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INTENSIVE APPLE ORCHARD BASED ON ADVANCED TECHNOLOGIES

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Executive Summary

The purpose of the project was to modernize the apple cultural production in Kazakhstan and to examine the effects of apple rootstocks on efficiency of water use in Israel. All the purposes of the project were achieved albeit after prolongation of its duration by the Kazakh researchers.

Three objectives were set up for Kazakhstan: To examine new dwarfing apple rootstocks adapted to the continental climate of the country, To examine ways to improve production on M9 by specific pruning and training methods and to examine the significance of irrigation and fertigation using drip irrigation in comparison to the conventional furrow irrigation methods.

Two new dwarfing rootstocks were proved superior to M9 under Kazakh climatic and edaphic conditions. Clearly this sets up the stage for future new apple plantations in Kazakhstan and elsewhere.

As to drip irrigation and fertilization, improved performance was shown on trees drip irrigated but no advantage to drip fertigation versus fertigation in furrow was observed.

In the trial with high density planting it was found that a severe pruning to the perrenial wood on both sides of the row improved productivity and fruit quality and prolonged the commercial life of the orchard.

In Israel, an advantage to the dwarf M9 rootstock over more vigorous ones was shown with regards to water use efficiency on a two year production basis.

The results obtained in Kazakhstan besides advancing apple production there also introduced new techniques there were not available before:

Use of light interception and distribution in orchard canopies, awareness to water use by the trees and to modern means of supply of water and nutrients leading to improved yields and fruit quality.

Research Objectives:

The following were the research objectives of the project:

Kazakhstan:

- To select dwarfing apple rootstocks for high yield adapted for Kazakhstan climate
- To improve irrigation and water use efficiency by modifying traditional irrigation management; to test fertigation in apple orchards.
- To introduce advance methods for improving training and pruning in high density dwarf apple orchards in order to extend their productive life span.

Israel:

- To test the water use efficiency for apple production on various rootstocks and re-examine irrigation practices.

All the objectives were met. The three lines of approaches in Kazakhstan meet the basic problems of apple, the most important fruit grown in Kazakhstan. No doubt the results of this project will be implemented at leat partly in future apple plantations there.

The innovative aspects of the project were:

- Selecting better dwarfing rootstocks for continental hot climate than the commercial used ones.
- Exhibiting the advantage of drip irrigation system under the specific semi dry growing conditions in South western Kazakhstan
- Introducing simple means to measure light regime in the orchard
- Measuring season long water use by heat pulse system in Israel.

Introduction

The project that was intended for a period of 3 years was extended to 5 years because of difficulties in the technical operation in Kazakhstan. The situation in Kazakhstan was very difficult due to political reasons and the duration of the project coincided with the major changes in Agricultural organization from the large state farms to smaller private farm. The transfer was very problematic due to loss of control of the former system and anarchy that led to loss of experiments started in 1996. The Kazakh team led by Dr. Karychev managed to reestablish in 1998 two of the experiments in private farms and asked therefore for the extension of the project without added budget. This request was also justified by climatic problems of severe spring frosts in 1998 and 1999 that made it very difficult to get meaningful results in Kazakhstan.

The present final report is therefore a summary of activities during a period of 3 years in Israel and 5 years in Kazakhstan. This report also presents the data of the last two years 1999 and 2000 in Kazakhstan

Kazakhstan

Soil- climatic conditions of Kazakhstan and Israel are similar-both countries suffer from the shortage of irrigated water, are situated in dry and hot conditions for the growing of fruit crops. The modern intensive and adaptive fruit growing is based on the wide use of low-vigour rootstocks in fruit production, on progressive training of tree crowns taking info account light regime, on the background of local drip irrigation with simultaneous fertilizer application.

The planned program for 1996-2000 was fully implemented. The obtained results of investigations are used in the practice of Kazakhstan fruit growing. Thus only in Almaty region for these years 418 ha of new intensive apple orchards were established where technology elements of the results of investigations on the Grant were used.

The considerable help of the Israeli scientists in the problems of training of progressive crown types, light regimes, system of drip irrigation and others allowed to solve the problem of fruit-growing intensification under conditions of water deficit from the scientific point of view, what allowed to elaborate scientific methods in fruit-growing in Kazakhstan.

Overall aim and specific objectives

The aim of investigations was the creation of intensive apple orchards, based on progressive technologies and adapted to dry and hot conditions of southeast of Kazakhstan under severe shortage of irrigated water.

1. Conditions of investigation conducted.

1.1. Place of the work.

The investigations were conducted in the experimental farms of the Institute: "Almaly" (mountain plot) and "Gigant" (experiment 1) and in the farm "Mountain Gigant" (experiment 2) and Dzhandosov farm (experiment 3).

1.2. Soils and meteorological conditions.

Description of soils and meteorological conditions for 1996-1999 was given in the previous Report. It worth noting that weather conditions in 2000 were favorable on the whole territory of south east and south of Kazakhstan. Fruit yield was very high almost for all fruit crops.

2. Experimental

2.1. Experiment 1. Testing of new dwarf rootstocks for high-density orchard.

Investigator K. Karychev

Matrials and methods

Two experimental apple orchards were used. The first was planted in 1989 in the mountain zone of Zailiskei Alatau on the terrace slopes altitude of 1200 m above sea level) with planting density of 1250 tree/ha, planting scheme 4 x 2 m, (orchard A).

The second orchard was in the plain zone (altitude – 600 m above sea level) planted in 1992 – with the density of 2000 tree/ha, planting scheme 5 x 1 m (orchard B).

Clonal dwarf rootstocks of apple were under study: M9 (standard, control), Arm 18, B7-35, 62-396, SPS-7. Their detailed characteristics are given in the Report for 1998-1999. The apple variety was Golden Delicious. For measurements, 16 trees of each rootstock-scion combination were taken. The following measurements were studied: Tree height, tree inclination from the vertical as an indication of level of ancoring, Yield per tree and yield calculated per hectare.

Results

The results of measurements in 2000 showed, that the apple variety Golden Delicious on new dwarfing rootstocks: Arm 18 and SPS-7 had the smallest vigor in both orchards: mountain conditions without irrigation (A) and in the low-lying orchard with irrigation. In comparison with the trees on M9 the height of Golden Delicious on Arm 18 and SPS-7 was 1/3 lower. Somewhat higher were the apple trees on rootstocks B7-35 and 62-396 but all the same they were less vigorous than on M9.

In dwarf orchards anchoring in soil is important, especially it is of great importance in the regions with strong winds and in the system of raw-spacing treatment of orchards under bare fallow. By the measurement of inclination it was found out that the greatest inclination was found on trees grafted to M9 - $14\text{-}25^0$, on the contrary the trees on Arm 18 and B7-35 were anchored firmly in soil and were not inclined.

Table 1. The height and apple tree-fixation in soil of the variety Golden Delicious on different rootstocks (measurement 2000)

Rootstocks	Tree height		Tree incline	
	m	% of M9	The angle of inclination (from vertical)	% of trees
Mountain orchard "Almaly" (A) – 13 year trees				
M9 (St)	3.5	100	14	100
Arm 18	2.3	67	0	0
B7-35	2.3	70	0	0
62-396	2.6	76	7	20
SPS-7	2.5	67	6	18
Orchard in "Gigant" (B) – 10 year trees				
M9 (St)	3.3	100	25	100
Arm 18	2.3	70	0	0
B7-35	2.4	73	0	0
62-396	2.4	73	6	20
SPS-7	2.1	64	10	25

In 2000 it was noticed the high productivity of apple trees. However the yield of fruits depended on rootstock form. The highest yield had the apple variety Golden Delicious in the irrigated orchard (orchard B) on rootstocks Arm 18 and B7-35 – 67-71 t/ha. There was no yield on the rootstocks M9, 62-396 and SPS-7. In the mountain zone (orchard A) the high yield was found out on forms B7-35, Arm 18 and 62-396 which was 3-5 times higher than on trees on M9 and SPS-7 (Table 2).

On the average for 6 years of investigation, regarding the productivity of the trees in both zones (orchards A, B) the Golden Delicious cv. on rootstocks Arm 18 and B7-35 had exceeded the M9.

With regards to yield on the basis of trunk cross section area , the highest values were found in combination of Golden Delicious with the rootstocks, SPS-7, B7-35 and Arm 18 – 0,41-0,49 kg/cm^2, followed by 62-396 – 0,2 kg/cm^2 and least of all with M9 – 0,11 kg/cm^2. On the base of these data, apple rootstocks Arm 18 and B7-35 appeared to be the most adaptive and productive rootstocks for the dry conditions of south and south – east Kazakhstan. They exceed 2,6-5,3 times the M9 rootstock in productivity.

Table 2. The yield of apple trees of the variety Golden Delicious depending on rootstocks

Rootstocks	Yield t/ha						
	1995	1996	1997	1998	1999	2000	Average
The mountain orchard "Almaly" 7-12 years after planting, 1250 tree/ha (A)							
M9 (St)	2.5	4.0	0.5	0	3.1	8.0	3.0
Arm 18	6.3	4.8	0.8	0.05	3.3	35.6	8.5
B7-35	4.0	3.8	0.8	0.4	3.1	34.1	7.7
62-396	4.5	6.3	0.8	0.1	2.8	26.7	6.9
SPS-7	0.4	7.5	0.1	0.9	3.7	6.6	3.2
The orchard in "Gigant" 4-9 years after planting, 2000 tree/ha (B)							
M9 (St)	0.2	2.0	0.9	11.8	10.0	0.3	4.2
Arm 18	4.6	22.4	7.6	12.8	15.0	71.0	22.2
B7-35	2.4	8.2	3.8	15.8	14.0	67.0	18.5
62-396	2.5	3.2	3.0	4.4	12.0	0	4.2
SPS-7	0.8	4.0	3.2	3.8	10.0	0	3.6

2.2a Experiment 2a: The evaluation methods with fertilizer irrigation in intensive orchards.

