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Annual Report

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TITLE OF PROJECT. AGROMETEOROLOGICAL APPROACH TO CROP WATER USE EVALUATION FOR IMPROVED IRRIGATION EFFICIENCY

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Executive Summary

The main purpose of the research is to adapt a meteorological evaluation of crop water use to improve irrigation efficiency in the conditions of the Kyrgyz Republic

This purpose entails

1 Technology transfer from the Israeli scientists through

- Setting up of computer and software for testing and adaptation of a model developed by Israeli scientists
- Installation of data collection and retrieval software from an automatic meteorological station purchased in USA
- Computation of the evapo-transpiration using data collected in the meteorological station

2 Definition of crop irrigation regimes

3 Adaptation of optimum irrigation modes to engineering solutions for furrow irrigation practiced in Kyrgyzstan

4 Apply irrigation scheduling according to the algorithm of Israeli scientists

5 Comparative analysis of the results achieved by Israeli technology and traditional (local) method

6 Recommendations for the dissemination of Israeli technology among farms of Kyrgyzstan

Work completed in the course of the past year

1 Purchase of the American equipment (meteorological station)

2 Organization of the trip for two Kyrgyz scientists to Israel, where they studied the software, model of the evapo-transpiration and the meteorological station in the field and laboratory conditions

3 Installation of the meteorological software in the computer of Kyrgyzstan

4 The testing of the meteorological station in the laboratory and the field conditions (including 6 gauges)

5 Preparation of the experimental field for the summer experiments

Section 1

A Research Objectives

The purpose of the research is to apply an agrometeorological approach to evaluate plant water use and improve irrigation efficiency in the conditions of the Kyrgyz Republic

B Research Accomplishments

1 Research activity in Kyrgyzstan at the Scientific and Research Institute for Irrigation

We completed the organizational measures, prospecting works and researches Field trips to scientific-pilot farms of the Agrarian Academy in Sokuluk, Kant and Alamedin regions of Kyrgyzstan were made We obtained the consent to establish research plots in the cooperative farm "Vetka" of the Alamedin region and made the necessary inspections of the experimental plots

We surveyed the grounds and drew the map at 1 10000 scale (fig 1) of a plot assigned to be planted by corn The plot was divided in two blocks One block was sprinkle irrigated by a "Fregat" watering machine The second block received furrow irrigation

We conducted a survey of the soil hydraulic properties in the research plots prior to corn emergence Table 1 summarizes the results of these measurements for 20 cm soil layers to dwpth of 100 cm The sampling sites are marked on the map The soil type is meadow-grey, a heavy clay Based on the soil hydraulic data and the estimated rate of moisture loss, the differentiated watering norm DWN are calculated according to

$$DWN = 10H_g d\beta_{yd} (1-g) \text{ (mm)}$$

where Hg is the layer of soil in which the deficit of a moisture is observed

Irrigation scheduling should follow the physiological response of corn to the diminution of a soil moisture The method is based on meteorological parameters collected by of an automatic meteorological station Instructions for the use of the weather station and the training on the method of the crop water requirement are obtained in the laboratory of Prof M Fuchs from the experiments made in Israel

The research continues at the country farm "Eleman" in the village of "Kok-Jar" (10 km south of Bishkek) All the preparatory work and surveys were conducted

The map derived from the land reclamation survey (fig 2) shows the plot assigned to the experiment in the orchard The orchard area is 30 ha The altitude is 995-1011 m above a sea level The topography of the district is hilly The soil is a medium-textured gray loam with variable profile depth up to 2 5 m The soil is occasionally stony

The orchard is watered by flood and furrow irrigation The provisional watering norm is 50-60 mm wetting a 20-80 cm soil layer The depth of root penetration can reach 9 m For practical purposes it is enough to know soil moisture content to a depth of 150 cm Prevention winter frost damage require filling the soil profile with water during the autumn before permanent soil freeze The irrigation dose for this purpose is 100-150 mm The first

application of irrigation in the spring should follow the drop of redundant fruitlets The last irrigation of the current growing season is after harvest and pruning to set favorable flower buds development conditions for the next year

