## *1.7. AGRICULTURAL CROP CAPACITY CHANGE DEPENDENCE ON WATER CONSUMPTION*

### 1.7.1. Introduction[*]

With regard to growth of ecological requirements and change of soil-hydrogeological and water-meliorative processes, caused by the water resources available shortage and exhaustion as well as under effect of antropogenic measures on environmental objects more restrictions of limited water use is required. From this point of view agricultural organizations activity, especially under preparation of water use schedules and reclamation measures on lands desalinization and their realization, should be supported by results of field research for agricultural crops biological demands, which differ depending on natural-economic and climatic conditions, sort and formation of dry mass (crop capacity) of agricultural crops.

It is known that the water necessary to cover plants water consumption (total evaporation and transpiration) in arid zone can be recharged only at the expense of natural sources (precipitation, overflow from groundwater). This water balance shortage is covered in artificial way – water supply to fields through agricultural crops irrigation which quantitative value constitutes plants biological demands for irrigation water.

Agricultural crops water consumption as well as plants requirement for water depend on many factors: climatic, hydrogeological-soil-meliorative conditions: soil fertility and soils-water feeding regime, agricultural crops verities and agro- and water-meliorative measures and other circumstances.

Numerous researches of agricultural crops water consumption, biological norms and irrigation regime during long time as on Central Asia area, so abroad, fixed certain dependence (conformities to natural laws) of their biomass and crop capacity change on water consumption. So different forms of crop yield relation with precipitation, soil moisture stock, irrigation norm and evaporation and agricultural crops transpiration were studied. These forms represent determination of dependence between crop yield and water balance positive components.

At the present moment there are different approaches to describe crop dependence on water consumption, of which determination of change (increase and reduction) of crop yield depending on water consumption growth is widely spread. By means of these researches it was determined for all agricultural crops dry biomass increase proportionally to water consumption growth and for majority of clean filled crops. Crop yield is connected proportionally with dry mass. Exception is for some industrial crops, in particular, cotton (dr. 2.1-2.6). The most wide-scaled researches of relation between crop yield and water consumption were conducted on wheat and maize. Equation determined relation between of crop yield and water consumption is represented in table 2.1.

This table shows that relation between yield of wheat, maize and even alfalfa and water consumption has linear character. Damage coefficient **K** is defined on equation of such type as

$$\mathbf{1 - Y @ K_1 [1 - (И_c/И_{опт}) ]} \quad (3.1) \quad \text{or} \quad \mathbf{1 - Y = K_2 [1 - (T_2/T_0) ]} \quad (3.2)$$

for wheat it changes within 0.92-1.7. However for majority of regions its value is equal to 1.0-1.2.

In above equations:

[*] Under preparation 2.1. V.Nasonov, Ph.D. materials were used

$$\mathbf{Y = Y/Y_0} \qquad\qquad \mathbf{И = И_c/И_{опт}} \qquad (3.3)$$

where: **Y** – actual crop yield; $\mathbf{Y_0}$ – potential crop yield;
$\mathbf{T_2}$ – transpiration corresponding to actual yield;
$\mathbf{T_0}$ – maximum transpiration corresponding to potential crop capacity;
$\mathbf{T_{opt}}$ – optimal transpiration;
$\mathbf{K_1}$ and $\mathbf{K_2}$ – sensibility coefficients.

According to FAO UNESCO damage coefficient **K** (crop yield reduction because of water consumption lack) under maize biomass formation is equal to 1.1-1.25, and for grain – 1.28-1.48. Damage coefficient for alfalfa according to experimental data 1.1 for Volga river basin conditions and 1.2 – for Kzyl-Orda oblast Toguzken massif conditions. Along with damage coefficient value for hydromorphous soil conditions is less than for authomorphous soils.