Investigators:
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G.P. Adrianova

Materials and methods

In 2000 the investigations in the experiment on the study of the efficiency of simultaneous application of water and fertilizers under drip irrigation in intensive orchards in the southeast of Kazakhstan were completed. Soils are dark-chestnut, typical for fruit growing in the studied regions. As a whole, the weather conditions in 1999-2000 were favorable for growth, development and getting optimal yields in apple varieties Golden Delicious and Zarya Alatau. The investigations were conducted on three main treatments in four replications:

1. Furrow irrigation and the application of fertilizers in furrows (control);
2. Drip irrigation and the fertilizer application in furrows;
3. Drip irrigation and the application of nitrogen and potassium through drippers, phosphorus – in furrows.

In all treatments, fertilizer doses were $N_{120}P_{50}K_{130}$ kg/ha of active substance. Fertilizes were applied in furrows once in spring, under drip irrigation during 6 weeks in the middle of May and June.

The following data were collected. Yield per tree and average fruit mass at harvest. Mineral composition of fruits (nitrogen phosphorus, potassium, calcium and magnesium) was determined by means of acidic ashing of average sample of fruit using mixture H_2SO_4 and $HCLO_4$. Further determination of phosphorus in electrophotocalorimeter (KFK-2), potassium- in flame photometer (FLAPHO-4), calcium and magnesium – in

Atomic Absorption AAS3 and nitrogen – by distillation according to Kjeldhal's method. Fruits for analyses were selected in the period of picking maturity (the end of August for the apple variety Zarya Alatau and the mid-September for variety Golden Delicious). Mineral composition was determined in dry samples of fruits and the results were presented in %.

Biochemical fruit composition (sugar, acidity) were determined for fresh fruits. The acidity was measured by means of PH-meter-150, total sugar by the Bertran's method with following titration with $KMnO_4$; dry matter was measured by refractometer.

Mineral composition of leaves was measured by the same methods as mineral fruit composition. Fifty leaves were collected by the end of July from the center of the current growth; they were washed by water and dried till the air-dry state, then were grinded and analyzed.

Soil samples were taken from the experimental trees under the crown in the 0-30 and 30-60 cm layers, dried and screened through a sieve (1 mm). pH in soil was measured in water extract by means of refractometer Ph-150. Total humus was measured by the Tyurin's method based on oxidation of humus carbon with further determination in spectrometer SPEKOZ-11. Mobile (easily hydrolysable) nitrogen in soil was determined by Tyurin's and Kononova's method with nitrogen extraction by 0.5N solution of sulphuric acid with further determination of nitrogen by Kjeldhal's method. Mobile phosphorus and exchangeable potassium were measured in carboammonium extract with further determination of phosphorus in colorimeter KFK-2, potassium- in flame photometer (FLAPHO-4) (Zerling, Moscow, 1980, 45p).

Short characteristic of existent investigation method on drip irrigation rate setting

The investigations were directed to determine drip irrigation efficiency in comparison with furrow irrigation, traditionally used in Kazakhstan and Central Asia. To determine this efficiency we provided optimal water-supply in the root zone, i.e. by optimal irrigation regime.

In Israel optimization of irrigation regime of fruit crops is widely used, it is based on the use of irrigation coefficient relative to type A pan evaporation which changes during the season in the range of 0.2- 0.8, reaching its maximum in the period of harvesting (I. Klein, 1993). Water-consumption is calculated as a part of potential evaporation, and the irrigation periods are controlled by tensiometer. Practically sum water consumption is covered by irrigated water therefore the irrigation rate setting is justified itself by the irrigation coefficient.

In Kazakhstan where the irrigation period does not exceed three months the irrigated water is only 35-50% of the total water-consumption. The rest is supplied by precipitations, active soil water-resources, accumulated in pre-vegetative period and also by capillary water uptake from high water table sources.

It is also known that total water-consumption does not depend solely on concrete hydrothermal conditions but also on biological growth rhythms and plant development. Therefore the establishment of biophysical indices determining plant role in water discharge during vegetation allows to use calculated method of irrigation rate setting, based on the use of potential evaporation.

Calculated total water-consumption in this case is determined by equation:

$$EW = E_0 C_b$$

Where EW - is total water-consumption in mm;

E_o - is the potentially possible evaporation, the most available determinant on water evaporator in mm;

C_b - is a biophysical coefficient, determining climatic and biological plant role in water consumption.

The main task in the developing of this calculated method is to establish biophysical coefficient, that will bridge the incompatibility between actual water consumption by plants and evaporation. Having the values of biophysical coefficients, connected with the values of total evaporation it is possible to set necessary irrigation regime without systematic control for water-resource dynamics, requiring the use of expensive devices which are not available at present for farmers in Kazakhstan. Therefore the proposed method intends to extend the investigations in this study and to collect data that will help in determining the biophysical coefficients of different fruit crops with the inclusion of different natural – economic zones.

Physical conditions

Climatic conditions for the years of investigation somewhat differ between themselves (1998-1999) are characterized by rainy and cool spring with April and May frosts, moderate hot summer and long warm autumn. Spring frosts were accompanied by snowfall. In 1998 daily air temperature in July and August reached 39^{0}C and in August 1999, the warmest month did not exceed 34-36^{0}C. Warm early spring, hot summer and cool rainy autumn characterize the year 2000. Air temperature in July and August reached 39-41^{0}C. In the second ten days of October the first snow fell and it turned cold.

According to natural water supply 1998 and 1999 were very wet, and 2000 average. Amount of precipitation for the vegetation period in 1998 was 1,6 and in 1999 1,5 times higher and in 2000 it was close to the average of the multi-year norm. In individual months (like July 1999) there were more then 4 times the regular level of precipitations, this characterizes the extreme irregularity of the distributions of precipitations during vegetation in the course of the duration of investigation.

The evaporation of water surface, (pan evaporation) was in direct correlation with the heat energetic resources of the atmosphere. In cold and humid years the evaporation was considerably below the multi-year average (1050 mm). In 1998 it was 701.4 mm, and 1999 – 650.8 mm, and 2000 – 950,3 mm.

Water-physical soil properties of the experimental plot. According the mechanical structure soil on the experimental plot is medium-loamy, coarse-silty with the content of clay particles (< 0,01 mm) in 1 meter layers of 35-36%. Low horizons at the depth of 1.3-1.6 m are bedded by medium and coarse-grained sand which includes clay and pebble. The volume density of the root layer (1 m) is equal to 1.36 t/m^3, specific mass is 2.61 g/cm^3, porosity – 48%.

Soils of the experimental plot are medium water – permeable, the rate of water absorption in the first hour is equal to 0.8-1.0 mm/min, filtration coefficient is equal to 0,5 mm/min.

For the background of the regulation means of soil water regime and efficiency evaluation of irrigation influence on moisture providing of plants the main water-physical soil properties, were determined. Maximum hydroscopicity (MH), corresponding to the moisture, unavailable for plants, is 69 mm in one-meter soil layer. The moisture of stable plant withering (MPV) or critical soil water-resources after which the plant cannot normally develop is equal to 93 mm. The least water-capacity (LWC) i.e. water-holding soil ability in one-meter layer is 333 mm. Thus, the productive, used by plants water-resources, corresponding to the difference between the least water-capacity and critical soil water-resources equals to 240 mm. This moisture is the lowest border of pre-irrigated moisture.

Tariration of the tensiometers was conducted in field conditions in 1998 on a specially arranged ground with periodical taking of soil samples for moisture test, determined by thermo-weight method. Diapason of control measurements of water-resources was in the limits of maximum hydroscopicity and full water-capacity (FWC) and tensiometers reading from 17 to 90 KPa (Fig.1). The low border of preirrigated moisture, corresponding to 240 mm (or 72% of the least water-capacity (LWC) is equal to 35 KPa).

Tasks and method of investigation. Investigation tasks included:

1. To determine quantity characteristics of the main elements of water balance in root layer and its structure;
2. To reveal the intensity of water-consumption and irrigation norms according to the period of vegetation;
3. To determine water-resource dynamics under different irrigation means and natural water-supply;
4. *To find out biophysical indices of intensive orchard depending on the sums of* evaporation.

The method of conducting these works is usual (B.A. Dospekhov, 1979) and is given in "Instruction for hydrometeorology stations".

The observation on water content in soil was conducted by tensiometers arranged at the depth of 30, 60 and 90 cm and at the distance of 25 cm and 50 cm from drippers. The measurements were systematically conducted from the beginning to the end of vegetation period. The low preirrigated moisture was considered by tensiometers reading, equal to 35KPa.

The determinations of the precipitations use efficiency. For rate setting of irrigation it is necessary to determine the structure of water balance in root layer, i.e. participation share of the main elements of water balance in water consumption of orchard. Under conditions of the mountain terrain of Kazakhstan where a considerable amount of precipitations falls, plants effectively do not use all precipitations, the necessity to determine their productivity appeared.

With this aim, we initiated a study to determine the losses of precipitations by deep filtration and by surface runoff.

The following works are included:

1. Measurements of water losses by deep filtration from precipitations, determined by soil evaporators with the thickness of soil profile of 1 m.
2. Determination of surface runoff on specially built runoff plot with regards to the difference between flow and outflow of heavy precipitations.
3. Regular observation on water-resource dynamics of the active soil layer by tensiometers.

Results

As it is evident in Table 3, in 2000 the yield was high in both apple varieties but true differences in comparison with control in the treatments of drip irrigation were obtained only in the variety Zarya Alatau. The highest yield was in the treatment 2, where fertilizers were applied in furrows and drip irrigation was used. The same observations were found in the apple variety Golden Delicious but true differences between treatments were not observed in 2000.

It is known that it is difficult to get objective evaluation on yield in apples using the data of one year, due to biennial bearing, therefore it is important to evaluate apple productivity for at least two years. The conducted analysis on yields for two years (1999-2000) showed that essential differences were confirmed in the variety Zarya Alatau in both treatments under drip irrigation in comparison with control and the variety Golden Delicious the essential differences were found between control and treatment 2 with drip irrigation and furrow application of fertilizers (Table 3). It may be explained by the fact that under furrow application of fertilizers great zone of contiguity of apple root system to fertilizers was formed, wider than under their application with drip irrigation. At the same time, furrow application of fertilizers and drip irrigation possess an advantage over control in water regime of soil, where furrow irrigation does not supply optimal humidity during the whole vegetation period.

