspiration, and Irrigation Management Efficiency

Farm # 1 — Type of Irrigation: Localized (drip)

DA 27 Unit No 439

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Grapes	2 67	201	226	107	0	0	0	272	761	487	362	146	325	1081	162 7	1659 7	1086 0	87 3

Farm # 2 — Type of Irrigation: Localized (drip)

DA 26 Unit No 138

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Grapes	24 87	2520	3058	1298	836	0	0	2332	4135	6614	3721	3238	4564	1299	162 7	1659 7	1086 0	74 3

Farm # 4 — Type of Irrigation: Localized (drip)

DA 25 Unit No 226

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Citrus	30 88	7478	5922	6242	3657	1358	1338	3457	3471	4994	6609	6220	4147	1778	162 7	1659 7	1244 8	64 2

Flows estimated from JVA records

Farm # 5 — Type of Irrigation: Localized (drip)

DA 25 Unit No 178

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Tomat (T)	6 61		-	225	243	0	206	630	1648	2020	-	-		752	18 8	617 8	624 0	80 9
Potato	5 62	-	764	1056	974	0				-	-	-	-	497	28 5	205 9	189 4	36 0
Squash	6 04	-	965	955	667	-		-		-	-	-	-	428	7 0	161 6	122 8	28 2
Eggplant	2 78		1265	151	258	0	-	-		-	-	-		602	30 0	352 4	292 5	46 3
Beans	1 36	-	602	64				-		-		-		490	3 1	150 2	114 2	23 2
Tomato2	11 60			-	-		363	1106	2896	3544		-		682	18 5	492 1	457 7	65 4

* The last harvest of tomato (T) and tomato2 was on 28th of May 1994

Farm # 6 — Type of Irrigation: Localized (drip)

DA 25 Unit No 68

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Grapes	9 92	557	655	0	0	0	0	0	1452	1373	932	1244	822	709	162 7	1659 7	1086 0	100 0

Table B 1 Continued

Farm # 7																		Type of Irrigation	Localized (drip)
		DA 25		Unit No 31															
	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME	
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%	
Cabbage	20 00	-		7566	2734	574	470		-		-			567	32 4	220 9	190 0	31 7	
Califlower	3 30			4275	451	95		-	-					1461	32 4	220 9	190 0	12 7	
Squash (T)	19 80	-		5371	2706	568	1081		-		-			491	15 0	239 0	198 4	39 2	
Potato	5 30			1779	725	152	470		-	-				590	44 0	242 5	230 4	36 4	
Tomato	12 00	-			-	344	328	894	3952	2188				642	42 4	589 6	554 3	81 0	

* The last harvest on 31th May 1994

Farm # 8																		Type of Irrigation	Localized (drip)
		DA 25		Unit No 18															
	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME	
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%	
Banana	34 20	11231	9601	7426	4461	1774	1745	2166	12276	13452	12430	12990	13774	3021	162 7	1659 7	1493 8	46 9	

Note Microjet emitters

Farm # 9																		Type of Irrigation	Surface
		DA 24		Unit No 76															
	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME	
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%	
Onion	10 30	-			1915	812	566	1511			-	-		466	147 5	356 5	338 7	55 2	
Berseem	5 62	2299	713	0	221	406	566		777	143		-	-	912	162 7	997 5	948	88 2	
Wheat	35 00	-	-		664	0		5940	4320	893				338	141 4	484 6	445 8	93 1	

* Wheat was harvested on 15th May 1994

Farm # 10																		Type of Irrigation	Surface
		DA 24		Unit No 39															
	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME	
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%	
Citrus	36 00	9538	10108	5294	1857	0	400	0	3200	8294	9333	4224	8294	1682	162 7	1659 7	1245 0	67 5	

Table B 1 Continued

Farm # 11																		Type of Irrigation	Surface
		DA 24		Unit No 5															
	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Onions	32 00		-	2100	5658	301	2844	1518	6958	2087	-			671	147 9	643 5	617 7	75 5

* Onions washarvested on 28th May 1994

Farm # 13																		Type of Irrigation	Surface
		DA 23		Unit No 249															
	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Alfalfa	29 00	6571	6963	6403	5060	257	1082	1241	4538	2087	2836	3626	7338	1655	162 7	1659 7	1544	84 9