It worth to note that R.Gorbacheva determined non-linear relation between maize crop yield and water availability (water consumption), described by parabola (dr. 2.7 and 2.8) and equation for Kyrgyzstan Chu valley conditions and Almaty oblast of Kazakhstan:

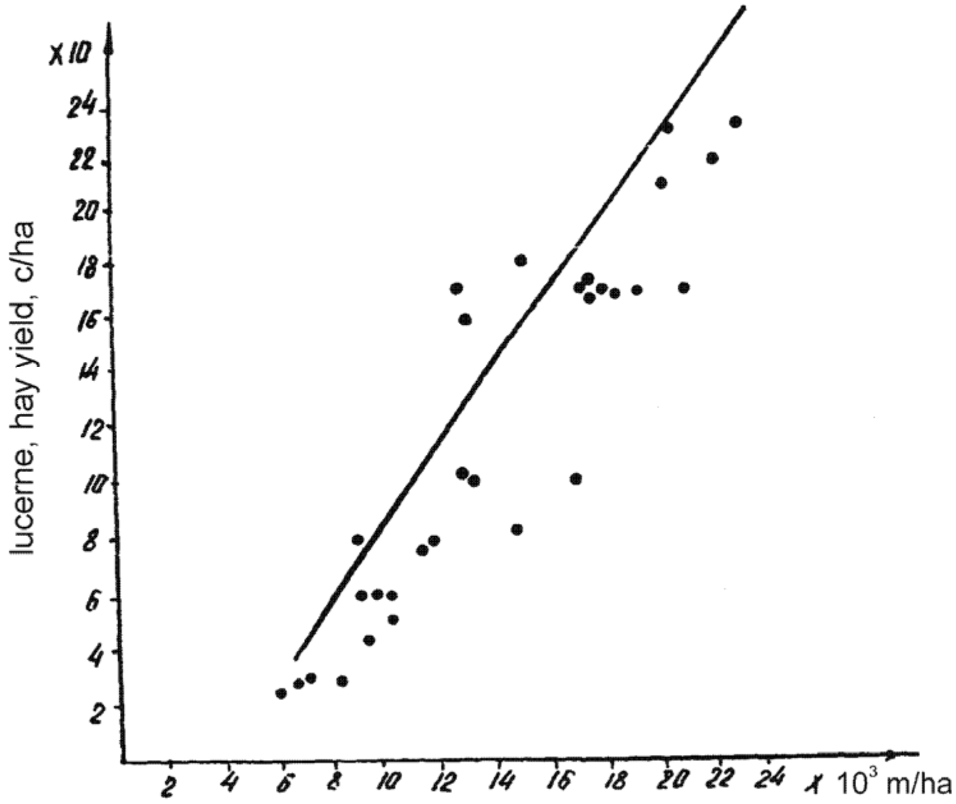
$$\mathbf{Y/Y_{max} = a\,(K - K_0)^n - b\,(K - K_0)^m} \qquad (3.4)$$

Table 2.1

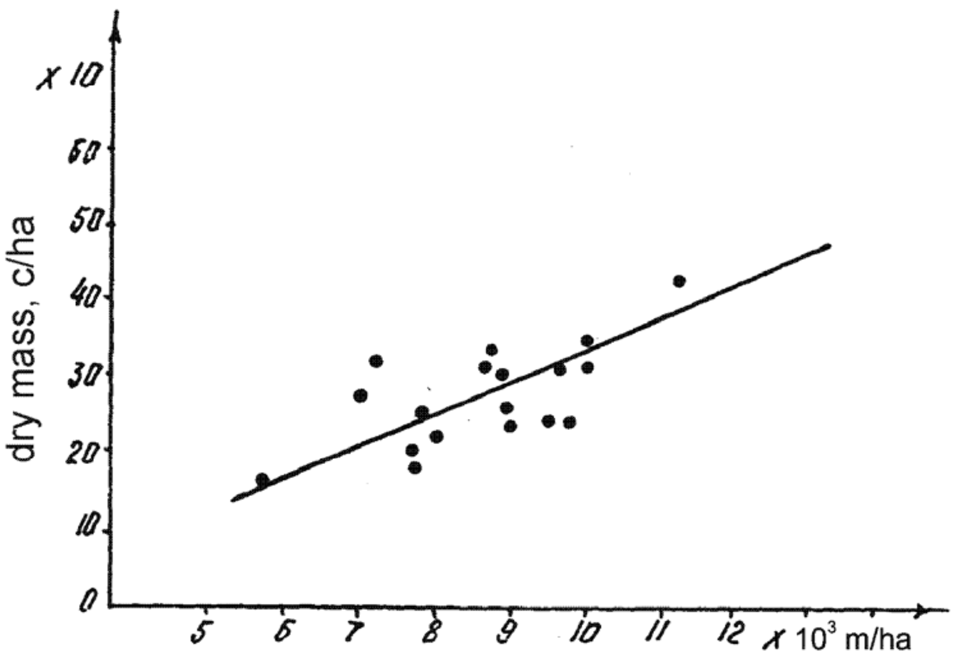
Damage coefficient K and yield dependability on water consumption