Table 3. Apple yield in experiment treatments under drip irrigation (t/ha)

Treatments	Yield (t/ha)					
	Golden Delicious			Zarya Alatau		
	2000	For 1999-2000	Addition to control	2000	For 1999-2000	Addition to control
Var.1.Furrow irrigation fertilizer application in furrows (control)	53,5	82,6	-	52,0	57,4	-
Var.2. Drip irrigation + fertilizer application in furrows	62,6	103,8	21,2	82,7	89,5	32,1
Var.3. Drip irrigation + nitrogen and potassium application through drippers, phosphorus in furrows	51,2	87,9	5,3	60,7	68,7	11,3
$HCP_{0.05}$, t/ha,	16,6	18,9		6,7	7,0	
P%	12,9	9		4,4	4,2	

Differences in biochemical and mineral fruit composition were not observed too. Sugar content in fruits experimental treatments varied in the range of 12-13%, acidity 0,5-0,6%, and dry matter 13,5-14,5%. Nitrogen amount was in the limits of 0,5-0,8%, phosphorus 0,13-0,29% and potassium 0,87-1,1% on dry substance (Table 4).

Table 4. The content of nutrition elements in apple fruits of the variety Zarya Alatau according to experimental treatments with drip irrigation and fertilizer application (mean for 1999-2000)

Treatments	Nutrition elements % of dry substance				
	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Calcium (CaO)	Magnesium (MgO)
Var.1.Furrow irrigation + fertilizer application in furrows (control)	0,53	0,13	0,87	0,13	0,07
Var.2. Drip irrigation + fertilizer application in furrows	0,69	0,23	1,09	0,16	0,07
Var.3. Drip irrigation + nitrogen potassium through drippers, phosphorus -in furrows	0,77	0,29	1,10	0,15	0,07

Nitrates in fruit do not exceed 36-37 mg/kg of dry mass.

Data on Table 4 clearly testified to the fact that the content of nitrogen, phosphorus and potassium in fruits was higher in treatments with drip irrigation than in control with furrow irrigation. More even soil moisture during the whole vegetation period under drip irrigation provided presumably better penetration of nutrition elements to apple fruits. Consequently, mineral composition of apple fruits under drip irrigation with fertilizers was richer than under furrow irrigation and fertilizer application.

It is interesting to notice the fact that calculation of the amount of fruit formations on experimental apple trees in autumn 2000 allowed again to distinguish according to productivity the same treatments on the variety Zarya Alatau as in 1999 where the amount of fruit formations was higher than in control (1229 fruit/ tree in the first treatment, 2005 – in the second treatment and 1765 – in the third treatment). It was also observed the increase of fruit formation amount in the second treatment on Golden Delicious. All these facts testify to the effect of positive influence of applied fertilizers under drip irrigation on the setting of fruitlets, what determines the yield next year.

Integrated value of growth processes in fruit tree is the trunk diameter and its increment for a definite period of time in our experiment for 1998-2000.

The data of the Table 5 testify to the fact that on the variety Golden Delicious the indices of trunk diameter and its increment for 1998-2000 did not differ in treatments. However on the variety Zarya Alatau according to these indices, essential differences were obtained in both treatments under drip irrigation in comparison with control (Table 5).

The same regularity was observed on the variety Zarya Alatau in summary of shoot increment. On the whole, for 2 years (1999-2000) shoot growth was considerably higher in drip irrigation treatments in comparison with control (Table 6) and in treatment 3. However the average shoot length was low in all treatments of the experiment (11-14 cm) *what testifies to the necessity of regenerative pruning in the orchard. More active growth* processes of apple variety Zarya Alatau on the background of drip irrigation with fertilizers stipulated higher productivity of fruit plantations. To this fact testified also the data on leaf surface of trees. According to the data of 1999 the largest leaf surface was found in treatment 2 on both apple varieties under drip irrigation and furrow fertilizer application. The best growth of fruit trees provides higher setting of fruit buds what increases the yield. The improvement of growth processes and productivity increasing in the treatments with drip irrigation and fertilizer application is explained by initial low soil fertility, especially it concerns nitrogen and potassium soil regimes. Drip irrigation in comparison with furrow one, creating more even and optimal soil wetting, provided considerable better nutrient soil regime (Table 7).

After 2 years of fertilizer application (1999-2000) the content of the main nutrition elements in soil increased in all treatments (Table 7). In the first place it refers to nitrogen, where it managed to reach optimal content. The quantity of exchangeable potassium for two years of fertilizer application did not reach optimal level as the initial content of this element in soil was very low.

The marked regularity in distribution of nutrition elements in soil was confirmed by the data of leaf analysis (Table 7). The results testified to the fact that in 1999 and 2000 nitrogen content in apple leaves of the variety Zarya Alatau was optimal only in treatments with drip irrigation. The amount of phosphorus in leaves was high in all treatments of the experiment; the potassium content on the contrary did not reach the optimum, what was also observed in soil. Low potassium content in leaves once more confirmed the conclusion about the importance of the application of increased doses of potassium fertilizers to chestnut soils.

The output of nutrient elements was conducted on the apple variety Golden Delicious. The output was determined by the calculation of exported NPK, by the yield and the pruned shoots. According to our data on fruit yield of 80-100 t/ha for two years the output of nitrogen and potassium was 80-100 kg/ha, phosphorus 30-35 kg/ha. Under annual application of fertilizer doses $N_{120}P_{50}K_{130}$ kg/ha of active substance the balance on

Table 5. The growth of apple trees in experimental variants under drip irrigation and fertilizer application

Variants	Variety Golden Delicious Trunk diameter, mm/tree		Shoot increment on tree			Variety Zarya Alatau Trunk diameter, mm		Shoot increment on tree		
	2000	Increment 1998-2000	2000, m/tree	Sum 1999-2000, m/tree	Average shoot length cm	2000	Increment 1998-2000	2000, m/tree	Sum 1999-2000, m/tree	Average shoot length cm
Var.1. Furrow irrigation + application of fertilizers in furrows (control)	111	11.3	19.5	64.0	10.7	123.1	9.0	13.2	36.8	14.0
Var.2. Drip irrigation + fertilizer application in furrows	111.7	11.1	18.1	65.6	11.7	140.6	10.6	20.4	65.2	13.4
Var.3. Drip irrigation + application of nitrogen, potassium through drippers, phosphorus – in furrows	112.2	10.7	22.8	60.1	11.5	129.4	10.1	20.5	54.0	13.1
$HCP_{0.05}$	$F_f < F_t$	$F_f < F_t$	$F_f < F_t$	$F_f < F_t$	$F_f < F_t$	4.0	1.1	$F_f < F_t$	13.3	$F_f < F_t$
P,%						1.3	4.9		11.1	

Table 6. Initial and following content of nutrition elements in soil of experimental orchard under drip irrigation and fertilizer application. Apple variety Zarya Alatau

Variants	PH of water	Humus, %	1998			2000		
			Mobile elements of nutrition in the layer of 0-60 cm, mg/100g					
			N	P_2O_5	K_2o	N	P_2O_5	K_2o
Var.1. Furrow irrigation + fertilizer application into furrows (control)	7.4	3.6	5.1	5.5	23.3	6.0	6.0	27.0
Var.2. Drip irrigation + fertilizer application into furrows	7.3	3.7	5.3	5.6	24.0	6.5	6.0	30.0
Var.3. Drip irrigation + application of nitrogen, potassium through drippers, phosphorus into furrows	7.4	4.1	5.8	5.0	23.1	6.7	5.5	29.0
Optimal content	7.0-7.5	3-4	6-10	2-3	35-40			

Note: Hydrolysable nitrogen was determined by Tyurin and Kononova method, mobile phosphorus and exchangeable potassium in carboammonium extract nutrition elements in soil remained positive. This fact allows drawing a conclusion that the level of macronutrients will increase under drip irrigation resulting from the optimal soil moisture and hence the better root uptake of the nutrients.

Table 7. The content of macronutrients in leaves of apple variety Zarya Alatau in experimental variants under drip irrigation and fertilizer application

Variants	The content of nutrition elements, %					
	1999			2000		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Var.1 Furrow irrigation + fertilizers application in furrows (control)	1.8	1.0	1.5	1.9	1.1	1.6
Var.2. Drip irrigation +fertilizer application in furrows	2.0	1.1	1.6	2.2	1.2	1.7
Var.3. Drip irrigation + application of nitrogen, and potassium through drippers, phosphorus – in furrows	2.2	1.0	1.6	2.3	1.2	1.8
Optimal content, %	2.2-2.6	0.3-0.5	2.0-2.4			

2.2b Exp. 2b: The evaluation of new irrigation means in intensive orchards

It was found out that the efficiency of precipitations use, was 50% in humid 1998 and 1999 (Table 10). Unproductive losses were distributed as follows: deep filtration below the root layer was 31-33%, surface runoff from heavy precipitations, with the intensity higher than 0.5 mm/min was equal to 17-19%. On the average, according to water supplying in 2000, the efficiency of precipitations use was higher and reached 62%, the losses on filtration and surface runoff were less than in the previous years and were equal to 38%.

By previous, long-term investigations (Bondartsev, 1998) it was established that the coefficient of precipitation use depends mainly on natural pattern of water-supply in the vegetative period. In wet years it was 0.5-0.53, and in mid-wet and dry years – 0.67-0.7.

Evaporation as the main bioclimatic parameter was determined by daily measurements in a water evaporator with the area of 3000 cm^2 and the depth of 0.65 m. In the warmer 2000 the evaporation was somewhat higher than in previous years (Table 9,10). Evaporation reached its maximum in July-August and dampened in September-October i.e. towards the end of the vegetation period. Maximum evaporation value was in August 2000 and was equal to 228.3 mm. In some hot days the evaporation reached 10-13 mm/daily. Average daily evaporation was in the limits of 1.64 mm/daily in October 2000 to 7.36 mm/daily in August. In wet 1999 these fluctuations were larger, from 0.72 to 5.5 mm/daily (Table 9).