The use of water of an orchard during vegetation depends on its age and the sum of daily average temperatures In our conditions it can be within the limits of 650-750 mm

Table 1

Horizons sm	0-20	20-40	40-60	60-80	80-100	Average value in a meter stratum
Facilities "Vetka" (p 1, 2, 3)						
Humidity of soil in % dry weight of soil	26 40	25 55	24 10	23 37	26 58	25 20
Mechanical structure of % of particles < 0 01 mm	44 98	46 05	47 49	50 44	64 08	50 61
Least moisture capacity in % dry weight of soil	24 6	25 0	26 0	26 3	31 0	26 6
Critical moisture capacity of soil as a fraction of least moisture capacity	0 72	0 72	0 74	0 74	0 83	0 75
Volumetric mass of soil, t/m	1 29	1 28	1 25	1 24	1 13	1 24
Garden at village "Kok-Jar" (p 1, 2, 3)						
Mechanical structure in % of particles < 0 01 mm	37 32	37 36	43 64	46 40	43 84	41 71
Least moisture capacity of % from dry weights of soil	22 0	22 0	24 0	25 0	24 0	23 4
Critical moisture capacity of soil as a fraction of least moisture capacity	0 67	0 67	0 71	0 77	0 71	0 57
Volumetric mass of soil, t/m	1 35	1 35	1 31	1 28	1 31	1 32

