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PILOT IRRIGATION MANAGEMENT INFORMATION SYSTEM FOR THE CHO VALLEY

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EXECUTIVE SUMMARY

In the second year, work was concentrated in Kyrghyzstan, and the following was accomplished:

1. Automated weather station equipped with CR23 (Campbell Scientific, Inc.) data logger and sensors was installed and activated at Kant Machine Irrigation Station (MIS) near Bishkek.
2. Three small weighing lysimeters designed and constructed in Israel were installed in the field and connected to the data logger of the weather station using long signal cable.
3. Meteorological data and weights of lysimeters were received by telecommunication (cellular telephone) at KSRII; potential evapotranspiration (PET) was calculated by Penman equation method using weather data (global radiation, air temperature, relative humidity and wind speed); actual ET was determined by soil water content changes in weighing lysimeters.
4. Irrigation commenced at beginning June and ended beginning July; the quantity of water for irrigation was determined according to potential evapotranspiration (PET) calculated by Penman equation method. From beginning June, soil water content in the field was also monitored with WATERMARK sensors.
5. Dr. J. Tsipris traveled to Kyrghyzstan at April 2002 and participated in the installation of lysimeters and weather station and partly in operation of the field experiment.
6. All of data were processed in the winter months by Kyrghyz and Israeli team.

For the 2003 irrigation season the following is planned:

- The installed weather station and lysimeters will be used to continue field experiment with winter wheat in Kyrghyzstan at MIS near Bishkek.
- Potential evapotranspiration will be evaluated by modified Penman equation from meteorological data acquired with weather station connected by phone communication to the KSRII.
- Irrigation will be applied according to above estimation with up and down bracketing (70%, 100% and 130% of PET, three treatments) in field experiment and lysimeters using a traveling lateral sprinkler system.
- Actual ET will be determined by soil water content changes in the weighing lysimeters; soil water content will be monitored with a WATERMARK sensors in the field experiment.
- The IMIS software with Russian language outputs will be developed.

Section I.

A. Research Objectives.

The aim of the program is to introduce a pilot Irrigation Management Information Service, similar to the Israeli one, adapted to Kyrghyz conditions, to fill the void in knowledge support generated by the agrarian reform.

Specific objectives of the program are:

1. Test and validate the scheduling algorithms and calibration parameters, against actual water use of main field crops.
2. Create a pilot IMIS, introduce it to the new extension organs, and analyze the response of the farmers.
3. Evaluate the efficiency of the hourly calculated, day-light time summed, modified Penman algorithm, compared with the new FAO version of the Penman-Monteith formula

B. Research Accomplishments.

B.1 First stage: Equipment installation and testing.

In February- March 2002, a possibility of telecommunication between data logger in the field and PC in office was tested in Kyrghyzstan using DC112 Modem (Campbell Scientific, Inc., CCITT V.22 Compatible), SLN 3032A Cellular Connection and Motorola GP68 standard cellular telephone unit. Modem US Robotics 14.4 was used as PC modem. Dr. J. Tsipris participated in the installation of lysimeters and weather station and partly in operation of the field experiment at April 2002. During this period three weighing lysimeters and automatic weather station were assembled and tested.

B.2 Field experiments - Materials and Methods

An experiment was initiated at Kant Machine Irrigation Station (MIS) near Bishkek, in the Chu Valley, Kyrghyzstan. Area of experimental plot was 0.96 ha (120 x 80 m), scheme in Fig. 1. Three lysimeters were installed and filled with soil on 3-5/04 (see Table 1). Each lysimeter bin was 0.65 m in diameter and 0.8 m deep container. The bottom 5 cm of container was filled with gravel, so the effective soil volume was $3.14 * 0.325^2 * 0.75 = 0.249\ m^3$. The total weight of the lysimeter filled with soil was near 500 kg. The lysimeter bin was hanged free inside of the outer container (Fig. 2) and leaned on three TEDEA 3411 Shear Beam Load Cells. The load cell's nominal full-scale output is 3 mV/V excitation. The three load cells were connected in parallel to a Campbell Scientific 23X datalogger. Outputs were recorded every 6 seconds and processed through a 1/10 low pass filter to reduce environmental noise, and to increase the resolution. A pit was excavated to accommodate the outer container, and it was laid on four concrete slabs. The lysimeter was filled with previously (20/03) excavated soil (taking in account three layer of soil profile: 0-25 cm, 25-55 cm and 55-90 cm.). Filling procedure included of weighing every bucket of soil, and summing the refill weight in increments (taken from the bottom) of 5 cm (gravel), 20 cm (soil from lower layer), 30 cm (soil from middle layer) and 25 cm of upper soil layer.