* Water applield during Nov and Dec was estimated from JVA record

Farm # 14																		Type of Irrigation	Surface
		DA 23		Unit No 197															
	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Spinach1	0 64	-	68	233	115	-	-	-	-	-	-	-		650	17 0	112 3	89 8	13 5
Spinach2	0 57	-		233	115	-	-	-	-	-	-	-	-	611	14 0	254 9	203 9	32 6
Carrots1	3 00	1289	273	698	345	-	-	-	-	-	-	-		868	21 3	407 9	346 7	39 0
Carrots2	2 40	-	681	931	461		1645	-	-	-	-	-		1549	133 0	393 1	338 1	20 1
Onions	3 65	-	-	698	345			211	492		-			478	148 0	464 6	436 7	69 7
Eggplant	0 75	644	136		-	-	-	-	-	-			-	1040	7 3	295 6	298 6	28 5
Tomato	2 70	-	-	-		513		211	492	501			-	636	141 4	597 4	585 5	75 3
B Beans	3 98	1289	204	465	230		-		-		-		-	550	21 3	305 9	247 8	43 4
Fennel	0 65			233	115								-	535	156 0	429 0	364 7	52 7
Beans	3 52		-	-	-	256		211	820	-				366	141 4	390 3	347 4	68 5
Garlic	3 26		-	1164	576			211	164	-	-	-		649	148 0	502 6	472 4	59 3
Wheat	2 95		-			769		211		550	-	-	-	519	147 7	514 1	478 1	71 7
Okra	4 00		-	-	-	-	-	-	164	742	875	714	-	624	0 0	796 3	621 1	99 6
Molokhia	5 70	-	-	-	-		-	-	328	1058	1246	678	-	581	0 0	697 5	551 0	94 9

* Beans and Garlic were harvested by the 30th of April 1994
* Tomato was harvested by 31th of May 1994
* Wheat was harvested on 15th of May 1994
* Okra and Molokhia were harvested on 30th July

Table B-1 Continued

Farm # 15 — Type of Irrigation: Localized (drip)

DA 23 Unit No 224

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Beans1	4 20	-	-		355	0		404	628	307	-		-	403	7 0	417 6	342 4	83 5
Potato	5 46	-	801	121	574	361	-	-	-	-		-	-	340	28 1	198 9	183 0	49 7
Onions	1 35		-	268	77	0		125	194	98		-		564	147 9	637 0	611 6	85 9
Beans2	5 30	-	-	-	-	-		510	793	388	-	-	-	319	19 0	467 1	401 7	100 0

* All the Crops were harvested by the end of May, 1994

Farm # 16 — Type of Irrigation: localized (drip)

DA 23 Unit No 202

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Grapes	30 00	3843	222	0	0	0	5023	1442	1728	2764	2737	3456	1647	762	162 7	1659 7	1086 0	100 0

Farm # 17 — Type of Irrigation: Surface

DA 23 Unit No 215

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Citrus	28 00	7861	4740	3008	1994	0	422	0	200	6316	4089	4320	4665	1343	162 7	1659 7	1244 8	82 7

* Farm rented out Poorly managed
* Check number of dunum
Oranges 3 du 2300 6900 kg

Lemons 6 du 300 kg/du 1800 kg
Mandarine 14 du 2000 28000 kg
Ave Yield = 15 950, Gross Margin = JD 1498/ha

Farm # 18 — Type of Irrigation: Localized (drip) in plastic house

DA 23 Unit No 216

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Cucumbers (H)	6 03	-		880	170	153	259	609	1556	-	-	-	-	601	0 0	580 8	328 4	54 6
Molokhia (H)	6 03	-	-	-	-		-	-	-	890	1320	1400	-	599	0 0	647 6	466 3	77 9

* Harvesting of cucumber was ended by 30th of April, 1994
The same area were then planted b Molokhia till the end of May

Table B 1 Continued

Farm # 19 — Type of Irrigation: Surface

DA 23 Unit No 69

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Potato	4 72			308	945	523								376	151 0	313 0	297 4	56 4
Onion	4 48			284	343		232	1440						513	155 4	422 6	397 2	59 4
Bean	4 73							1440	1922					711	142 9	395 5	352 0	41 2

* Harvesting of Beans was ended by the 30th of April 1994

Farm # 20 — Type of Irrigation: Localized (drip)

DA 22 Unit No 266

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Citrus	31 00	6527	4246	5061	6022	1446	0	0	2410	6222	4142	3558	4697	1430	162 7	1659 7	1244 8	78 2

Lemons 3 0 du — Nov Dec Jan estimated from JVA Seems too high May discard

Mandarine 7 5 du — Oranges 20 5 du

Aver Yield = 30 900 kg/ha Gross Margin = JD 5210/ha

Farm # 21 — Type of Irrigation: Surface

DA 22 Unit No 265

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Citrus	30 00	4570	5980	2344	2308	586	0	0	1563	4691	4625	3363	4775	1160	162 7	1659 7	1244 8	94 1