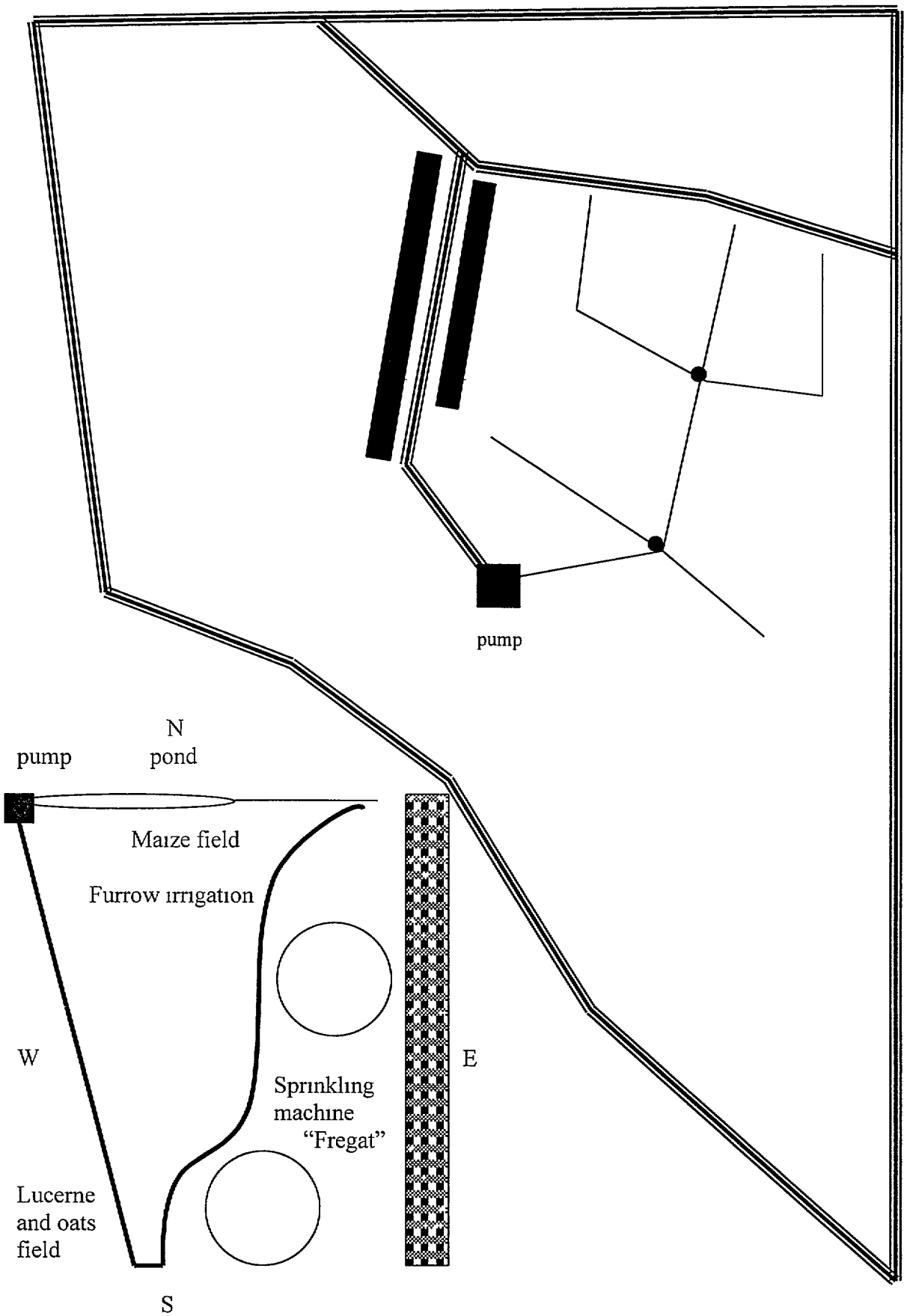

Fig 1 Map of the farm «Vetka»