Figure 1. Experimental site at Kant Machine Irrigation Station(MIS), Kyrghyzstan

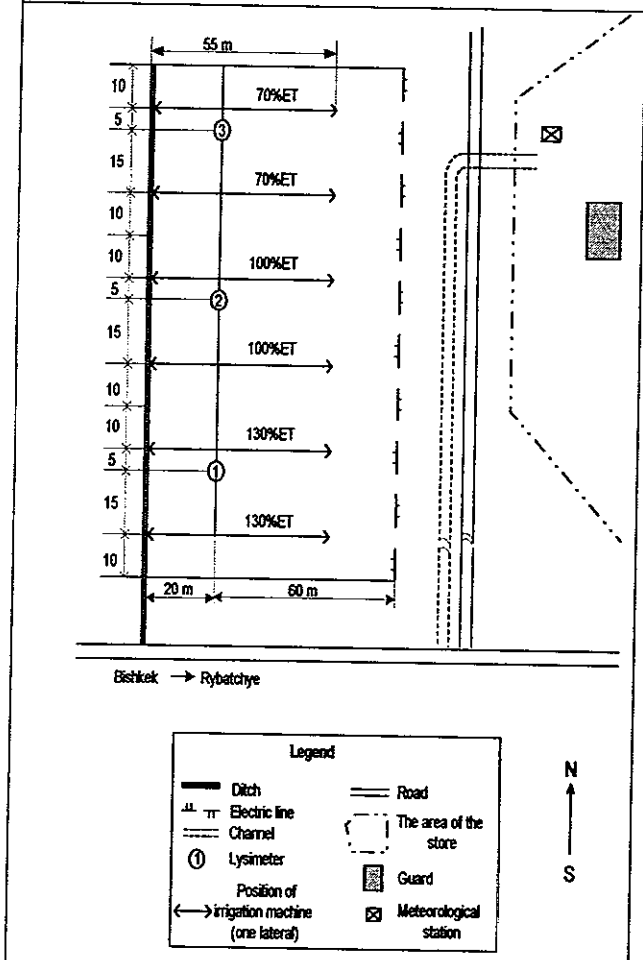
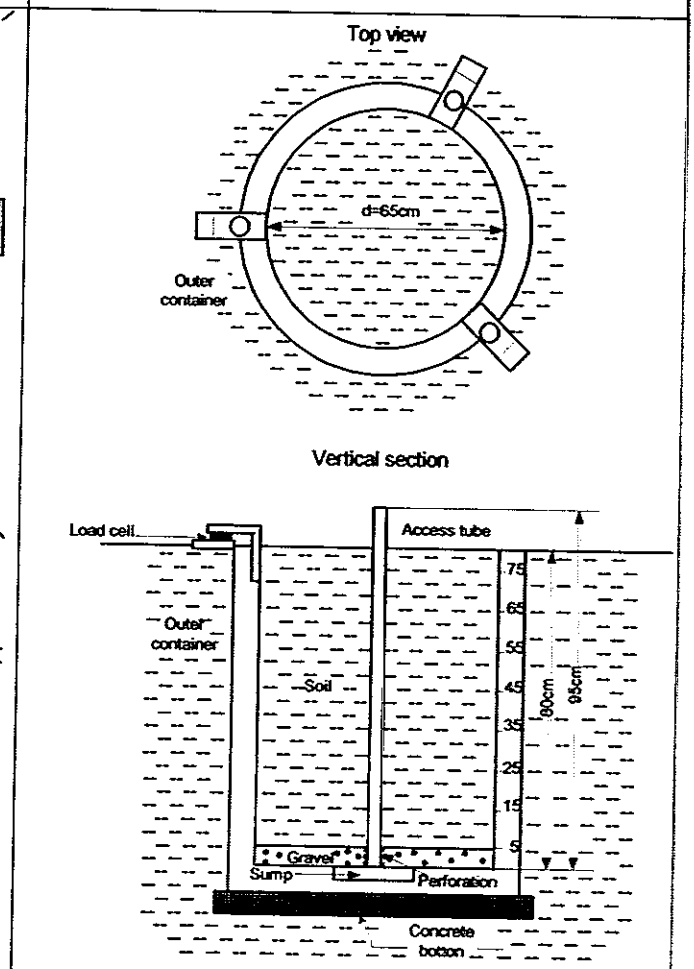


Figure 2. Design of weighing lysimeter



The datalogger millivolt readings were recorded simultaneously to enable weight calibration (Table 1).

The weight W of lysimeter is a linear function of the voltage output V from the load cell:

$W = \mathbf{a} * V + \mathbf{b}$,

where **a** and **b** – coefficients to be defined in the process of calibration.

Initial lysimeter calibration from filling data (Figure 3) shows excellent linear relation and very good linear fit. Since the surface area of the lysimeter is 0.3318 m², so 1 mm of rainfall or evaporation results in a 0.3318 kg change in mass. The maximum daily change in water content caused of ET was expected as 6 mm, so the marginal calibration range was 2 kg, for full lysimeters. A two point calibration (filled lysimeter – filled lysimeter+2 Kg) was performed again on 9/04 on the full and re-watered lysimeters (Figure 4), and these calibrations were used afterwards.

Table 1: Lysimeters soil filling at MIS, 3-5/04/2002.

Lysimeter #1				
layer	**gravel**	**5-25**	**25-55**	**55-80**
added soil, kg	33.18	87.58	145.28	95.88
accumulated soil, kg	33.18	120.76	266.04	361.92
Data logger reading mV	0.25340	0.44519	0.76407	0.97448

Lysimeter #2	0.18187 was the data logger reading when lysimeter was empty			
Layer	**gravel**	**5-25**	**25-55**	**55-80**
added soil, kg	33.32	82.50	129.20	109.34
accumulated soil, kg	33.32	115.82	245.02	354.36
Data logger reading mV	0.25593	0.43648	0.71710	0.95635

Lysimeter #3	0.17474 was the data logger reading when lysimeter was empty			
Layer	**gravel**	**5-25**	**25-55**	**55-80**
added soil, kg	32.70	79.40	127.16	111.12
accumulated soil, kg	32.70	112.10	239.26	350.38
Data logger reading mV	0.24708	0.42082	0.69970	0.94271