Water soil regime during the vegetation period is dependent on meteorological conditions and the irrigation regime. The measurements at a depth of 30, 60 and 90 cm were conducted by tensiometers on the plot without irrigation (under natural water-supply) and on the variants of drip and furrow irrigation (Fig.2, 3).

Soil moisture on the plot without added irrigation, towards the beginning of the third ten days in June 2000 reached its critical value (35 KPa) in the layer of 0-90 cm, and at the end of the second ten days of September it was reduced almost to the level of plant withering (Fig.3). The driest layer was the upper 0-30 cm soil, where moisture fluctuations were the most. In the variants of drip and furrow irrigation the irrigation began in the third ten days of June when soil humidity reached 35 KPa according to tensiometers reading. Further 3 irrigations were given one in July and two – in August. Water-resource dynamics before and after irrigation in the variant of drip irrigation is presented in Fig.3. Irrigation norms were in the limits of 20-30 mm during 2-3 days. The total irrigation norm for the vegetation in 2000 was 230 mm and in 1998-1999 it was less than 100-120 mm.

In the variants of furrow irrigation, water norms were 1.5-2 times higher and irrigated norms were 250,200 and 360mm for 1998, 1999, and 2000 respectively. The increasing of irrigated water in comparison with drip irrigation is explained by the fact that under furrow irrigation the whole area of inter rows is actually wetted while under drip irrigation only the area in a row is damped, i.e. not more than 40-50% of the whole area.

The use amount of soil water-resources, accumulated in autumn – winter and springs precipitations by the trees, differed in drip and furrow irrigation and depended on the size of the wetted area. Under drip irrigation accumulated water-resources in non-irrigated inter row spacing are available for summary water-consumption almost in its full volume, while under furrow irrigation, water availability from the soil is partially substituted by irrigated waters, applied in inter rows during irrigation. The conducted observation on soil humidity dynamics showed that under drip irrigation the consumption of accumulated soil water-resources is almost three times higher than under furrow irrigation (Table 6,8).

Thus, under drip irrigation natural water-resources are used more effectively.

Total water consumption, i.e. the sum of physical soil evaporation and transpiration by plants depends mainly on the annual meteorological conditions and the peculiarities of biological plant development.

Maximum values of water-consumption were reached in July 1998 and 2000 and in August 1999 and were equal to 160.2, 181,7 and 179.0 mm respectively (Table 6). For the years of investigations, annual water-consumption was the highest in 2000 – 950 mm. The highest daily value was reached in July 2000 and was 5.86 mm.

The correlation between water balance elements with respect to total water-consumption for the years of investigations and irrigation means was different (Fig.4). The most part constituted the productive precipitations 51.3 (1998), 55.6 (1999) and 39.7% (2000).

The share of irrigated water under drip irrigation for the years of investigations 1998,1999,2000 was in the limits of 19.0, 19.6 and 32.3 % respectively while under furrow irrigation almost twice – 35.6, 39.6 and 50.8% respectively. The use of soil water however, wass higher under drip irrigation and was 24.8 -28.0%, under furrow irrigation it is in the limits of only 8.8 and 9.8%.

Biophysical coefficients were obtained as a result of the three-year study and are presented in graph 5. The curve of biophysical coefficients was given depending on the increasing of evaporation sums from the beginning to the end of fruit tree vegetative period. Maximum values of the coefficient are reached in June – August at the time of the highest water consumption and are reduced to the minimum in autumn when the defoliation began. Quantity indices were in the range of 0.5-1.09 (Table 6).

Conclusion

The efficiency of drip irrigation is expressed only under conditions of optimal level of root-system water supply providing for complex measurements of water balance of availability and uptake and of their regulation.

For the climatic conditions of Kazakhstan, where precipitation and soil water resources compose the main part of water consumption, the most acceptable method of irrigation rating is based on a bioclimatic method, using biophysical coefficients, taking into account not only climatic coefficients but also the change of plant requirements for water according its developmental stages.

The main investigation results

1. The efficiency of precipitation use during the years of investigation was in wet years about 50% and in the middle-wet year (2000) – 62%. The unproductive losses by deep filtration were in the range of 31-33 %, while surface outflow reached – 17-19 %.

2. Irrigation norms under drip irrigation needed for local wetting of the root system layers were 1.5-2 times lower than under furrow irrigation. Irrigation was dependent on natural precipitations and varied in the range of 110-230 mm.

3. Total water consumption, depends on meteorological supply and biological peculiarities of plant development. The share of irrigated water out of total water consumption was under drip irrigation in wet years 19.0-19.6 %, and in middle wet year – 32.3 %. The rest of the water used for the years 1998, 1999, and 2000 was covered by precipitations and reached 51.3, 55.6 and 39.7 % of total consumption respectively. Soil water resources was 24.8-28.0%.

4. For calculation of total water consumption by biological method the curves of biophysical coefficients were experimentally determined with due regard for the accumulation of evaporation sums, determining by water evaporator.

5. Technological means, including drip irrigation with fertilizer application in furrows or through drippers influence positively some growth processes and apple productivity. Fruit yield on variety Zarya Alatau for two years of fertilizer application under drip irrigation was 20-55% higher than control; on the variety Golden Delicious

these variants exceeded control by 25% on the overage. The local variety of the selection of the Institute, Zarya Alatau was more responsive to these means. The introduced apple variety Golden Delicious possessed higher productivity but was less plastic with respect to regulated parameters of water-nutrition regime under arid conduct on dark-chestnut soils in the southeast of Kazakhstan.

6. Exact trend was marked on the improvement of soil fertility and the enhance of nutrient substances taken up in leaves and fruit of studied apple varieties on all variants of the experiment. Improvement of mineral nutrition in fruit trees was noticed especially on the variants under drip irrigation with fertilizer application in furrow or through drippers.

7. The obtained results may serve as a basis for future recommending for apple growers, both small and large. The technological methods of simultaneous application of water and fertilizers under drip irrigation is especially important for arid conditions with shortage in irrigated water in south and southeast of Kazakhstan. This technological method may be widely used in the Republics of Central Asia region.

Table 9. The intensity of the average-daily values of evaporation and water consumption, mm/daily. 1998-2000

Years	Months							For the period IV -X
	IV	V	VI	VII	VIII	IX	X	
1. Evaporation								
1998	1.17	2.13	4.01	5.17	4.36	3.83	2.24	3.28
1999	0.72	2.41	3.10	4.16	5.50	3.65	1.68	3.04
2000	2.50	4.36	5.22	6.16	7.36	4.38	1.64	4.68
II. Summary water consumption								
1998	0.70	1.68	3.85	5.17	4.79	3.06	1.34	2.95
1999	0.12	1.57	2.48	3.95	5.77	3.10	1.09	2.62
2000	1.64	3.5	4.89	5.86	5.45	1.65	2.41	3.51

Table 8. Water balance elements and irrigated regime in the orchard under furrow irrigation. 1998-2000

Period, months	Evaporation mm	Precipitations, mm		Furrow irrigation		Drip irrigation		um of ater onsumption m	Biophysical coefficient
		total	productive	the use of water resources ±ΔW,mm	irrigated norms, mm	the use of water resources ±ΔW,mm	irrigated norms mm		
1998									
IV	35.1	130.1	20.0	1.1		1.1		21.1	0.62
V	66.2	253.2	37.7	14.4		14.4		52.1	0.79
VI	120.5	80.4	80.4	35.2		35.2		115.6	0.96
VП	160.2	106.3	106.3	53.9		53.9		160.2	1.0
VШ	135.1	22.0	22.0	16.6	110	66.6	60	148.6	1.09
IX	114.9	42.0	42.0	-20.1	70	19.9	30	91.9	0.70
X	69.4	15.6	15.6	-44.0	70	-14.0	40	41.6	0.6
Total for IV-X	701.4	649.6	324	57.1	250	177.1	130	631.1	0.90
1999									
I V	21.7	83.9	14.7	-3.9		-3.9		10.8	0.50
V	75.0	76.5	53.5	-4.8		-4.8		48.7	0.65
V I	93.0	185.8	67.2	7.2		7.2		74.4	0.83
V П	129.1	156.1	73.4	49.2		49.2		122.6	0.95
V Ш	170.5	34.5	34.5	44.5	100	84.5	60	179.0	1.05
I X	109.5	56.6	56.6	-13.5	50	16.5	20	93.1	0.85
X	52.0	12.8	12.8	-29.0	50	-9.0	30	33.8	0.65
Total for I V -X	650.8	606.2	312.7	49.7	200	139.7	110	562.4	0.86
2000									
I V	75.0	44.0	37.0	12.3	-	12.3	-	49.3	0.65
V	135.1	85.1	60.2	48.3	-	48.3	-	108.5	0.80
V I	156.7	66.9	49.7	37.0	60	57.0	40	146.7	0.93
V П	190.9	74.0	42.2	-30.6	170	29.4	110	181.7	0.95
V Ш	228.3	27.0	21.6	17.5	130	67.5	80	169.1	0.74
I X	131.4	68.0	32.5	17.0	-	17.0	-	49.5	0.38
X	32.9	92.2	40.0	-31.8	-	31.8	-	8.2	0.25
Total for I V-X	950.3	457.2	283.3	69.7	360	199.7	230	713.0	0.75

Note: +ΔW – water-resources discharge for water consumption
-ΔW - water-resources replenishment by precipitations or irrigated waters

Table 10. Correlation between the water-balance elements (%) and summary water consumption. 1998-2000