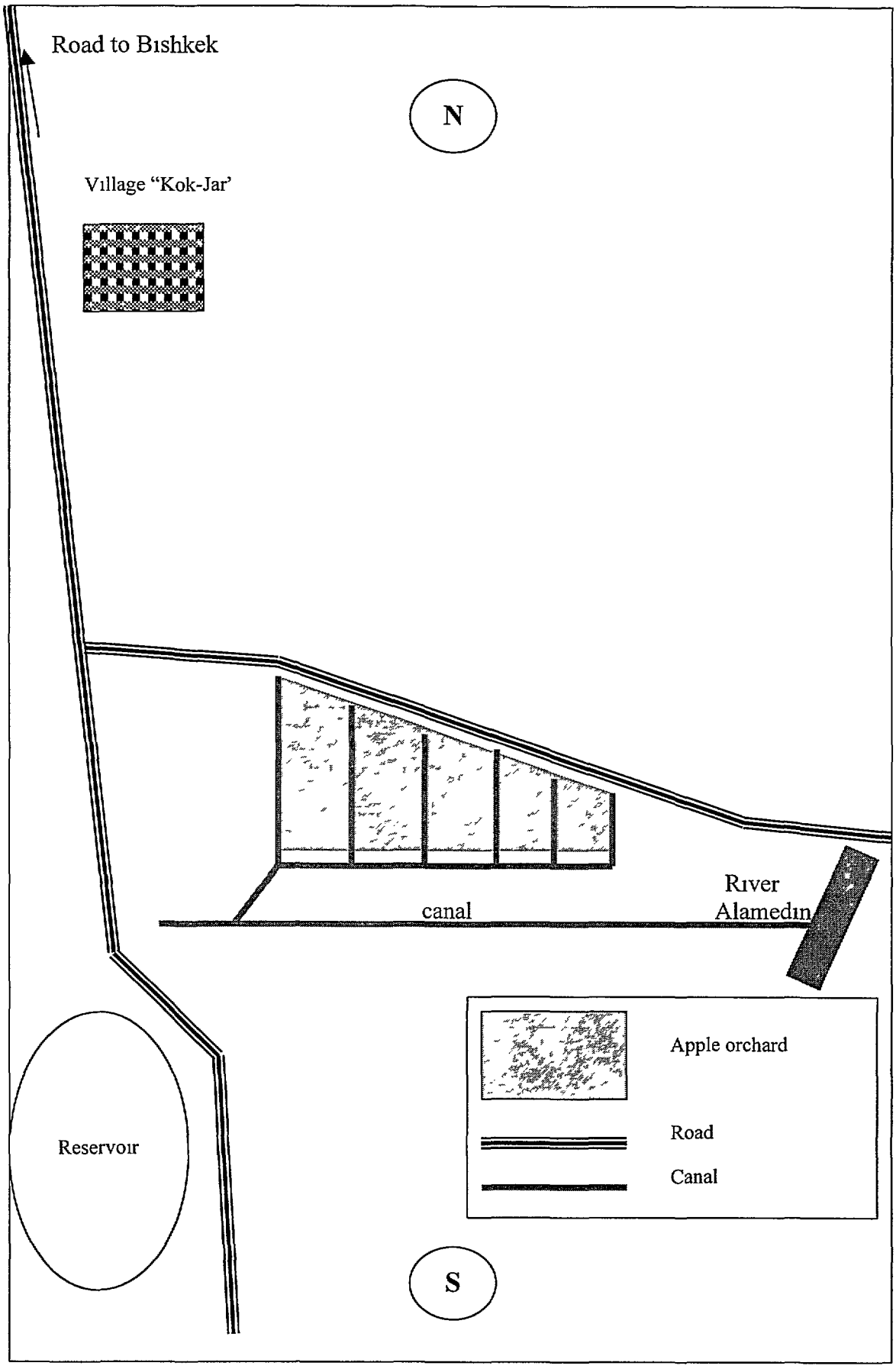

Fıg 2 Map of farm «Eleman»