| Location | Agricultural crop | Regression equation | Maximum c/ha U | Maximum $m^3$/ha W | K | Research data |
|---|---|---|---|---|---|---|
| | | | **Wheat** | | | |
| South-East Kazakhstan | summer wheat | $U = 1.74W_c - 0.7$ | 40.5 | 3810 | 1.7 | V.Lim. /80/ |
| South Kazakhstan | summer wheat | $U = 1.36W_c - 0.36$ | 51.2 | 3385 | 1.36 | Sh.Begishev /17/ |
| Kulunda Steppe | summer wheat | $U = 0.98W - 0.16$ | 43 | 4700 | 0.98 | S.Verigo, P.Razumova /25/ |
| North Kazakhstan | summer wheat | $U = 1.31W - 0.4$ | 20 | 2500 | 1.3 | |
| USA (Texas) | summer wheat | $U = 1.16W_c - 0.1$ | 30.0 | 5500 | 1.16 | /163/ |
| | | | | | | S.Verigo, P.Razumova /25/ |
| Volga side - Orenburg | summer wheat | $U = 1.1W - 0.18$ | 44 | 4700 | 1.1 | |
| North Caucasus | winter wheat | $U = 1.18W - 0.2$ | 41 | 5500 | 1.18 | A.Uskov, L.Pyatygin /135/ |
| Novosibirsk | winter wheat | $U = 0.92W - 0.08$ | 33 | 3300 | 0.92 | A.Uskov, L.Pyatygin /135/ |
| Engels | winter wheat | $U = 0.99W - 0.88$ | 37.7 | 4714 | 1 | A.Uskov, L.Pyatygin /135/ |
| Lower Volga side | winter wheat | $U = 1.82W_c - 0.82$ | 80 | 4900 | 1.82 | P.Kruzhilin /73/ |
| | | | **Maize** | | | |
| South Kazakhstan | dry mass | $U = 1.07W_c - 0.1$ | 435.4 | 5845 | 1.07 | Sh.Begishev /17/ |
| Israel | dry mass | $U = 1.57W_c - 0.57$ | 218 | 5440 | 1.58 | /163/ |
| USA (Colorado) | grain | $U = 1.06W_c - 0.06$ | 144.2 | 7650 | 1.06 | /163/ |
| Israel | grain | $U = 2.06W_c - 0.04$ | 108 | 5440 | 2.06 | /163/ |
| USA (Florida) | grain | $U = 4.04W_c - 3.73$ | 51.9 | 4200 | | /163/ |
| | | | **Lucerne** | | | |
| South Kazakhstan | Lucerne for hay | $U = 1.17W - 0.19$ | - | - | 1.2 | /163/ |
| Lower Volga side | hay | $U = 1.1W - 0.12$ | 200 | 16000 | 1.1 | /163/ |