Period	Sum of water consumption	Productive precipitations		Soil water resor. + - discharge from soil - - income				Irrigated norms			
				furrow		drip		furrow		drip	
		mm	%	mm	%	mm	%	mm	%	mm	%
1998											
IV	21.1	20.0	94.8	1.1	5.2	1.1	5.2				
V	52.1	37.7	72.4	14.4	27.6	14.4	27.6				
VI	115.6	80.4	69.6	35.2	30.4	35.2	30.4				
VII	160.2	106.3	66.4	53.9	33.6	53.9	33.6				
VIII	148.6	22.0	14.8	16.6	11.2	66.6	44.8	110	74.0	60	40.0
IX	91.9	42.0	45.7	-20.1	-21.9	19.9	21.7	70	76.2	30	32.6
X	41.6	15.6	37.5	-44.0	-105.8	-14.0	-33.7	70	168.3	40	96.2
Total for IV -X	631.3	324.0	51.3	57.1	9.1	177.1	28.0	250	39.6	130	19.0
1999											
IV	10.8	14.7	136.1	-3.9	-36.1	-3.9	-36.1				
V	48.7	53.5	109.8	-4.8	-9.8	-4.8	-9.8				
VI	74.4	67.2	90.3	7.2	9.7	7.2	9.7				
VII	122.6	73.4	59.9	49.2	40.1	49.2	40.1				
VIII	179.0	34.5	19.3	44.5	24.8	84.5	47.2	100	55.9	60	
IX	93.1	56.6	60.8	-13.5	-14.5	16.5	17.7	50	53.7	20	21.5
X	33.8	12.8	38.0	-29.0	-85.9	-9.0	-26.6	50	147.9	30	88.6
Total for IV -X	562.4	312.7	55.6	49.7	8.8	139.7	24.8	200	35.6	110	19.6
2000											
IV	49.3	37.0	75.0	12.3	25.0	12.3	25.0				
V	108.5	60.2	55.5	48.3	44.5	48.3	44.5				
VI	146.7	49.7	33.9	37.0	25.2	57.0	38.8	60	40.9	40	27.3
VII	181.7	42.3	23.3	-30.6	-16.8	29.4	16.2	170	93.5	110	60.5
VIII	169.1	21.6	12.8	17.5	10.3	67.5	39.9	130	76.9	80.	47.3
IX	49.5	32.5	65.7	17.0	34.3	17.0	34.3				
X	8.2	40.0	487.8	-31.8	-387.8	-31.8	-387.8				
Total for IV -X	713.0	283.3	39.7	69.7	9.8	199.7	28.0	360.0	50.5	230	32.3

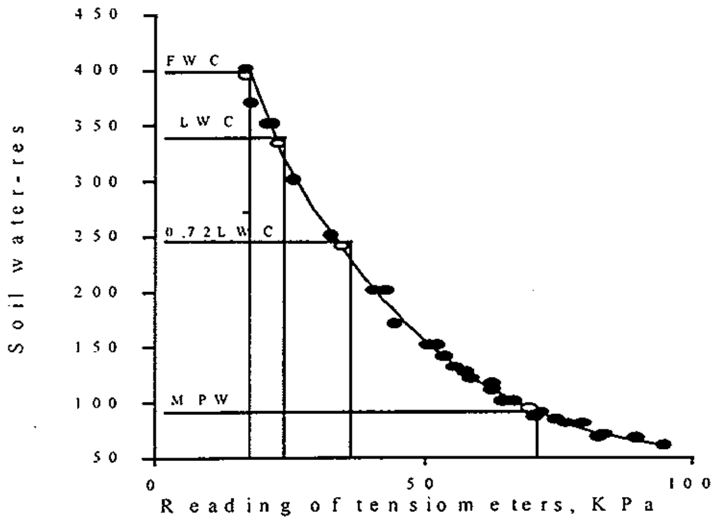

Fig. 1 Chart of tensiometer graduation
FWC - full water capacity
LWC - the least water capacity
0,72LWC - llow border of preirrigation moisture
MPW - moisture of plant + withering

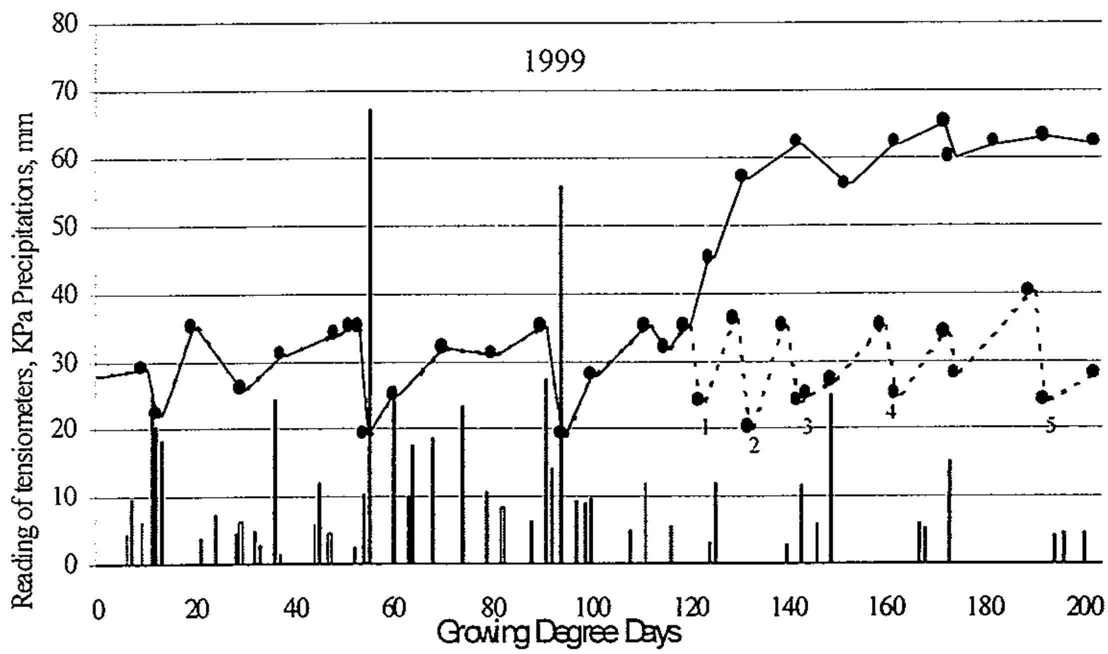

Fig.2 Dynamics of water resources in root-layers (0-90 cm)

— Under natural conditions without irrigation
---- Under drip irrigation
number

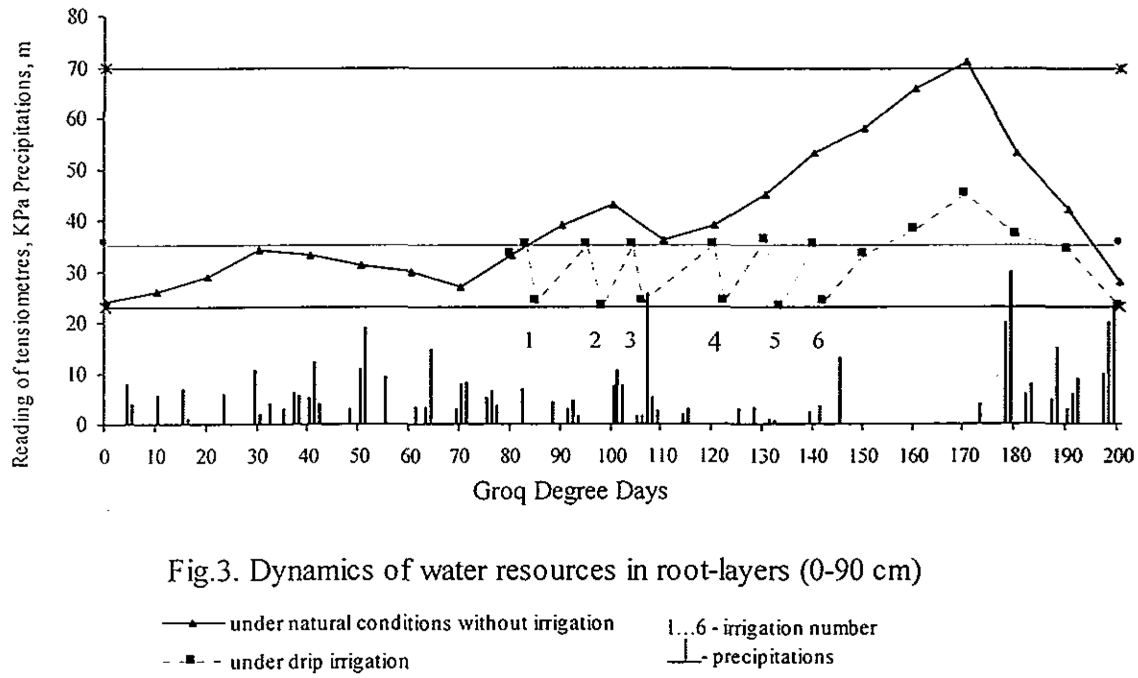

Fig.3. Dynamics of water resources in root-layers (0-90 cm)