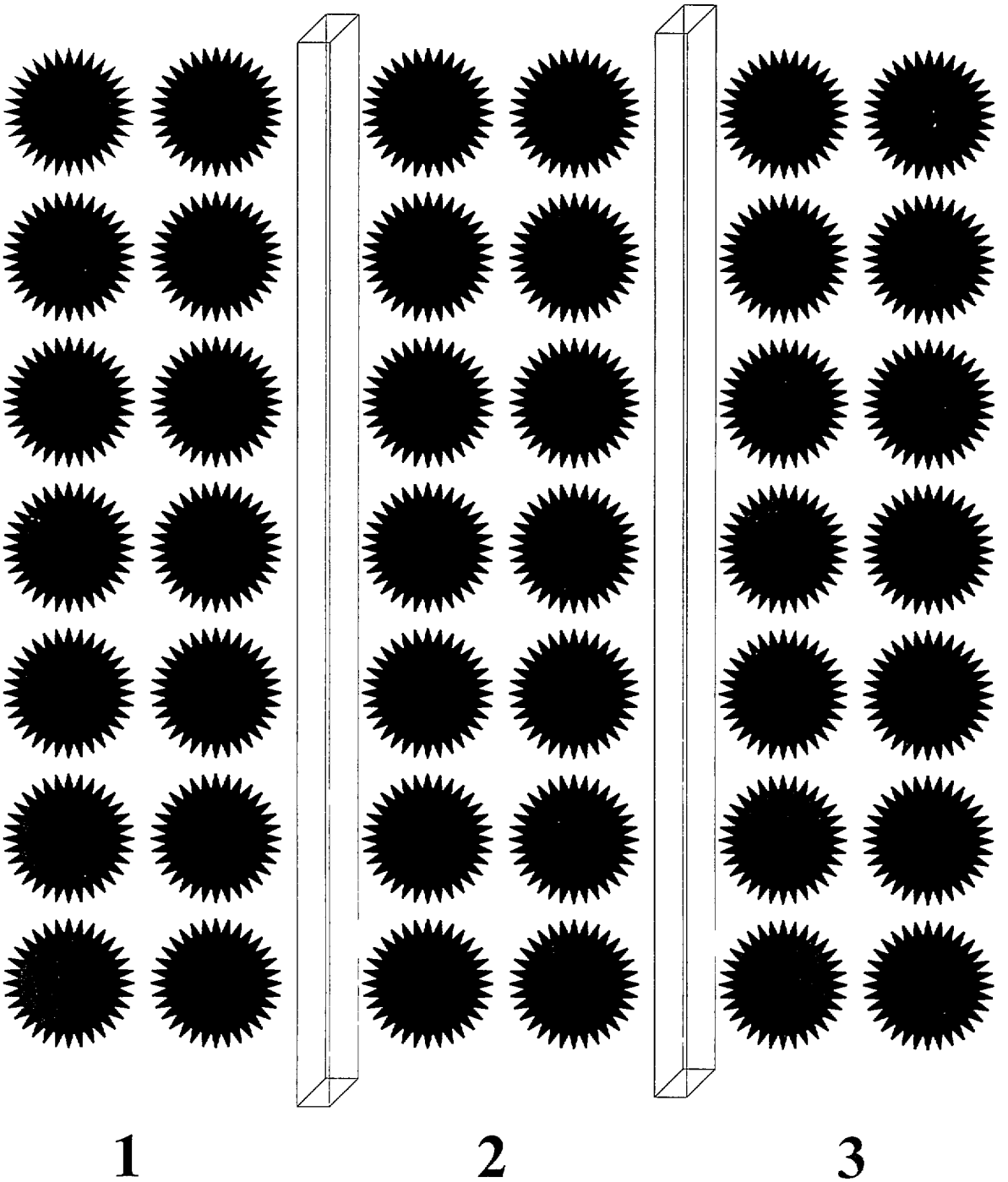

Fig 3 The map of the experimental field

1 – The rows of the apple-trees for irrigation treatment by the method of Kyrgyzstan scientists

2 – The rows of the control apple-trees

3 – The rows of the experimental apple-trees for irrigation treatment by the method of Israel scientists

Duplication of the biologically sustained terms the watering is supposed to follow the algorithm developed by Dr Panova A V It will use a tendency factor of magnification of the integrated rate of climatic moisture deficit as explicitly is stated in the plan of field works

In summer, 1999 the research plan will continue with the installation of the meteorological station in the experimental site

In parallel with main operations for choosing an experimental plot, the purchase of the equipment of meteorological station is made Mounting and testing of the meteorological station in laboratory conditions, programming and set-up of gauges is conducted All gauge tests have shown, that a relative error of gauges of humidity, temperatures, solar radiation and velocity of a wind within acceptable limits

2 Research activity in Israel at the Volcani Center

Physiological basis of the model Stomatal response of maize to water stress

The transpiration model based on the combination approach (Monteith, 1964) introduces the physiological control of water vapor flow in the leaves by a leaf resistance parameter To adjust for deficit moisture supply from the soil, the leaf resistance increases In the original formulation of the model, this resistance referred to a lumped resistor representing the foliage, hooked-up in series with the aerodynamic resistance of the atmospheric surface layer Experimental investigation of the foliage resistance required an inversion of the transpiration model and independent measurements of the transpiration (Van Bavel, 1967) Yet, the relation to direct measurements of the stomatal resistance on leaves remained undefined A sub model with identifiable parameters about the mechanism regulating stomatal opening is needed to render the model operational As light is the main environmental factor, to which stomatal aperture responds it is reasonable to parameterize the relation between incoming photosynthetically active radiation (PAR) and stomatal resistance Previous research with cotton (Petersen et al , 1991) has shown that moisture stress changed the value of the coefficients in the mathematical function relating leaf resistance to PAR The current project refines this finding by establishing directly the effect of a soil water deficit on these coefficients