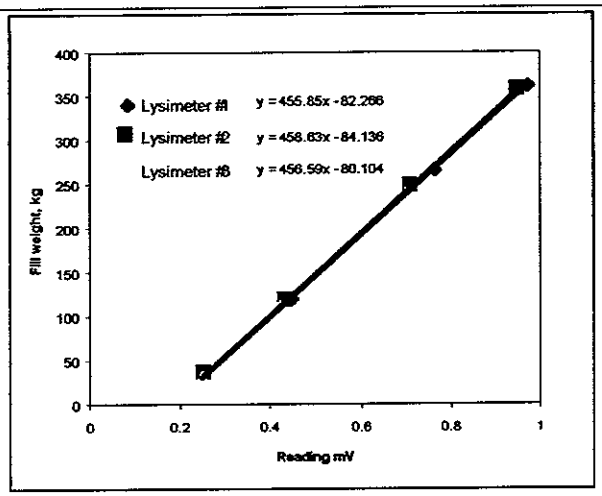


Figure 3 Initial calibration of lysimeters

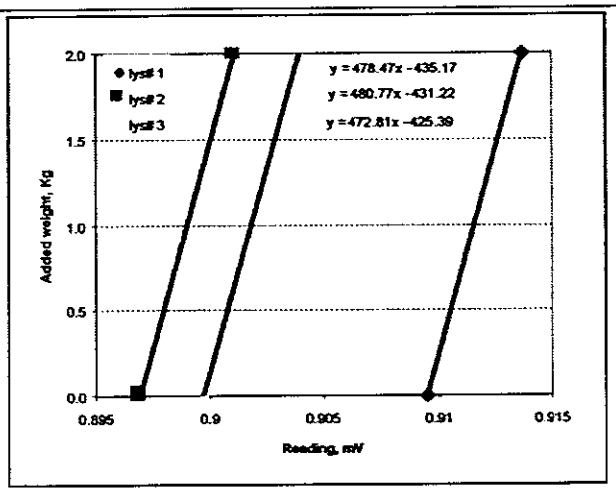


Figure 4. Fine calibration of filled lysimeters

Access tubes were inserted in the center of each lysimeter and were used for drainage water evacuation. At filling the lysimeters, soil water content was determined using sampling and drying; bulk density of natural soil was obtained by core sampler of 250 cm^3 from soil profile of lysimeter location. Soil sampling and determination of initial soil water content was done on 3-5/04 (Tab. 2). The filling volume and the soil weight were recorded simultaneously during the filling procedure.

When the experiment was started, the volumetric water content of the soil was approximately 0.25 g/cm^3 in 0-55 cm layer of soil in each lysimeter and it was taken as the reference for irrigation scheduling. Irrigation was estimated according to potential evapotranspiration (PET) with up and down bracketing (70%, 100% and 130% of PET, three treatments).

Table 2. Bulk density and initial soil water content of the lysimeters before watering.

## of lysimeter	Bulk density, g/cm^3			Volumetric soil water content, g/cm^3		
layer	*0-20 cm*	*20-50 cm*	*50-80 cm*	*0-25 cm*	*25-55 cm*	*55-75 cm*
1	1.35	1.33	1.39	0.23	0.25	0.37
2	1.36	1.39	1.45	0.24	0.26	0.38
3	1.41	1.49	1.42	0.29	0.26	0.30

Irrigation amounts were calculated from hourly meteorological data by Penman formula:

$$ET = \gamma/(\gamma+\Delta)*R_n*3600/latent + VPD*\Delta/(\gamma+\Delta)*f(w), \qquad (1)$$

where:

ET	potential evapotranspiration, mm/hour;
R_n	net radiation, W/m^2, calculated from global radiation;
VPD	vapor pressure deficit (kPa);
γ	psychrometric constant (kPa/°C);
Δ	slope of saturated vapor pressure curve (kPa/°C);
w	wind speed (m/s);j
f(w)	wind function, 0.034+0.054*w for daytime or 0.125+0.382*w for night;
latent	specific vaporization heat (J/kg).

To measure the necessary variables for ET calculation (radiation, air temperature, relative humidity and wind speed), the Campbell Scientific CR23 automatic weather station was assembled and deployed near the experimental farm. Telecommunication set was consisted DC112 Modem (Campbell Scientific, Inc., CCITT V.22 Compatible), SLN 3032A Cellular Connection and Motorola GP68 standard cellular telephone unit. Modem US Robotics 14.4 was used as PC modem. Weather station was supplied with the following sensors:

LI200X Pyranometer
CS500 Temperature and Relative Humidity Probe
RM Young 03001 Wind Sentry
TE525 Tipping Bucket Rain Gage.

Data processing was done on a PC, with Campbell PC208W data processing software and additional software and routines developed by the Kyrghyz team under the program while staying in Israel.

On 9/04 spring wheat was sowed in the field and lysimeters, and 5 liter of water was immediately added to each lysimeter as irrigation. The period from 17/04 till 17/05 of 2002 was abnormally wet (228 mm of rain in comparison with many years average of 136 mm). It was even necessary to drain 5 liter of water from lysimeter #3 on 16/05. So, the first irrigation was performed only on 3/06. Field and lysimeter irrigation was intended using a

traveling lateral sprinkler system but it was not ready on time. To prevent damage to the crop in the lysimeters, it was decided to add water to the lysimeters until the irrigation system will be repaired.