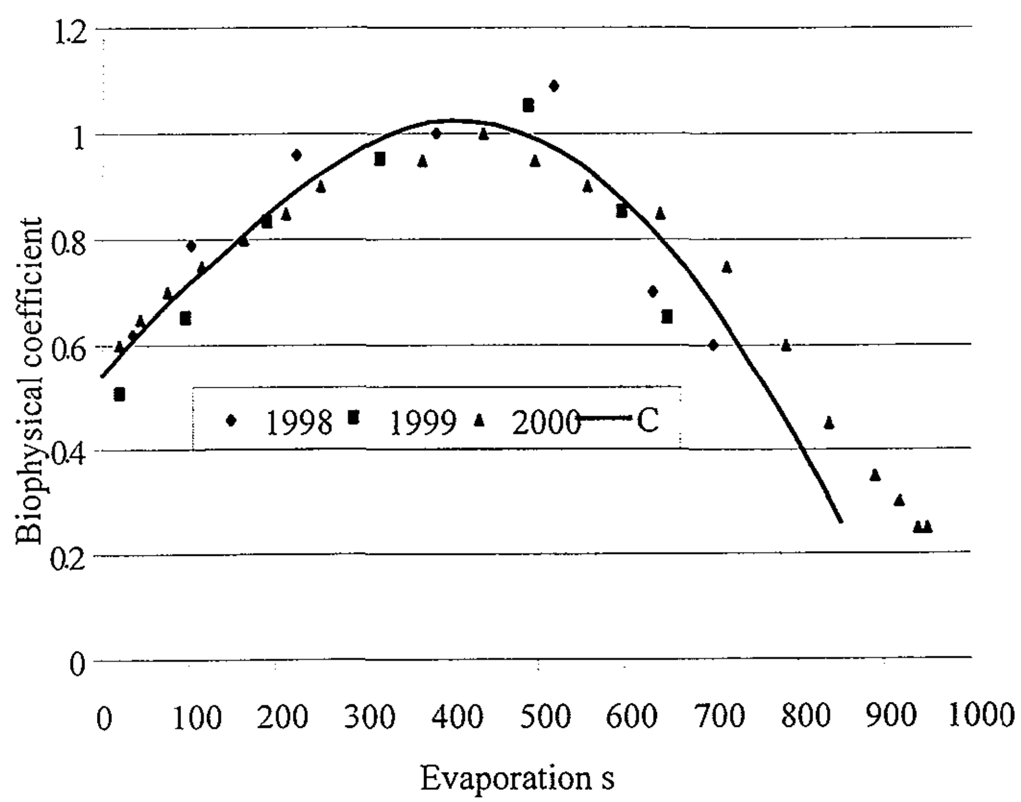

Fig4. Dependence curve of b coefficients on evaporati

References

1. Agrotechnical methods of soil investigations, Moscow, 1975, 565 p.
2. Arinushkina E.V. Instruction on chemical analysis of soils, Moscow, 1970, 488p.
3. Bondartsev A.I. The efficiency of precipitations use depending on their amount and uniformity of distribution. "Coll. of Sci.works of Kaz.NIIPiV",vol.15. Almaty, 1998, p.87-90.
4. Dospekhov B.A. Method of field experiments. Moscow, 1979, p.416.
5. Kondratjev K.N. Ecological resources of apple productivity in pre-Volga. Saratov, 1991, 168 p.
6. Klein I., Spieler Y. 1987. Fertilization of apples with nitrate or ammonium nitrogen drip irrigation. Tree performance. Commun. Soil Sci.Plant Anal. 18, 311-322.
7. Klein I., Levin I., Bar-Yosef B., Assaf R., Berkovitz A. Drip nitrogen fertigation of "Starking Delicious" apple trees. Institute of Horticulture, Institute of Soil and water, Agricultural Research Organization, The Volcani Center P.O., Box 6, Bet Dagan 502250, Israel, Shaal, Golan Heights, Israel. April, 1989.
8. Klein I. 1993. Irrigation modeling of deciduous trees and grapes. Agrotechnical 1th International Conference on irrigation proceedings.p.55-66. Tel-Aviv, Israel.
9. Quinlan I.D. and Preston A.D., 1971.The influence of shoot competition of fruit retention and cropping of apple trees. I.Hort.Sci., 46, 525-534.
10. Program-method instruction to orchards, small-fruits and fruit nurseries. Kiev-Uman, 1985, p.106.
11. Strime M., Klein I. Potassium uptake in the grape is reduced by low rates of irrigation. Institute of Horticulture, Agricultural Research Organization. The Volcani Center, Bet Dagan 50250, Israel.
12. The instructions to hydrometeorological stations and posts. Leningrad, 1963, vol.7, part II, p.310.
13. The instructions to the execution of observations on evaporation from soil and snow cover.
14. Zerling V.V. Methodical instructions on mineral nutrition of apple and other horticultural crops. Moscow, 1980, 48 p.

2.3 Exp. 3: Increase productivity of old apple trees in dense orchards

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Materials and methods

After several years of high productivity period at the age 10-12 years the annually yield of super-density orchards is considerably decreased. The aim of the present experiment was to extend the productive life of old apple orchard. The tasks of investigations: the elaborating of effective methods of trees reforming, different degree of rejuvenating pruning and to study the peculiarities of growth and fruit bearing of variety Golden delicious on the rootstock M9 in dense orchard, to evaluate the efficiency of methods on productive period extension.

The experimental plot of commercial orchard was situated in the zone of Zailiiskii Alatau in Dzandosov farm of Almaty region at 850 m above sea level, Slope exposition was northern with an average slope of 4-5 ^{0}. Soils were dark chestnut with clay and sand interspersing and low content of carbonates, humus was 2.1-2.6 %, pH – 7,73. The content of nitrogen was low, phosphorus also low and potassium content was at the level of norm.

Thermal conditions are characterized by moderate hot summer with the average temperature of 24-26^0 in July and moderate warm winter. The average frequency of damage by frosts in this zone is once in 10-12 years.

The precipitations are 350-550 mm per year – is quite insufficient. The first snow appears in the middle of November, snow cover – in the middle of December; snow melting begins in early March.

Air humidity is 76-80 % in winter and 30 % and lower in summer. Winds from the west, as a rule, bring precipitations, east wind (Chilik) – clear warm weather.

Swelling and splitting of buds begin at the end of March – the beginning of April, flowering – May 1-9. Fruit harvesting begins from the middle of August to September 10-15. Defoliation usually occurs in October–November.1989 year of planting. Scheme of planting: 4 x 0.8 m (3125 trees/ha). Till the last years the orchard gave a high yield of fruits of 24-32 t/ha, in 1997 the periodicity of fruit bearing was sharply revealed.

Treatments:

1. Contour pruning of fruit wall on distance from row line 70 cm and horizontal shorting of 1-year old sprouts on altitude 220 cm (control);
2. Heading back of the tree down to 60 cm above the graft union with shortening of lateral branches;
3. Pruning down to the base of the skeleton branches to the perennial wood on 30 cm and shorting of leader;
4. One-sided severe pruning at a distance 30 cm from row line. This operation was repeated two years later on the other side.

Mechanical contour cutter has been used in treatment 1, and saw in treatment 2,3 and 4 in early spring period in 1997. 4 replications, 10 trees of each were spread in six rows. The middle rows were used for the measurements. Setting of the experiment has been randomized block design.

Measurements: soil condition, mass of removed wood, growth stages of sprouts, spur production, diameter of trunk, Leaf Area Index, setting of fruit buds, light interception in trees canopies by actinometric method (Avidan, Erez, 1986), beginning of fruit bearing, productivity and quality of fruits, degree of hardness in winter. Measurements were carried out during during 1997-2000.

RESULTS

Winter of 1997-1998 was critical for fruit crops and spring frosts damaged flowers and there was actually no commercial yield, what provided for the formation of high potential of productivity (PP) by 1999-2000.

According to the results of inventory the Orchard State in 1999 was evaluated as 3.8 balls – satisfactory. Conducted in 1997 tree pruning in experimental variants influenced essentially the shoot length and trunk diameter (Table 11).

Table 11. Growth dynamics of apple trees depending on means and stage of rejuvenating pruning

Treatment	Tree height, cm				Shoot length, cm				Trunk diameter, cm			
	1997	1998	1999	2000	1997	1998	1999	2000	1997	1998	1999	2000
Contour pruning	220	283	220	237	28	27	17	24	5.7	6.2	6.6	7.40
Radical crown shearing	63	181	147	168	71	39	24	37	5.7	6.4	7.3	8.12
Cutting of crown bottom	210	285	278	290	36	28	16	28	5.7	6.3	6.8	7.38
One-sided pruning	235	304	316	324	29	25	21	19	5.7	6.2	6.8	7.18
LSD (P=0.05)										0.07	0.11	0.44

It was noticed the advantage of potential productivity of radical pruning when 70 % of vegetative increment was removed. The mass of removed wood influenced the increment length and the size of leaf area, especially of radical rejuvenated trees.

The strong stage of rejuvenation activated the renewal shoot growth and for 3 years it was more potentially productive with respect to moderate and wear grade of rejuvenation.

Potential productivity (PP) of variants was estimated according to the methods of A.S. Devyatov (1980) by the ratio of total area of trunk section to area unit of the orchard (table 12).

During the determination of illumination of crown center with the use of tubes with sulphate uranium. The following data were obtained: the highest level of penetration of solar radiation was found out in radical pruning – by 90-95 % of FSL. The center of the crowns were satisfactory exposed in cutting of low part of crowns – 64 % from FSL. Penetration of solar radiation was found out using uranyl oxalate filled tubes, arranged along trees With one-sided pruning and contour pruning light penetration values were 57 and 52 % respectively (see Appendix A).

The productivity of rejuvenated apple trees in comparison of usual pruning for 3 years was somewhat changed (table 13).

Table 12. The determination of trees PP and the lighting of crown center, depending on means and stage of rejuvenating pruning (1999)

Treatment	PP m^2 trunk/ha	Mass removed wood, %	Leaf Area (cm^2)	Light in crown center, % of full sun light (FSL)
Contour pruning	2.09	20	17.8±0.1	52
Radical pruning	2.28	70	28.1±1.4	92
Cutting of crown bottom	2.13	35	26.3±0.4	64
One-sided pruning	2.13	30	24.9±0.2	57
LSD (P=0.05)	0.08			

Table 13. The yield and the average fruit mass of the apple variety Golden Delicious, depending on the method of rejuvenating pruning

Treatment	Average fruit mass, (g)	Yield, t/ha				Total 1997-1999
		1997	1998	1999	2000	
Contour pruning	93	0.9	0.3	8.9	12.0	22.1
Radical pruning	159	0	0.5	7.3	2.8	10.6
Cutting of crown bottom	112	0.6	0.8	10.1	14.7	26.2
One-sided pruning	104	1.2	0.5	8.6	11.5	21.8
LSD (P=0.05)					1.6	1.7

As it is known an apple has three-year cycle of development: sprout – generative bud – fruit. Winter frosts of 1997-1998 and repeated frosts in May 1998 damaged severely not only the generative buds but also the vegetative increment – bark and wood of shoots. Strong annual shoots of radically rejuvenating trees were frozen at a level of 85 %. The moderate pruning saved partially from frosts the generative buds what gives some increase in yield.

Contour pruning with slight degree of shoot shortening did not provide sufficient increment of shoots and the setting of generative formations what led to small size of fruits. In 2000 it was noticed the moderate flowering and insufficient fruit bearing of trees.

The most productive were trees with cutting of the low fruited-off part of crown. The improvement of light conditions in central and upper parts of crown positively influenced fruit quality. One-sided shortening of crown with repeating in 2 years did not essentially influence the total productivity and the yield was at the level of control.