A series of stomatal resistance measurements under various conditions of the soil moisture deficit in the soil was made to deal with this problem in two 1000 m^2 plots receiving drip irrigation The actual transpiration was measured with the heat pulse method Potential transpiration was computed from the model assuming zero stomatal resistance The daily value of the actual to potential transpiration ratio was calculated In the dry treatment a drop to 60% of the initial value immediately after the last irrigation triggered a new water application restoring 60% of the accumulated soil water deficit In the wet treatment the irrigation triggering value was a 20% drop of the ratio with a full return of the total water depletion A steady state porometer (LI-1600) measured stomatal resistance The porometer bears a quantum sensor for PAR (LI-190) to measure incident radiation on the leaf The measurements were taken on the abaxial and adaxial faces of the leaf During a measurement the leaf remained in its original position A time domain reflectometer (TDR) monitored soil moisture content in three replicates at the following locations depth - 0 05, 0 35, 0 50 m, distance from dipper line - 0 15, 0 30, 0 45 m

The diurnal values of the resistances were plotted against incident PAR during several drying cycles The results are summarized in Table 1 The mathematical form of the relation between measured resistance and incident PAR followed an inverse hyperbolic function where $r_{L\,min}$ represents the minimum leaf resistance and S_{ph} is the value of PAR for which the actual resistance is twice the minimum value

Figures 1 and 2 illustrate this relation for two conditions of the soil water status In Figure 1 a recent irrigation has restored soil moisture to field capacity in the root zone The soil moisture deficit is low The parameters of the mathematical functions in the two treatments are similar, with a minimum resistance of the order of 60 s m^{-1} Figure 2 represents conditions of a large soil moisture deficit The minimum resistance reaches 120 s m^{-1} in the wet treatment and 160 s m^{-1} in the dry treatment Yet in the course of the day, the decrease of moisture content due to water uptake causes an increase of the minimum resistance from morning to afternoon The relative change of resistance with PAR appears independent of the soil moisture condition The diurnal difference increases as soil moisture deficit increases Although the value of Sph varies between data sets, the change is not associated with soil moisture Therefore, in the application of the model this parameter takes on a constant value of 740 μmol m^{-2} s^{-1}

The leaf resistance increases linearly with soil moisture deficit (Fig 3) The least square fit of the linear coefficient and offset shown in Figure 3 were used to update the stomatal function in the transpiration model In the current version this update is manual once a day The diurnal change of the minimum resistance at a high soil moisture deficit may impose a modification of the model for use in cases of severe deficit irrigation

References

Monteith, J L 1964 Evaporation and environment The State and Movement of Water in Living Organisms XIXth Symposium for Experimental Biology Swansea Cambridge University Press, , 205-34

Petersen, K L , Moreshet, S and M Fuchs 1991 Stomatal response of field-grown cotton to radiation and soil moisture Agron J 83 1056-1065

Van Bavel, C H M 1967 Changes in canopy reisistance to water loss from alfalfa induced by soil water depletion Agric Meteorol , 4 165-176

Table 1 Soil moisture deficit increases the minimum leaf resistance ($r_{L\ min}$) and the sensitivity of stomatal response to photosynthetic light (S_{ph}) At a high moisture deficit, the stress condition appears as increase of minimum leaf resistance in the afternoon

DOY	Treatment	Soil moisture deficit (mm)	a m		p m	
			$r_{L\ min}$	S_{ph}	$r_{L\ min}$	S_{ph}
198	dry	8 7	51 ± 13	425 ± 182	59 ± 19	617 ± 295
	wet	6 4	47 ± 19	575 ± 360	49 ± 24	1106 ± 665
200	dry	20 9	29 ± 34	1688 ± 2305	38 ± 36	2186 ± 2266
	wet	18 6	10 ± 19	2708 ± 5532	44 ± 15	951 ± 372
203	dry	4 6	42 ± 6	357 ± 173	42 ± 5	718 ± 162
	wet	4 6	31 ± 6	638 ± 210	31 ± 7	935 ± 400
205	dry	12 5	36 ± 38	1516 ± 1810	47 ± 50	1950 ± 2355
	wet	11 0	1 ± 28	38414	54 ± 40	1757 ± 1528
207	dry	28 3	36 ± 34	1604 ± 1765	181 ± 38	370 ± 1434
	wet	25 4	26 ± 13	1787 ± 1058	88 ± 15	558 ± 125
217	dry	60 3	117 ± 33	622 ± 251	192 ± 45	531 ± 198
	wet	44 4	93 ± 28	757 ± 323	165 ± 31	517 ± 150
219	dry	0 0	61 ± 15	1061 ± 345	88 ± 14	559 ± 118
	wet	0 0	45 ± 16	1073 ± 492	61 ± 15	731 ± 235
222	dry	15 9	53 ± 11	612 ± 226	60 ± 12	610 ± 171
	wet	11 9	60 ± 10	472 ± 124	75 ± 10	295 ± 53