* Surface irrigation was changed into Drip irrigation by the end of April 1994

Farm # 23 — Type of Irrigation: Localized (drip)

DA 22 Unit No 26

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Peaches	60 00	3665	0	0	0	0	0	2435	8902	8962	8342	5677	5742	729	162 7	1659 7	995 8	100 0

Farm # 24 — Type of Irrigation: Localized (drip)

DA 22 Unit No 4

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Apples	65 00	8932	1277	0	981	0	220	3240	10478	14196	14501	6071	5902	1012	162 7	1659 7	912 9	77 7

Table B 1 Continued

Farm # 25 — Type of Irrigation: Localized (drip) in plastic house

DA 22 Unit No 3

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Eggplant (H)	5 03		573	116	994	480	616	429						638	0 0	521 2	301 5	47 3
Cucumbers(H)	0 49		54	10	46	57	57	54						567	0 0	484 4	267 6	47 2
Tomato (H)	7 87		864	167	727	904	915	861	1229	440				776	0 0	761 7	500 1	64 4
Alfalfa (S)	0 68			154	221	0	0	406	614	40				2110	147 9	646 7	517 4	
Onions (D)	2 54			1220	883	0	0	1452	2196	139				2319	147 9	646 7	620 9	25 2

* Alfalfa and Onions are not covered

* The crops were harvested by the end of May 1994

Farm # 27 — Type of Irrigation: Localized (drip)

DA 22 Unit No 8

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Apples	28 00	2139	411	500	1665	0	0	914	2834	4838	3226	3264	2430	794	162 7	1659 7	912 9	95 5

Farm # 28 — Type of Irrigation: Localized (drip) in plastic house

DA 29 Unit No 199

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Cucumber1 (H)	3 60	146	422	418	160	318	372	780	877	-				970	0 0	576 2	318 4	32 8
Cucumber2 (H)	3 60	146	422	417	160	318	372	780	1755	970				1483	0 0	675 9	377 8	25 5
Molokhia (H)	3 60			-					527	2913				956	0 0			

* Cucumber1 was harvested by 30th of April 1994, Cucumber2 was harveted by 15th of May 1994 Molokhia was neglected by the farmer

Farm # 29 — Type of Irrigation: Localized (drip)

DA 21 Unit No 132

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Onions	0 33						49							148	39 3			
Potato	6 72		1207	818	2045	810								726	47 3	424 8	390 8	50 5
Eggplant	2 73	1899	1210	544	249		-							1429	6 4	407 9	359 0	25 0
Peppers	12 09	3368	2268	1124	1738		118	297	1380	3097				1108	30 0	997 5	917 7	80 7
Tomato	7 14				1006	44	289	584	1731	1547				728	44 3	616 9	623 1	80 6
Squash	6 72	1441	1660	202										492	6 4	300 8	231 6	46 5
Beans	5 00							376	776	1546				540	0 0	423 5	351 5	65 1

* Discard Onions (it was neglected by the farmer)

* All crops were harvested by the end of May 1994

Table B 1 Continued

Farm # 30 — Type of Irrigation: Localized (drip)

DA 21 Unit No 90

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Pepper	10 95	2280	1301	907	386									445	6 4	407 9	363 0	80 4
Potato1	10 63		950	1231	1021	0								301	28 5	254 1	218 4	66 2
Squash (T)	4 48			551	499	52	137							277	15 0	231 4	192 0	65 9
Tomato1	3 15				340	0	216	190	804	427				628	42 4	593 5	569 8	85 0
Onion	1 96			227	159	0		196	172	265				520	155 2	694 7	653 0	96 7
Squash	3 00	933	806	194										644	6 4	407 9	305 9	47 0
Tomato2	10 00						677	595	2513	1355				514	18 2	511 4	485 9	91 3
Corn	5 00							524	518	677	525			449	4 2	514 1	462 7	100 0
Potato2	8 00						435	916	1106	1084				443	42 4	390 3	378 6	78 1