Irrigation scheduling of lysimeters is shown in table 3 and the experimental plots in table 4

Table 3. Irrigation scheduling in lysimeters. MIS, Kyrghyzstan, 2002

Date	Irrigation, liter / mm(*)			Comments
	Lys #1 (130% ET)	Lys #2 (100% ET)	Lys #3 (70% ET)	
03/06	4 / 12	4 / 12	3 / 9	By hand
19/06	6 / 18	6 / 18	6 / 18	By hand
21/06	18 / 54	18 / 54	19 / 57	By hand
25/06	6 / 18	11 / 33	7.5 / 22.5	By hand
26/06	15 / 45	16 / 48	12 / 36	Irrigation system(**)
28/06	6 / 18			By hand
02/07	covered	covered	covered	Irrigation system
03/07	14 / 42	14 / 42	14 / 42	By hand
09/07	21 / 63	16 / 48	11 / 33	Irrigation system

(*) mm calculated on basis of the inner drum surface area from hand added water volume.
(**) liters added calculated on basis of the inner drum surface area from irrigation depth.

On 3/06 and 19/06, only small amounts were added in anticipation for machine irrigation, on 21/06 and 25/06 irrigation was scheduled to reach 0.8 of field capacity (FC), defined as full refill of the lysimeters to the highest drained water content after filling. Additional irrigation on 03/07 was added to reach near FC.

Table 4. Irrigation scheduling in field plots near lysimeters. MIS, Kyrghyzstan, 2002

Date	Irrigation, mm			Comments
	130% ET	100% ET	70% ET	
26/06	45	48	36	Treatment 130% was under irrigated
02/07	48	36	24	
09/07	63	48	33	130% In two steps

The last irrigation was performed on 9/07, and the crop was harvested – on 19/07/2002

B.3 Field experiments - Results and Discussion.

Meteorological Measurements.

The weather station operated well and properly from its installation to the end of the season. A brief description of the representative meteorological conditions in the experimental site from 17/04 to 17/072002 is given in figures 3,4 and 5. Average daily temperatures were between 8° C and 30° C. The stable average temperature transition of the 15° C line was observed on 22/05; from this date, minimum air temperature was greater than 10° C, and maximum varied between 20° C and 38° C. Global radiation was approximately 25-28 MJ/m^2 in June-July. Radiation drops below 25 MJ/m^2 indicate partly cloudy days. RH minimum was below 50% in June-July. The period from 17/04 till 17/05 of 2002 was

abnormally wet (228 mm of rain in comparison with many years average of 136 mm).

Figure 3. Average, Min and Max Temperatures at MIS, Kyrghyzstan, 2002.

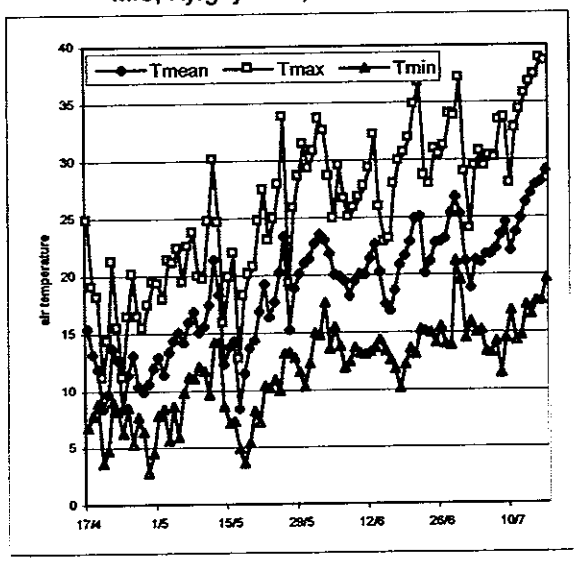
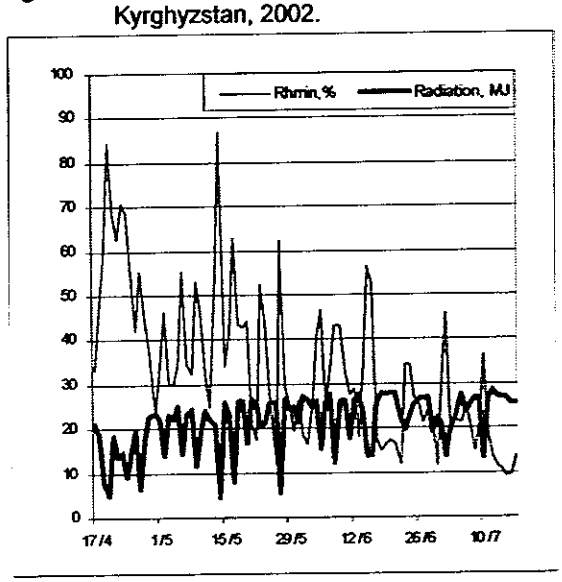


Figure 4. Global Radiation and Min RH at MIS, Kyrghyzstan, 2002.



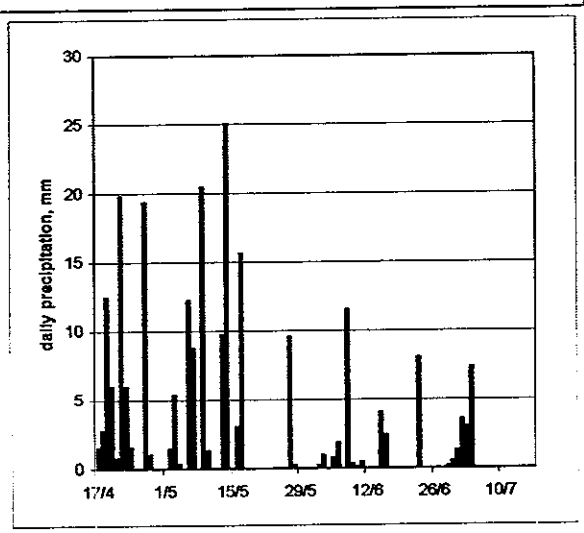


Figure 5. Daily Precipitation at MIS, Kyrghyzstan, 2002.