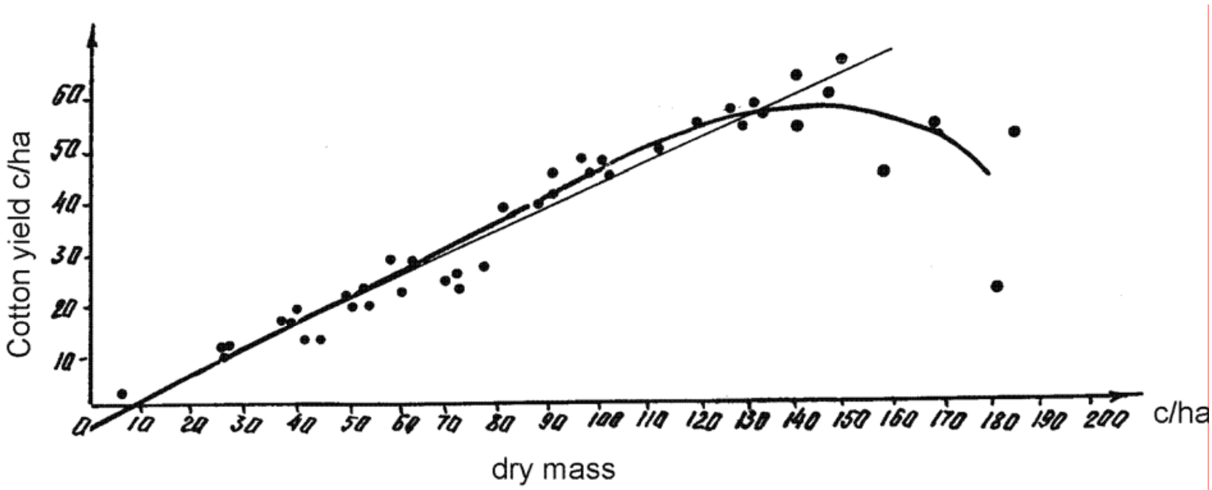
Note: K is damage coefficient from water consumption deficit.



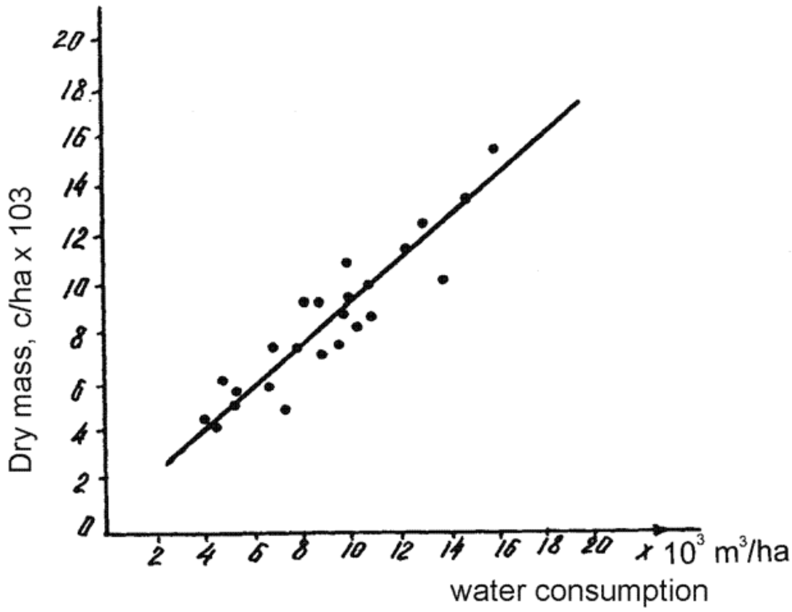

Dr.2.1. Lucerne yield versus total evaporation (after Sh. Begishev).