Farm # 31 — Type of Irrigation: Localized (drip) Plastic house Surface

DA 23 Unit No 222

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Beans	1 05		521	153	133									769	41 4	390 5	328 0	40 5
Peas	1 05		521	153	133									769	47 5	409 1	376 4	46 1
Potato (D)	2 10			306	266									272	39 6	243 0	221 1	70 9
Peppers	9 00	2273	1512	1327										568	4 6	367 6	363 9	63 6
Garlic (S)	5 60	1047	1172	817	709		1377							915	162 7	571 3	531 3	49 3
Onions (S)	4 80		517	699	608		344	278						510	157 5	482 8	444 2	66 6
Potato (S)	1 75		-	255	222									273	132 0	243 0	221 1	54 7
Cucumber(H)	2 59		397	379	329	1296	688	278						1300	0 0	409 4	212 9	16 4
Tomato	2 00							418	940	680				1019	44 3	616 9	629 3	59 2
Eggp+Corn	2 00							418	940	680				1019	33 9	545 6	474 7	45 1
Beans2	3 90							1672	940	1326				1010	0 0	377 0	312 9	31 0
Corn	5 10		-						940	1735	3093			1131	0 0	570 0	501 6	44 3
Molokhia (H)	2 59			-					868	881	1571	883		1623	0 0	713 0	375 4	23 1

* Tomato Eggplant and Beans2 were harvested by the end of May
* Corn were harvested on 30th June
* Last harvest of Molokhia was in 25th of July 1994

Table B 1 Continued

Farm # 32 — Type of Irrigation: Localized (drip)

DA 29 Unit No 91

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Banana	6 25	7864	3414	1510	1188	550	852	668	2531	2967	4499	3761	5371	5628	162 7	1659 7	1494 0	25 8

Farm # 33 — Type of Irrigation: Localized (drip)

DA 29 Unit No 50

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Cabbage	16 48		6718	6718	3000									997	30 0	323 1	271 4	26 4
Tomato1	4 36					57	53	584	1055	1428				729	42 4	589 6	589 6	76 5
Tomato2	17 00							865	4067	5586				619	0 0	423 5	389 6	63 0

* All the Crops were harvested by 10th June 1994

Farm # 34 — Type of Irrigation: Plastic house

DA 22 Unit No 294

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Tomato (H)	2 44		266	42	55	78	105	122	361					422	0 0	376 0	239 5	56 8

* Last harvest of Tomatoes was by 23th of April 1994

Farm # 35 — Type of Irrigation: Surface Plastic house

DA 22 Unit No 67

	Area	Water Applied (cubic meters)												Tot	ppt	ETp	ETc	IME
	du	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	mm	mm	mm	mm	%
Onions (S)	5 10			1524	822	86		1023	1476	960				1155	151 0	682 7	655 4	50 2
Cucumber (H)	11 10			1310	1814	188	852	1023	3320	2400				983	0 0	644 3	364 4	37 1
Tomato (H)	4 00			495	227	72	284	341	1476	1440				1084	0 0	644 3	427 2	39 4

* All the crops were harvested by the end of May, 1994

Annex C

Statistical Analysis

Winter Season Hypothesis Testing for IME Values of Different Irrigation Systems Using Z-test

$$z = \frac{\mu_1 - \mu_2}{\sqrt{\frac{(S.D._1)^2}{n_1} + \frac{(S.D._2)^2}{n_2}}}$$

1 Surface irrigation
2 Drip irrigation in open field
3 Drip irrigation in plastic houses

Confidence Interval (CI) = 90 % $\Rightarrow \alpha = 0.1$

For Standard Normal Distribution Tables

$Z_{0.1/2} = \pm 1.645$

Test

Null hypothesis (Ho)	$\mu_1 - \mu_2 = 0$	No significant difference
Alternate hypothesis	$\mu_1 - \mu_2 \neq 0$	There is significant difference

Accept Ho if $Z \leq -1.645$ or $Z \geq 1.645$
Reject Ho otherwise

$$z_{1-2} = \frac{70.43 - 56.52}{\sqrt{\frac{(19.84)^2}{27} + \frac{(23.50)^2}{45}}} = 2.68$$ $\Rightarrow$ There is a significant difference

$$z_{1-3} = \frac{70.43 - 42.67}{\sqrt{\frac{(19.84)^2}{27} + \frac{(15.85)^2}{12}}} = 4.658$$ $\Rightarrow$ There is a significant difference

$$z_{2-3} = \frac{56.52 - 42.67}{\sqrt{\frac{(23.50)^2}{45} + \frac{(15.85)^2}{12}}} = 2.403$$ $\Rightarrow$ There is a significant difference

Summer Season Hypothesis Testing for IME Values of Different Irrigation Systems Using Z-test

$$z = \frac{\mu_1 - \mu_2}{\sqrt{\frac{(S.D._1)^2}{n_1} + \frac{(S.D._2)^2}{n_2}}}$$