The least productive, because of weather conditions, was the variant with radical pruning of crown. Nevertheless according to indirect indices of PP and fruit quality this variant is the most perspective for extension of the productive period of super orchard life.

As to the apple variety Golden delicious it was noticed that side by side with high trade and flavor qualities, good keeping in storage, this variety has two essential shortages: scab infection and low winter hardiness, what should be considered during orchard laying out.

Thus, proceeding from the evaluation criteria such as trunk diameter increment light conditions in the center of the crown, increment length and the size of Leaf lamina, mean weight of fruit, productivity, had been made conclusion – the best result will be received in combination system of pruning , which in lower part of crown up to 15-20 %, in upper part – 25-30 % of vegetative increment are removed. It is necessary to keep carrier and fruiting brunches in the center part of crown for activating growing processes and bearing. Such degree of rejuvenation can increase the productive life of old apple trees in dense orchards by an estimate of 5-7 years.

Conclusion.

Conducted investigations on the US.AID Grant № - MOU 95-15-018 "Intensive apple orchard based on advanced technologies" testify to the importance of chosen scientific elaboration, which reflect the last scientific achievements in this field, which were gained in horticulture of the countries of West Europe, USA and Israel. On the base of conducted investigations new dwarf apple rootstocks Arm 18 and B7-35 were selected for intensive density orchards of dry and hot climate in Kazakhstan. The advantage of drip fertigation in fruit growing was convincingly ascertained for the regions with limited possibility of irrigation use. Undoubted factor in the productivity of density orchard is light regime of tree crown, which influence plant photosynthesis and the extension of productive period of density orchard. All these factors in the complex are the base for the creation of modern intensive orchards, the elements of which were emphasized by the scientific leader of the Grant Prof. Amnon Erez.

Israel

Materials and methods

On the basis on preliminary trials in apple trees with the heat-pulse system, in 1996, The setup of the full scale experiment was established in 1997. A wide scale trial, first time done with apples in Israel was set up in Kibbutz Ortal, Northern Golan heights at latitude of 30^0N and altitude of 950 m above sea level. The soil was of stony loamy structure of basaltic origin. The trial was set on Golden Delicious (var Smoothee) trees grafted to 3 rootstocks: M9, MM106 and Hashabi (Locally selected semi dwarf rootstock). The trees were all at bearing age and were 10 to 12 years old. Planting densities were 1680, 1070, and 910 trees/ha for M9, MM106 and Hashabi respectively.
In Spring 1997, prior to bloom, 15 trees of each rootstock were selected having a typical appearance verifying that the top scion did not root. Also only trees with plenty of flowers were selected.
For every rootstock, a set of 8 heat pulse (Cohen et alo 1981, Cohen, 1991) measuring units was operated individually for every rootstock. 7 of the 8 units were moved to adjacent marked trees in order to expand the number of replicates while always one tree was measured continuously. The units were in operation between May and November. This period covers the whole seasonal development of the apple in this area of Israel.
The data were collected daily and averaged including all the replicates.

In order to prevent any possible water shortage the trees were irrigated in excess. The orchards were drip irrigated and fertigated with 70 kg of N/ha and 250 kg K /ha.
To the normal one line of drippers having a dripper every 60 cm of 4 l/h output, a second identical line was added to the trees in the trial doubling the water applied to the trees.
The trees set heavily and were hand thinned on June 15. The thinning was decided according to tree sizes resulting in different loads to the different rootstocks.
The trees were harvested according to maturity index decided by the growers. Samples were examined to their TSS, average size and to the fruit taste in an anonymous trial.
Evaluation of water use by the trees was calculated on a few bases:
On per tree and per unit of area bases, on per unit of tree cross sectional area and on per unit of fruit produced. The data were also compared to the pan evaporation records during the course of fruit development.
In 1998 the experiment continued in the same location with the same system but with newly selected trees (15 per rootstock) for the heat-pulse measurements in Golden Delicious on the three rootstocks: MM106, Hashabi and M9. This time we tried to prevent excessive yield by a closer monitoring the fruit numbers per tree. The Hashabi trees were smaller than a year earlier. In addition, the trees measured in 1997 were observed as to their return bloom and fruit load.
T o prevent any water shortage the trees were irrigated in excess.

Results

Based on the calibration of water loss and heat pulse reading achieved in 1996, the trial in 1997 showed Considerable differences between the Golden Delicious apple trees on the 3 rootstocks. The differences were in the production potential resulting from the difference in densities relative to tree size. We present that in Table 14 in TCSA/Ha. Trunk cross sectional area was measured and calculated per tree in each of the 15 replicate in each rootstock. Clearly, MM106 has a higher production potential per area as can be seen from the TCSA/ha.

Water used per tree in 1997 reached a level of 7.2 m^3 for Hashabi, 6.6 m^3 for MM106 and 4.9 m^3 for M9. But as the fruit load was not identical, the water use efficiency (litres of water needed for production of 1 kg fruits) was the best for MM106 - 49 l/kg against 50.5 for Hashabi and as much as 68 l/kg in M9. The difference in efficiency was a result of the wide difference in fruit load which reached 140 130 and 70 tons/ha for MM106, Hashabi and M9 respectively. The extremely high yields of the first 2 rootstocks calls for a possible effect on biennial bearing.
Water requirements in the trial followed the rootstock. Clearly, water use was a function of the climatic conditions as depicted by pan evaporation as of day 178 of the year. During the whole summer, the transpiration levels of both Hashabi and MM106 was around 0.5 of evaporation from pan A, while M9 showed a factor of 0.3 of pan evaporation.

Table 14: Trunk cross sectional area per tree and per hectare in Golden Delicious apple trees grafted on M9, MM106 and Hashabi rootstocks in Ortal, Israel.

Rootstock	TCSA *(cm^2)	Trees/ha	TCSA/ha (cm^2)
M9	51.6±3.3	1680	8675
MM106	136.5±5.3	1070	14605
Hashabi	92.1±3.3	910	8386

* Trunk Cross Section Area

The complete data obtained on water flow measured in the 3 rootstocks and the pan evaporation on the same period is presented in Table 15 for measurements from early May till late November 1997. In spite of the variations, a consistent low level for M9 is observed till mid September and higher levels of MM106 is observed especially in the early period till end of July. The increase in values for the early May readings represent the increase in foliage cover by the trees.
In order to verify that water was not in shortage soil water tension was monitored using tensiometers from May to the end of September. Only in one case a higher water tension was monitored in the Hashabi rootstock in the 40 cm depth.

The Dynamics of water used by the 3 rootstocks indicated higher water use of MM106 persisted all the season and was already noted by end of May. The 2 other rootstocks diverged only in late June with a rather increased difference with time leading to a range of 729 mm (MM106) to 477 mm (M9). To this value, an added water used till the end of November (in case irrigation continues till this date) is 120 mm. It should be noted that rain in the Northern part of Israel falls only in winter time, Starts not before November and ends by early April. So no doubt that part of the water used till end of May came from this source. When calculating the water used as measured by the heat pulse on the 3 rootstocks vs. pan A evaporation (Table 15) during the period May 15 to Sep. 15, an interesting picture appears: As was calculated earlier, MM106 uses more water than the other 2 rootstocks. This holds till end of July when Hashabi overpasses MM106. Roughly speaking, these 2 rootstocks keep a level between 0.55 to 0.66 of pan evaporation from mid July till mid September when the fruit was harvested.

Table 15. Ortal irrigation, water use and crop coefficient in 1997

Month	Monthly Total (mm)		A Pan	Crop Coefficient	
	Sap flow	Irrigation			
Hashabi					
	Measured	Applied		Measured	Applied
May	153	82	264	0.58	0.31
June	155	151	250	0.62	0.60
July	163	232	280	0.58	0.83
August	144	225	238	0.60	0.94
Sept	113	186	236	0.48	0.79
October	83	75	124	0.67	0.61
Total	811	951	1392	0.58	0.68
M9					
	Measured	Applied		Measured	Applied
May	121	67	264	0.46	0.25
June	105	136	250	0.42	0.54
July	108	195	280	0.39	0.70
August	87	191	238	0.37	0.80
Sept	80	178	236	0.34	0.76
October	69	71	124	0.56	0.57
Total	571	837	1392	0.41	0.60
MM106					
	Measured	Applied		Measured	Applied
May	161	89	264	0.61	0.34
June	164	166	250	0.66	0.66
July	169	247	280	0.60	0.88
August	120	209	238	0.50	0.88
Sept	100	219	236	0.42	0.93
October	79	110	124	0.64	0.89
Total	792	1040	1392	0.57	0.75

M9 on the other hand, show a surprising decline of water used between early June and mid July when the water used stabilized at a level of about 0.35 of pan evaporation, a non predicted low value. When observing the ratio of water used from mid September till end of October, a marked increase is observed especially in M9 that reached similar levels to the other 2 rootstocks.

Yield as presented in number of fruits per tree show the same relative ratio as with total weight: Close to 1000 on MM106, 700 on Hashabi and 260 on M9. Per 1000 m^2 , the mean number of harvested apple fruits would be: 109,000 for MM106, 85,000 for Hashabi and 40,500 for M9.

Fruit quality was determined by grading it on a commercial fruit grader for each rootstock individually. M9 showed a better fruit size distribution in % than in Hashabi that had better fruit size distribution than MM106. No doubt this is a result of the higher load that was inversely proportional to the size distribution. Observing fruit color indicated the fruit on MM106 to be greener and on M9 to be yellower. Furthermore, a pink cheek appeared mostly on M9, an indication of higher quality.

Evaluation of samples of fruit from the 3 rootstocks (Table 16) show a better size for M9 >Hashabi> MM106; Higher TSS for M9 >Hashabi>MM106; similar fruit firmness in all 3 rootstocks; higher acidity in M9 >Hashabi>MM106 and a higher score for M9 and Hashabi fruits over MM106.

Table 16: Fruit characteristics of Golden Delicious apple trees grafted on M9, MM106 and Hashabi rootstocks in Ortal, Israel.