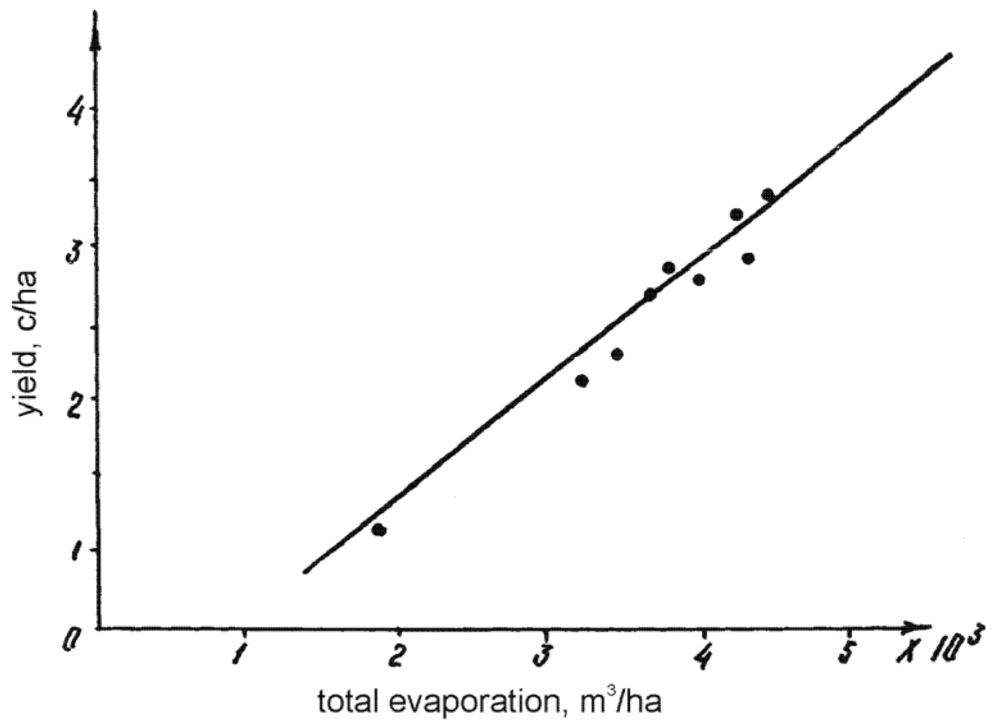

Dr. 2.2. Maize dry mass versus water consumption (Toguzteren massif) (after Sh. Begishev).



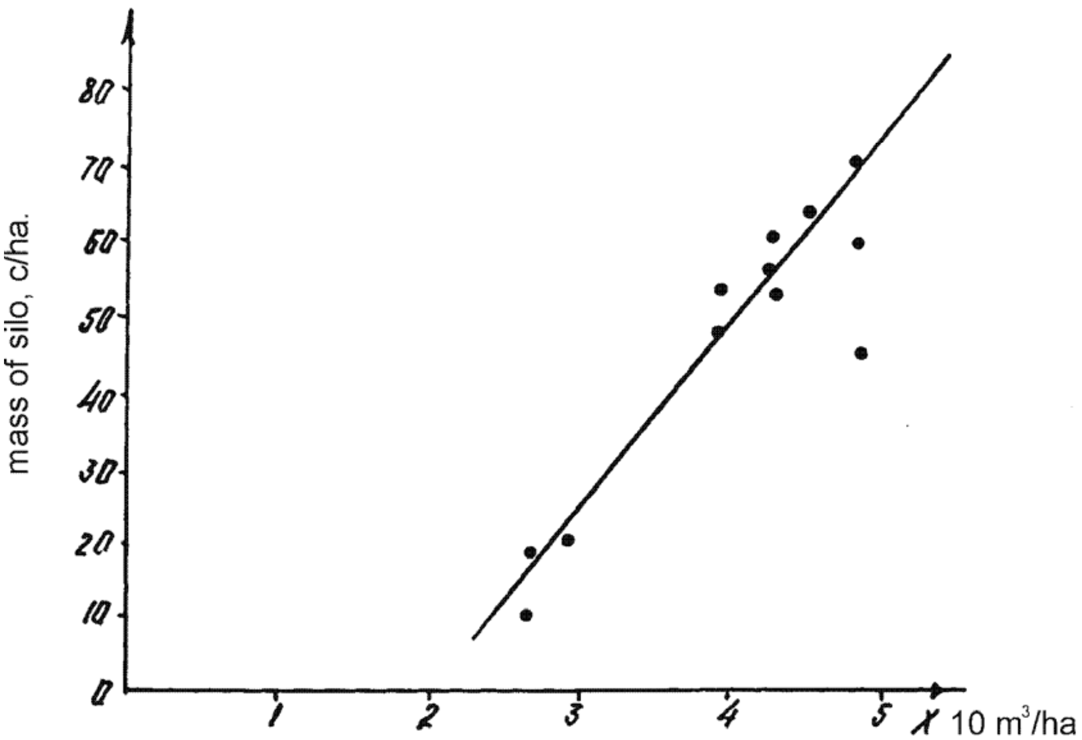

Dr.2.3. Cotton yield versus cotton dry mass (after N. Starov, S. Rizhov, M. Mednis, S. Yuldashev, V. Novikov).