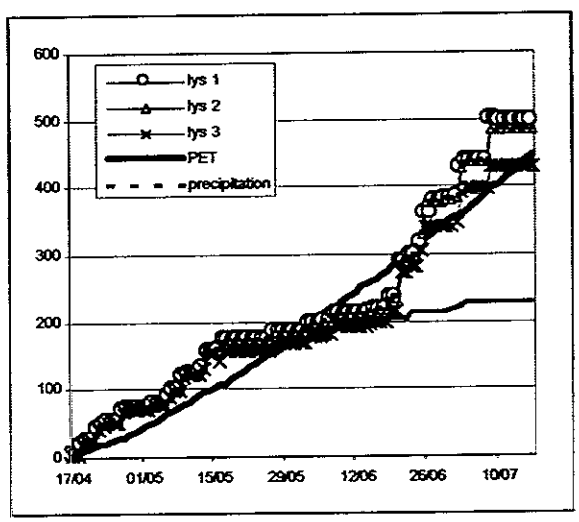


Figure 6. Daylight cumulative PET and irrigation + precipitation for lysimeters (ET based on nominal diameter).

Evapotranspiration from lysimeters

Potential daytime ET for fully covered, well watered reference crop calculated by formula (1) ranged between 3.2 to 7.2 mm per day (as opposite to 6.7 – 8.4 mm in Israel) considering only days with rain less than 2 mm. Averaged value of PET was 6.05 mm. Abnormal rains dominated the water regime of lysimeters till 17/05 (Fig. 6), so the first irrigation was given on 3/06. The amount of cumulative precipitation and PET were the same on 3/06; after that the lysimeters were under irrigated until 26/06. The ET/irrigation depth to lysimeter weight transition and *vice versa* was performed during the experiment on nominal surface area basis of 0.3318 m^2 of the inner container, represented in Fig 6.

Figure 7.Hourly calculated PET and actual ET measured in lysimeters. Sunny day 1/6

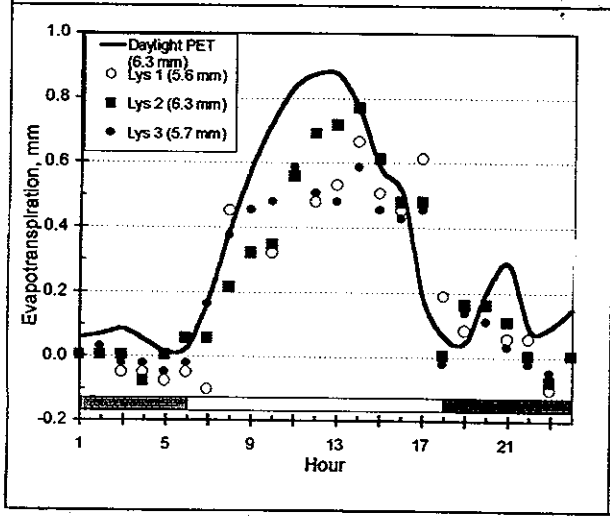
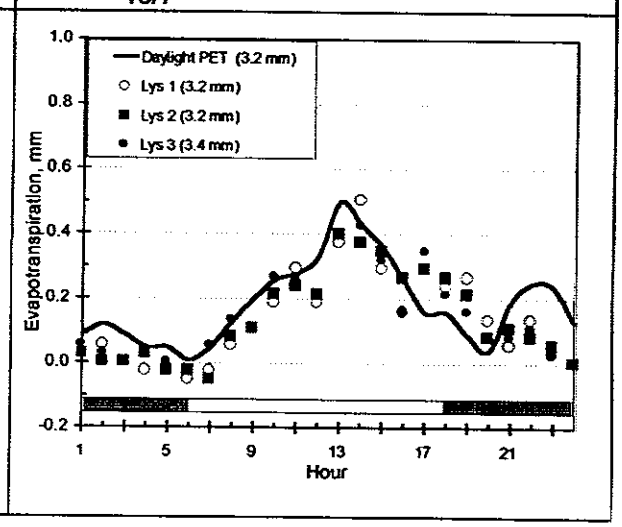


Figure 8. Hourly calculated PET and actual ET measured in lysimeters. Cloudy day 10/7



space for transpiration. Recalculating backwards the water balance in an iterative procedure, we found that the effective diameter was 0.70 m, about half the gap between the inner and the outer containers. This would be the default air and light interception space of the inner drum in case of an even and uniform inner and outer canopy.

The effective transpiration area of a small lysimeter is a key factor in weight loss to ET transition. In the first year we measured weekly the actual coverage diameter of a very dense canopy, relatively to the surrounding cover. Even this year no gaps were along the wheat rows, still the crop was quite sparse, thus effectively using some of the surrounding air