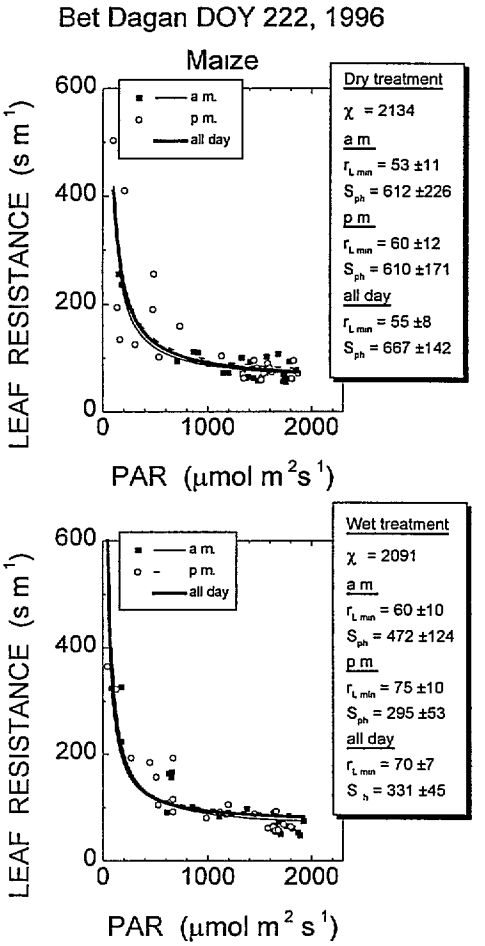

Figure1

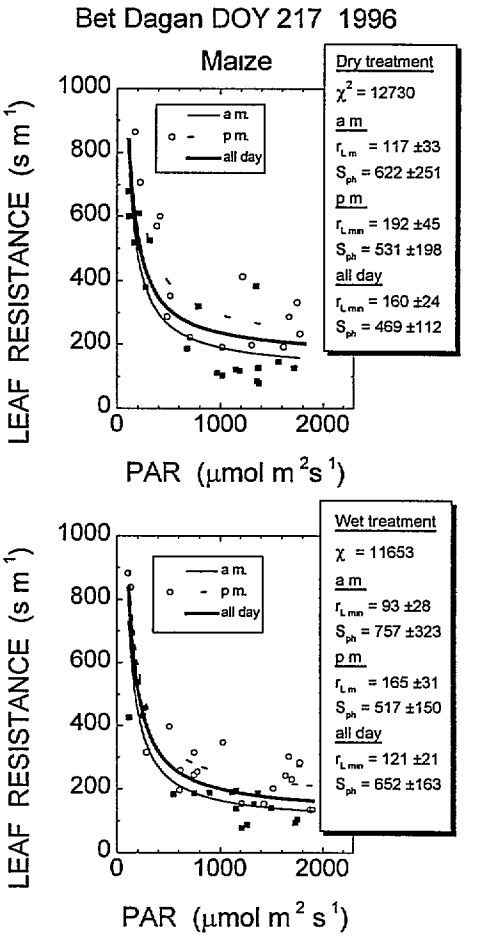

Figure 2

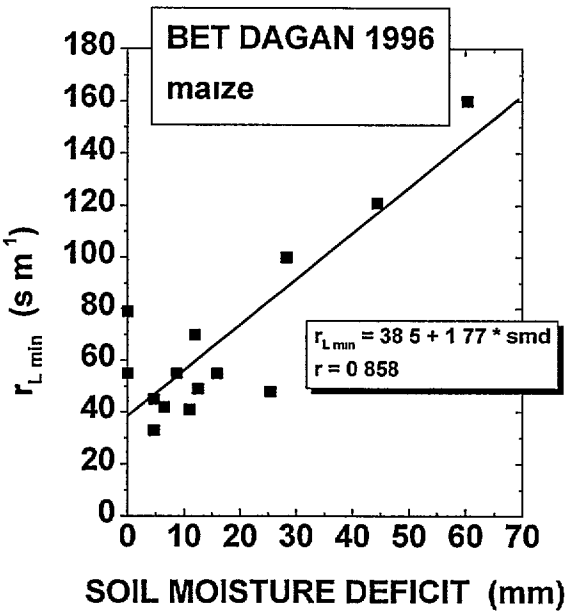

Figure 3

C Scientific Impact of Collaboration

1 In September 1, 1997 we received the money for the project activities
2 In November, 1997 we ordered and received from "Campbell Scientific", USA a price list of the equipment
3 In April, 1998, Prof M Fuchs prepared a list of the necessary equipment for the future field experiments in Kyrgyzstan
4 In May, 1998 we received the research equipment from "Campbell Scientific", USA
5 In July-August, 1998 has been organized training trip for two scientists (Dr Jalil Rahmanov and Dr Alla Panova) from Kyrgyzstan to Israel They have received some experience in installation of the software and training with the weather station in the laboratory and field conditions

D Description of Project Impact

The project results in the near future will be useful for farmers engaged with the orchards

E Strengthening of Developing Country Institutions

1 Purchase of the equipment (weather station) for the field experiments
2 Purchase of the office computer
3 Training in Windows, Spread Sheet and other software
4 Training in the modeling of crop water requirement
5 Training in the carrying out of the field experiments with using of new equipment

For the progress of the project implementation it is necessary

- to purchase of the portable computer,
- to purchase of new equipment for carrying out more complicate research experiments,
- to train of the using of new equipment in Israel,
- to visit of Israel scientist to Kyrgyzstan for the coordination and assessment of the project activities

F Future work