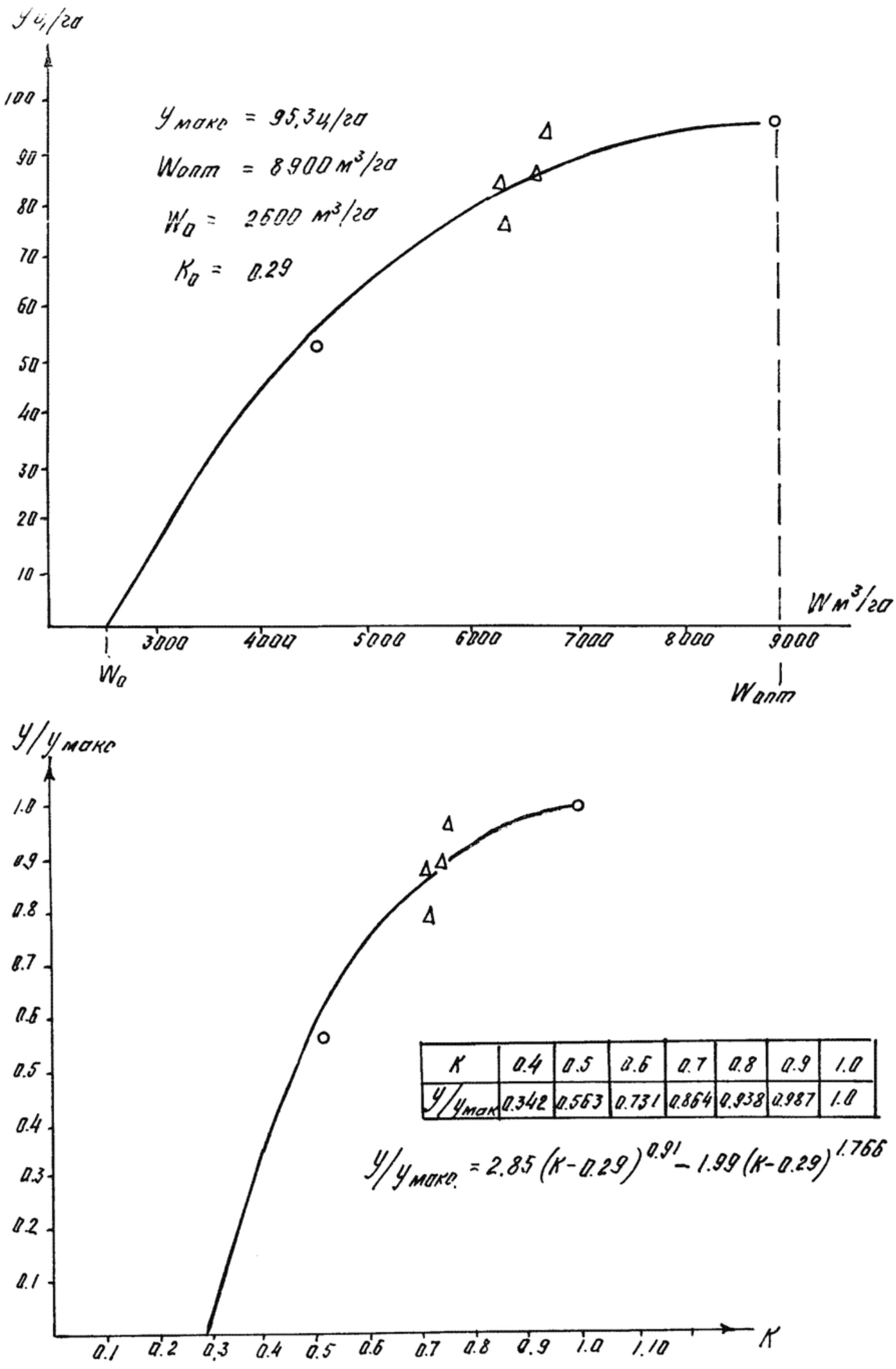

Dr. 2.4. Cotton dry mass yield versus water consumption (after N. Starov, S. Rizhov, L. Churyayev, E. Eremenko).