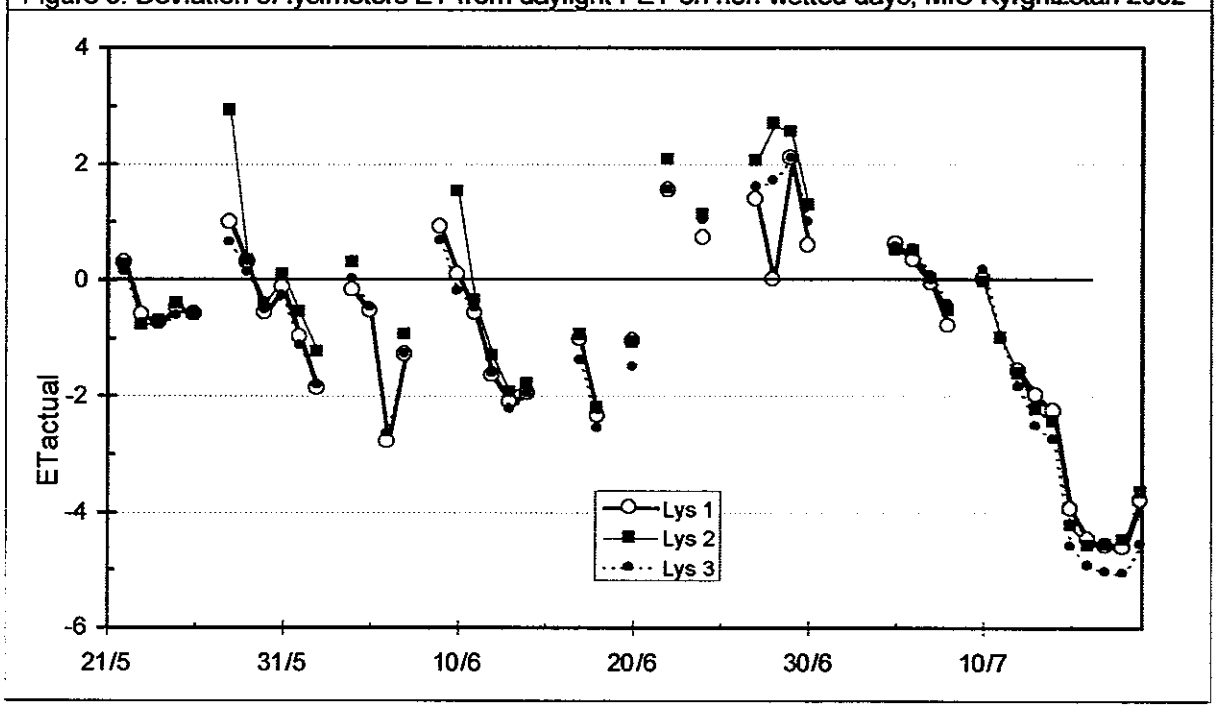
Hourly measured values of ET of three lysimeters **for a sunny day** are shown in Fig.7 with corresponding values of calculated PET on 1/06/2002. ET from these lysimeters determined by change in weight was quite close, 5.6, 5.7 and 6.3 mm versus 6.3 mm calculated daylight PET. The time course of lysimeters ET lags behind PET, something we observed also the year before, but a less extent. Even daily totals of Actual ET and daylight PET are close, the less exact overlap of the ET from weight loss over calculated PET demonstrates from one side the approximate nature of the use of calculated PET for actual ET evaluation, and the difficulties of measurement of actual ET by lysimetry from the other side.

Hourly measured values of ET of three lysimeters **for cloudy day** are shown in Fig.8 with corresponding values of calculated PET on 10/07/2002, one day after irrigation. This time the PET and actual ET values are almost identical and the time course overlap better, however the time lag still exist.

In order to compare lysimeter ET with daylight PET, a new dataset was constructed from May 22 and on, since the heavy rain period was irrelevant to the experiment. Days of rain and irrigation were excluded. In figure 9 is evident that ET rates are usually above PET immediately after irrigation, and decline with the time following irrigation. There might be several explanations to this quite natural behavior, but our experimental data are insufficient to go beyond speculations. Also after the 10/7/2002 ET rates decline sharply because of

documented senescence and deterioration of the crop, so those dates were excluded from further comparisons.

Figure 9. Deviation of lysimeters ET from daylight PET on non-wetted days, MIS Kyrghizstan 2002



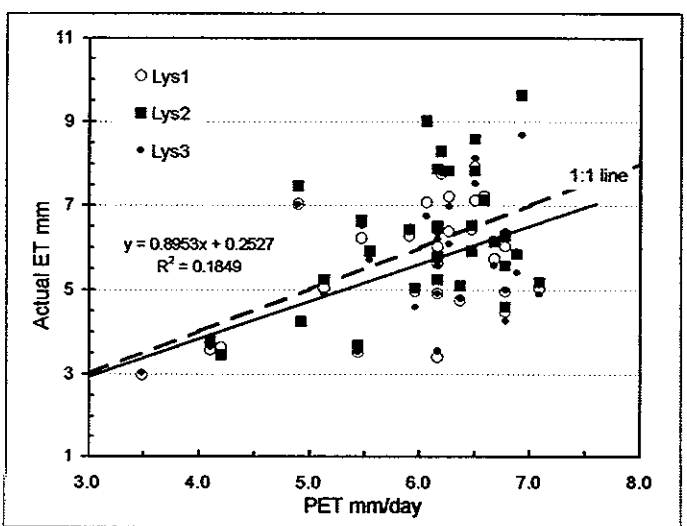


Figure 10. Relation between actual ET vs. PET. 1:1 line included as reference.

Regression analysis of the data (Fig, 10, data from 8/7 and on excluded) shows the sizable scatter around the1:1 reference line.

Still, considering the cumulative sums for the days included in the analysis (Table 5.), and the time course of the deviations show quite good agreement, indicating the usability of daylight PET for irrigation scheduling in this intermittent type irrigation over larger time intervals.

Table 5. Cumulative lysimeters weight loss and PET (transformed by effective diameter).