Because the long time have required for the initial organization and purchasing of the equipment, a decision about necessity for the changing of the crop and the extension of the project terms of the implementation has been made by both collaborative Israel and Kyrgyzstan sides

Reasons

- The experimental site is not sufficiently protected against thieves and too expensive for providing the field experiments
- Israel cooperators already completed the research with corn and have started a

continuation project with the same objective with apple orchard
- An apple orchards are an important crop in Kyrgyzstan

Section 2

C Budget

The modification of the articles of the budget is not supposed

D Collaboration, Travel, Training and Publication

From July 18 to August 1, 1998 Dr Jalil Rahmanov and Dr Alla Panova have made a visit to Israel for coordination of the project activities and for training with new equipment In the laboratory of Prof Marcel Fuchs we have studied mathematical modeling of transpiration the row crop, have made technical set up of the new equipment and speared sheet software They have been several times on the cotton and apple experimental fields with Dr Shabtai Cohen and with his students from Netherlands and China Especially, they have been very satisfied from conversation with Dr Amos Naor concerning to Stem Water Potential and Apple Size On the North and South of Israel they have seen many interesting experiments in which Israel cooperators have engaged They have received very useful information about carrying out research experiments and peculiarities of the field work in Israel

E Request for Tel Aviv, A I D or BOSTID Actions

Kyrgyzstan side urgently need from Tel Aviv and Embassy of Israel in Kyrgyzstan financial help in covering the expenses for Training Course in Israel Personal who will study in this Course will take part on the field experiment and will work with new equipment