Rootstock	Fruit wt. (g)	TSS (%)	Firmness (Lbs)	Acidity (%)	Tasting quality (Range 0-5)
M9	150.3±6.1	12.3±0.5	17.3±0.5	0.46±0.01	4.1±0.1
Hashabi	136.6±5.5	11.2±0.6	16.4±0.4	0.40±0.00	4.0±0.4
MM106	125.2±1.2	10.7±0.2	16.7±0.6	0.37±0.01	2.2±0.4

During 1998, a more uniform yield between rootstocks was obtained on newly selected trees for the trial. MM106 was higher in yield but not significantly (See 1998 report). Fruit quality with regards to size was rather very good. M9 had a little better fruit size in the distribution of grading especially compared to Hashabi. Fruit quality was very negatively affected this year by sunburn as extremely high level of damage was noted on the M9 fruits that was much more exposed than on Hashabi and MM106 rootstocks. But even on these two rather vigorous rootstocks, close to 40% of damage was noted (Table 17). The cause for the unprecedented damage was the extreme heat in summer 1998. Measures to avoid such damage are being taken by growers as of 1999.

The summer of 1998 was exceptionally warm and higher values of transpired water was recorded in this year compared to 1997.While values of about 6 mm/day were found in 1997 for Hashabi and MM106 and 4 mm/day for M9 in the highest transpiration period, maximal values of 6.8, 8.8 and 5.5 were recorded in 1998 for Hashabi, MM106 and M9 respectively. Considering the smaller Hashabi trees in 1998 than in 1997, a mean increase of about 40% in water use was noted in 1998.

Details on sap flow measurements in this year presented in the 1998 report

Reaffirmed clearly the major finding that by early June apple trees reach their maximal coefficient of pan A evaporation. In spite of the very warm summer in 1998 with pan A evaporation values reaching 14 mm a day (compared to less than 12 in 1997), no increased in relative demand was noted after the beginning of June (160 -170 days of the year). This verifies previous year results.

Return bloom and yield on the 1997 trees.

No flower buds were formed on the MM106 trees due to the heavy yields they bore in the previous year. Few flowers were seen in the Hashabi trees while abundant bloom was noticed in the M9 trees. (0.4 for Hashabi in the scale of 0 [no bloom] to 5 [heavy bloom load]) and a moderate bloom in M9 (2.9 in the scale 0-5).Only the M9 trees produced a commercial crop.

Evaluation of efficiency of fruit production under this system was examined again by dividing the cumulative yield in both years by the water use of the trees during the two years 1997-1998. By that, we could count for the biennial bearing on two of the three rootstocks. A different picture is emerging as compared to 1997.(Table 18). While in 1997, the most efficient rootstock was MM106, when comparing on the basis of the two years, the most efficient one seems to be M9 the only rootstock that bore fruit in 1998 too.

Table 17: Fruit color and sunburn damage in Golden Delicious apples harvested in 1998

Rootstock	year of start	Green	Green/yellow	Yellow	Sunburn
M9	1998	1.2	25.9	4.3	68.1
M9	1997	0.6	30.9	2.8	65.6
MM106	1998	2.0	56.6	4.0	37.1
Hashabi	1998	0.7	58.7	1.3	39.2

Table 18: Yields, water use and water use efficiency in Golden Delicious apples grafted on three rootstocks. Yields are in Tons per Dunam (1/10 of hectare; Water use in mm and water use efficiency in liters of water require to produce one kg of fruit).

	Water used by trees			Yield (Tons/ Dunam)			Water use efficiency (Litres/kg)		
Rootstock	1997	1998	Combined	Yield 97	Yield 98	Combined	1997	1998	Combined
Hashabi	811	861	1672	13.0	0.0	13.00	62.4		128.6
MM106	792	1115	1907	14.6	0.0	14.60	54.2		130.6
M9	571	699	1270	7.0	6.7	13.69	81.6	104.4	92.7

Discussion

The data obtained in 1997 indicated a few interesting and innovative observations: It seems that water used by the trees is lower than is expected. Total use of 850 mm for the extremely loaded MM106 trees is lower by 250 mm compared to regular irrigation practices. With the M9, only 600 mm were needed for the whole season. This finding support our preliminary observation in 1996 that water could be saved to a considerable level and thus have an impact on the rational use of water in locations like Israel where water is the most limiting production factor.

Another interesting aspect that is connected to the former one is the practice of irrigation with respect to pan evaporation. Still this method is being used as a guideline for irrigating orchards in Israel. As against the recommendations of increasing the ratio to pan evaporation from early summer till harvest in September. It was clearly shown here that there is no increase in water use by heavily loaded trees from early June on. This finding was supported also in the data taken in 1998. This indicates that fruit development does not have an added requirement and that probably vegetative growth is the critical element in increasing water requirement by the tree. Even in the warm 1998, although the level of transpiration recorded was considerably higher than in 1997, still maximal levels of sap flow were recorded already by early June. This has a bearing on orchard irrigation practices. With the critical shortage of water imposing heavy cut on farmer water allocation, this finding may save considerable amount of water if no added water in the season up till fruit harvest in August-September will be adopted

With regards to water use efficiency, It should be stressed that load on the trees was not proportional to the tree size in 1997. Especially on MM106, the fruit load was excessive, what led to the more inferior fruit quality on this rootstock. Furthermore, the late fruitlet thinning led to a complete biennial fruit bearing pattern in MM106 and in Hashabi. By evaluating the combined effect of the two years 1997-1998 with regards to water use efficiency, an advantage to the dwarfing M9 rootstock was noted due mostly to the lack of biennial bearing in this rootstock. The limited vegetative growth is probably one element in a better flower bud differentiation apart from the moderate fruit load. Although the yields were not extremely high on M9 rootstock, they were excellent by any commercial standard. The drawback of this rootstock was very well manifested in 1998 by the sunburn damage resulting from direct solar exposure and heating of fruit tissues to damaging levels. A need for protecting fruit from direct exposure to the sun during the summer period seems indispensable.

The use of the heat-pulse system to monitor water use in apple orchards demonstrated the importance of the system to monitor the actual use of water by the trees and the potential of establishing a guiding system for irrigation.

The two main achievements of the project in this respect were the demonstration of the different efficiencies of the rootstocks with regard to water use and the demonstration that commercial practices should be corrected in order to save on irrigation water without affecting negatively tree and fruit development.

References

Avidan B., and Erez A. (1986) A reliable actinometric method for characterizing the light regime in plant canopies. J. Amer. Soc. Hort. Sci. 111:187-191.

Cohen, Y. (1991) "Determination of orchard water requirement by a combined trunk sap flow and meteorological approach." *Irrig.Sci.* 12:93-98.

Cohen, Y., M. Fuchs, and G.C. Green. (1981) "Improvement of the heat pulse method for determining sap flow in trees." *Plant,Cell and Environment* 4:391-397.

Impact relevance and technology transfer

The project had a profound impact on the researchers involved from the Institute of fruit and grape growing in Kazakhstan. No doubt, the knowledge transfer by the trained personnel and the visits have strengthened the researchers and the Institute. The data obtained in the 3 different experiments in Kazakhstan enable now to modernize the apple orchards grafted to dwarf rootstocks, examine on a commercial basis the locally selected dwarfing rootstocks especially the ARM 18. And the first establishment of drip irrigated and fertigated orchards in Kazakhstan may lead to expansion of this technique that indicated commercial advantages. The prolongation of the project to 5 years enabled to cope with the shortcomings of the political situation s well as with the unfortunate winter and spring climate in the first 2 years of the project. The prolongation of the project allowed utilizing the equipment bought and shipped to Kazakhstan to its full capacity, to allow for more exchange of visits and views. Out of the project the following equipment is left in the a/m Institute: Computers and printers, fax machine, whole irrigation – fertilization system including an irrigation computer, in addition to small lab equipment bought during the project.

In addition, a new technique for measuring light interception and distribution in tree canopied was studied in Israel and used in Kazakhstan.

The results of all three-field experiments will be utilized in future planted apples in Kazakhstan. No doubt the impact of the collaborative work will be long lasting. This achievement should be viewed on the background of extreme difficulties in performing the experimental plan in Kazakhstan due to the changes in the agricultural systems there. No doubt the dedication of the researchers of the Institute of Fruit and wine growing in Almaty allowed the successful completion of this project. Also the good will of the CDR authorities that allowed the prolongation of the project foe another 2 years enabled the successful completion of the project. We look forward to keep collaboration after the finish of the AID project

Project activities:

The following meetings and visits took place during the project activity:

- Visit of the Israeli principle investigator in Kazakhstan to discuss the problems and to decide of the experimental plots in 1996
- Visit of 3 researchers from Kazakhstan visited Israel 15-24.9 1997
- Visit of The Israeli principle investigator in Kazakhstan May 1998. To change experimental plots due to specific difficulties that appeared and to discuss the prolongation of the project with special emphasis on the irrigation trial that started late due to delays in shipping the equipment and the need to secure a safe experimental plot

- Visit of 2 researchers from Kazakhstan in May 1999
- Training of Mr Raul Karychev in 1997 for a period of 3 months

Project productivity

With satisfaction we can declare that the project achieved all its goals. Apart from achieving all the objectives, continuous collaboration takes place in a new proposal to the CDR in a different horticultural area. The project also has established connection between the Kazakh researchers and the western horticultural scientific activity, an important element for future development in this part of the world.

In Israel, the data collected call for a potential saving in water for irrigation especially in the second part of the growing season. This may lead to a considerable saving in water without affecting tree or fruit development. Also, it did demonstrate the significant role that rootstocks play in water use by the tree.

Strengthening of Developing Country Institution

No doubt, the knowledge transfer by the trained personnel and the visits will strengthen the researchers and the Institute. The data obtained in the 3 different experiments in Kazakhstan enable now to modernize the apple orchards grafted to dwarf rootstocks, examine on a commercial basis the locally selected dwarfing rootstocks especially the ARM 18. And the first establishment of drip irrigated and fertigated orchards in Kazakhstan may lead to expansion of this technique that indicated commercial advantages. We look forward to keep collaboration after the finish of the AID project.