	PET	Lys 1	Lys 2	Lys 3
Total kg loss	70.3	67.2	71.1	66.9
Relative	1.00	0.96	1.01	0.95

Soil water content

Soil water content and field capacity in the lysimeters was determined from dry soil weight (calculated from water content samples at sampling time) and fully wetted weight after irrigation and free drainage. Time course of field capacity in the relevant period is presented in Figure 11. The lysimeters was unintentionally allowed to dry down to 50% FC , before the Irrigation machine was repaired, and only from June 20 and on was adequately irrigated. Differential irrigation treatments became effective only late in the season.

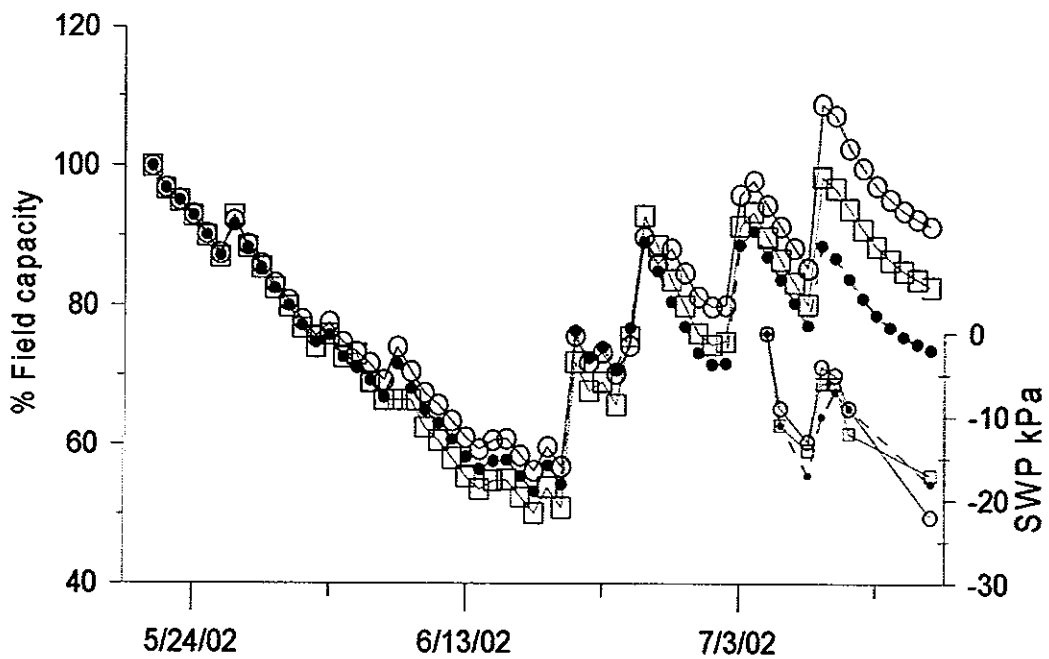


Figure 11. Relative water content of lysimeters and SWP at adjacent monitoring points in the field at 0.3 m depth.

Soil water potential.

Soil water potential (SWP) was measured by two granular matrix soil moisture sensors ("Watermark", Irrometer Co., Riverside, CA) installed at 30 and 70-cm depth in four repetitions for each irrigation treatment on 5/07/2002, quit at the end of the season.. The Watermarks were installed along the line near the lysimeters at distance of 3; 6; 9 and 12 m from each one in the field. One sensor was installed in lysimeter #2 (100% ET) at 10-cm depth. Soil water potentials measured at 0.3 m depth are shown also in Figure 11. The two irrigation events are evident in the SWP monitoring points in the field in parallel to the FC trends in the lysimeters.

The sensors at 0.7 m remained at very high values, indicating saturated soil at that depth.

Vegetative observations and yields.

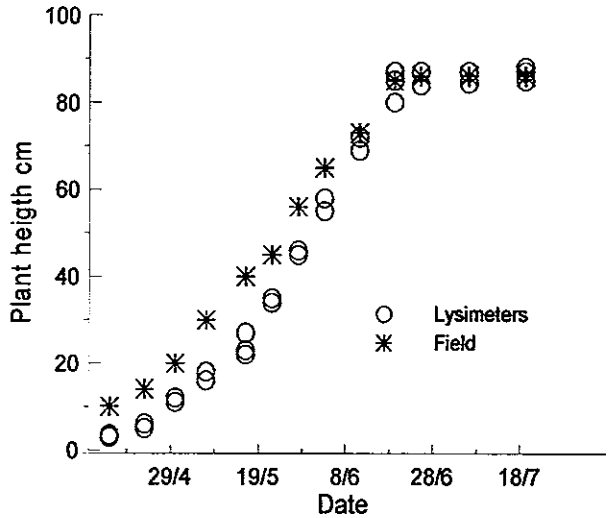


Figure 12. Plant height measurements, MIS, Kyrghyzstan 2002

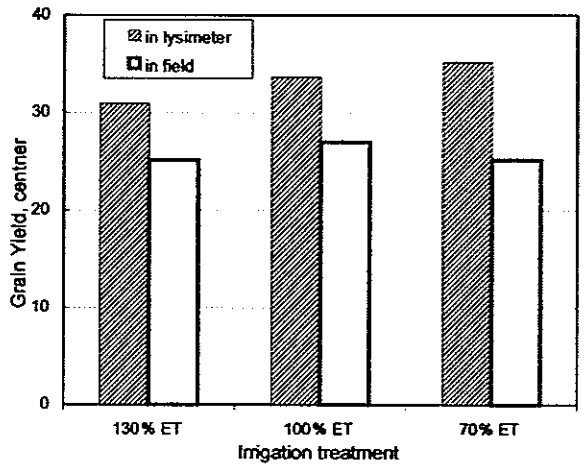


Figure 13. Grain yields in the field an the lysimeters MIS, Kyrghyzstan 2002.