1 Surface irrigation
2 Drip irrigation in open field
3 Drip irrigation in Plastic houses

Confidence Interval (CI) = 90 % $\Rightarrow \alpha = 0.1$

For Standard Normal Distribution Tables

$Z_{0.1/2} = \pm 1.645$

Test

Null hypothesis (Ho)	$\mu_1 - \mu_2 = 0$	No significant difference
Alternate hypothesis	$\mu_1 - \mu_2 \neq 0$	There is a significant difference

Accept Ho if $Z \leq -1.645$ or $Z \geq 1.645$
Reject Ho otherwise

$$z_{1-2} = \frac{81.96 - 80.18}{\sqrt{\frac{(10.75)^2}{6} + \frac{(24.71)^2}{13}}} = 0.218$$ $\Rightarrow$ No significant difference

$$z_{1-3} = \frac{81.96 - 61.4}{\sqrt{\frac{(10.75)^2}{6} + \frac{(38.7)^2}{2}}} = 0.706$$ $\Rightarrow$ No significant difference

$$z_{2-3} = \frac{80.18 - 61.4}{\sqrt{\frac{(24.71)^2}{13} + \frac{(38.7)^2}{2}}} = 0.665$$ $\Rightarrow$ No significant difference

Whole Year Hypothesis Testing for IME Values of Different Irrigation Systems Using Z-test

$$z = \frac{\mu_1 - \mu_2}{\sqrt{\frac{(S\,D_1)^2}{n_1} + \frac{(S\,D_2)^2}{n_2}}}$$

1 Surface irrigation
2 Drip irrigation in open field
3 Drip irrigation in Plastic houses

Confidence Interval (CI) = 90 % $\Rightarrow \alpha = 0\ 1$

For Standard Normal Distribution Tables

$Z_{0\ 1/2} = \pm 1\ 645$

Test

Null hypothesis (Ho)	$\mu_1 - \mu_2 = 0$	No significant difference
Alternate hypothesis	$\mu_1 - \mu_2 \neq 0$	There is significant difference

Accept Ho if $Z \leq -1\ 645$ or $Z \geq 1\ 645$
Reject Ho otherwise

$$z_{1-2} = \frac{76\ 05 - 70\ 37}{\sqrt{\frac{(22\ 49)^2}{29} + \frac{(24\ 68)^2}{53}}} = 1\ 056$$ $\Rightarrow$ No significant difference

$$z_{1-3} = \frac{76\ 05 - 46\ 72}{\sqrt{\frac{(22\ 49)^2}{29} + \frac{(17\ 31)^2}{12}}} = 4\ 504$$ $\Rightarrow$ There is a significant difference

$$z_{2-3} = \frac{70\ 37 - 46\ 72}{\sqrt{\frac{(24\ 68)^2}{53} + \frac{(17\ 31)^2}{12}}} = 3\ 92$$ $\Rightarrow$ There is a significant difference

Irrigation Method Hypothesis Testing for IME Values of Summer and Winter Season Using Z-test

$$Z = \frac{\mu_1 - \mu_2}{\sqrt{\frac{(S.D.1)^2}{n_1} + \frac{(S.D.2)^2}{n_2}}}$$

1 Winter Season
2 Summer Season

Confidence Interval (CI) = 90 % $\Rightarrow \alpha = 0.1$

For Standard Normal Distribution Tables

$Z_{0.1/2} = \pm 1.645$

Test

Null hypothesis (Ho)	$\mu_1 - \mu_2 = 0$	No significant difference
Alternate hypothesis	$\mu_1 - \mu_2 \neq 0$	There is significant difference

Accept Ho if $Z \leq -1.645$ or $Z \geq 1.645$
Reject Ho otherwise

Surface Irrigation

$$Z_{1-2} = \frac{70.43 - 81.96}{\sqrt{\frac{(19.84)^2}{27} + \frac{(10.75)^2}{6}}} = -1.98$$

$\Rightarrow$ There is a significant difference

Drip Irrigation

$$Z_{1-2} = \frac{56.52 - 80.18}{\sqrt{\frac{(23.5)^2}{45} + \frac{(24.71)^2}{13}}} = -3.07$$

$\Rightarrow$ There is a significant difference

Drip Irrigation in plastic house

$$Z_{1-2} = \frac{42.67 - 61.4}{\sqrt{\frac{(15.85)^2}{12} + \frac{(38.7)^2}{2}}} = -0.67$$

$\Rightarrow$ No significant difference