Dr.2.5. Soya been yield versus water consumption.



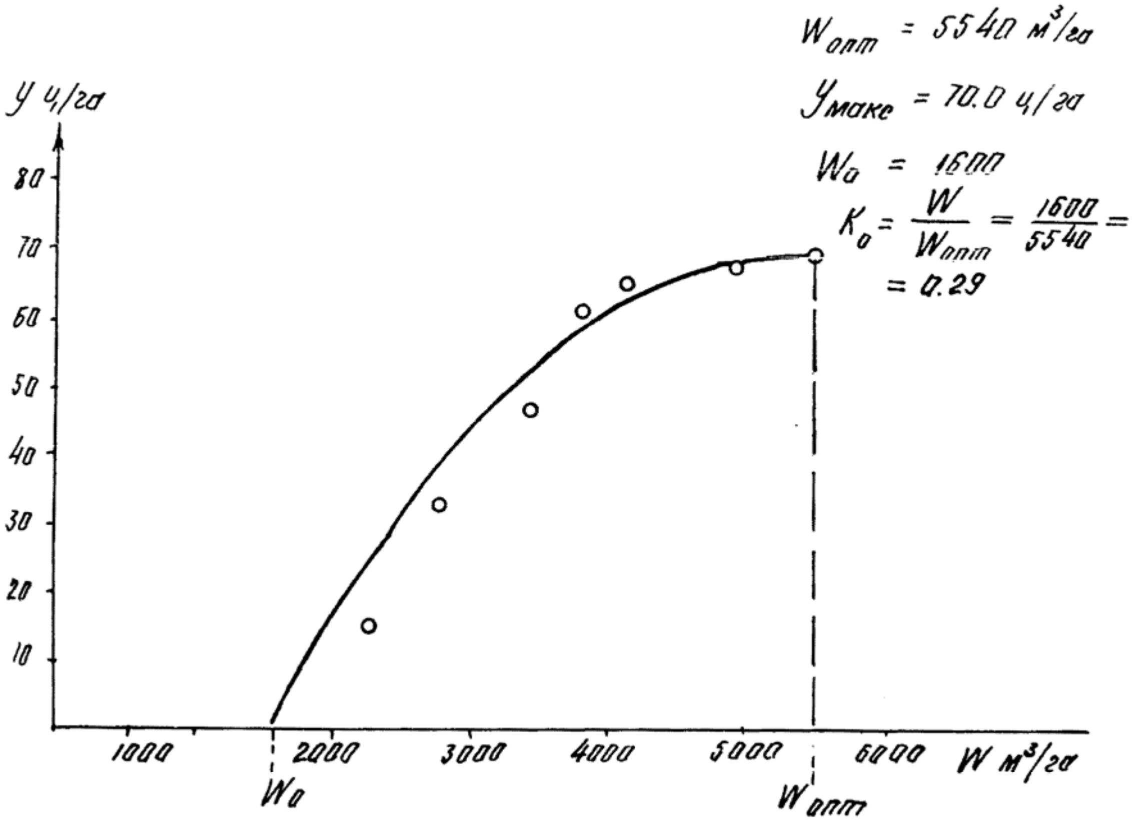

Dr. 2.6. Maize yield water consumption.