Plant heights were monitored from germination, to evaluate crop cover. At May 21, when the substantial lysimetry was started, the canopy height reached about 0.3 m and continued to grow rapidly. That allows considering near full crop cover for PET evaluation. Only little difference was observed between field and lysimeters grown wheat canopy height.

Grain yields responded negatively to increase in irrigation in the lysimeters, however in light of the late and small effectiveness of the treatments in soil water content, and no replications, it seems to be an incidental effect. Field yields, harvested in four replicates of 4 sq.m. did not differ significantly and were not affected by irrigation treatments.

Data handling and report generation software.

The software components for weather stations remote data acquisition, storage and processing were developed and tested during the stay of Dr. Litvak in MIGAL in 2001. They were used along the field experiment for irrigation scheduling and lysimeter performance evaluation on a daily routine in Kyrghyzstan. Final formats for irrigation scheduling information management, with Russian language outputs will be developed next season.

C. Scientific impact of collaboration:

It is too early to evaluate the impacts, however the intentions are as follows:

1. Initial impact of the collaboration is the mutual familiarization with scientific abilities of both sides and proper definition of objectives and goals to achieve though the project.

2. Introduction of state of the art irrigation scheduling methods for field crops to Kyrghyz agronomy.

3. Verification of the meteorological ET estimation model under high altitude - intermittent rainy conditions.

D. Description of Project Impact

At this stage too early to evaluate impacts

E. Strengthening of Developing Country Institutions

- Scientist from the KSRII spent a period of knowledge exchange in MIGAL.
- The KSRII team was exposed to hands-on operation of advanced environmental and irrigation research equipment and learned to use it in real life situations at home.
- The KSRII was enriched with advanced equipment which is strengthening local research capabilities.
- In the last season the KSRII team gained experience in remote data collection and technology under local conditions.

F. Future Work

Work in 2003 will concentrate in Kyrghyzstan. The existing weather station and lysimeters assembled at MIS will be functioned to improve the results of 2002 with similar culture – winter wheat. Irrigation will be applied according to calculated daylight PET with up and down bracketing (70%, 100% and 130% of PET, three treatments in contrast to one in 2002) in field experiment and lysimeters using traveling lateral sprinkler system.

A second weather station will be installed at another large farm to extend the IMIS and to provide information to the surrounding farms. The automatic data acquisition, processing and distribution software, developed in collaboration with MIGAL will be implemented

SECTION II.

A. Managerial Issues

In April 2002, the meteorological station and lysimeters were installed under the supervision of Dr. Joseph Tsipris. The field experiment of 2002 was begun with the help of S.I.Ulitin, the chief hydro technician of the Kant Mashine Experimental Station.
As a result of breakage of the lateral sprinkler system, first irrigation in the field was produced later than it was needed; it was decided to add water to lysimeters by hand to prevent damage for plant.

Because the neutron probe procured in previous cooperative project (CA14-003) was found out of order, it was decided instead to use WATERMARK sensors (IRROMETER Company, Inc., USA) for soil moisture measurement, which were procured spring 2002 and were installed near the end of the experimental season.

As one of the consequences of this seasons work, the Ceptometer procured in CA14-003 was re-commissioned and will be used in 2003.

B. Budget

In order to enable smooth and fast requisitions of Kyrghyz equipment, $27,600 - were transferred from the Kyrghyz budget to MIGAL. With this sum three lysimeters, accompanying equipment and two weather stations (Campbell, USA) were bought, assembled and tested at MIGAL and subsequently shipped to the KSRII. All the other budget items were spent according to the original workplan. The new instructions of quarterly expense reports and advance disbursement were implemented.

Financial reports were submitted periodically by MIGAL GM, Mr. J. Arzi.

C. Special concerns

No special concerns arise from beginning of the project.

D. Collaboration, Travel and Training

Israeli PI's: Trip to Bishkek for 7 days (September 4 - 13 2001) J. Tsipris.
Achievements: Selection of experimental site and program development.

Dr. J. Tsipris visited Kyrghyzstan in April 2002 for ten days;

Achievements: During this period he assisted in the installation of the weather station and lysimeters.

All the correspondence and ongoing technical and scientific support is carried out by Dr.Tsipris remotely from MIGAL.

Kyrghyz PI's and team: Dr. R. Litvak Ms E. Nemaltseva and Ms. I. Poddubnaya spent 6 weeks in summer 2001 at MIGAL for knowledge exchange and training.

Achievements: Update of knowledge in Agro meteorology and ET estimation methods, IMS data acquisition, processing and reporting via telecommunication and media. Hands on training in lysimeter construction and operation, plant and soil measurements, irrigation scheduling and IMS data handling.

The Kyrghyz staff of the project is now complete, consisting of Dr. R. Litvak (co-PI), and research assistants E. Nemaltzeva and I. Poddubnaya. The permanent staff of the Kant Machine Experimental Station provides technical assistance on site.

E-mail: An electronic mail link was established through the account of Dr. R. Litvak in the KSRII. This link enables fast exchange of written material in all the common formats.

Fax and phone contacts: Phone and fax communications between Kiryat-Shmona and Bishkek are simple and straight, especially thanks to the Russian fluency of Dr. Tsipris.