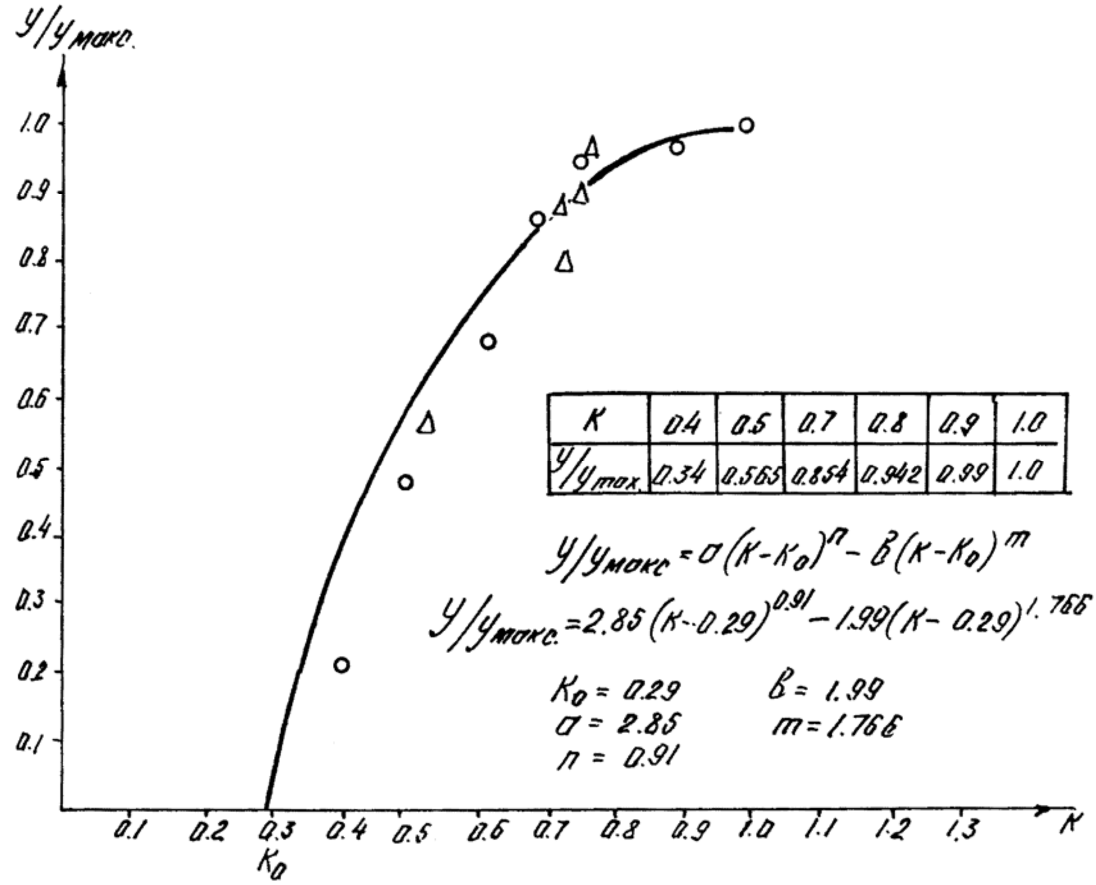



| K | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|
| У/Умак | 0.342 | 0.563 | 0.731 | 0.864 | 0.938 | 0.987 | 1.0 |

$$У/У_{макс.} = 2.85\,(K-0.29)^{0.91} - 1.99\,(K-0.29)^{1.766}$$

Dr. 2.7. Maize for grain yield versus water availability for Chu valley




| K | 0.4 | 0.5 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|
| $У/У_{max}$ | 0.34 | 0.565 | 0.854 | 0.942 | 0.99 | 1.0 |

$$У/У_{макс} = a(K-K_0)^n - в(K-K_0)^m$$

$$У/У_{макс.} = 2.85\,(K-0.29)^{0.91} - 1.99(K-0.29)^{1.766}$$

$K_0 = 0.29$ $в = 1.99$
$a = 2.85$ $m = 1.766$
$n = 0.91$

Dr. 2.8. Maize for grain yield versus water availability in wide diapason of its change in s/f "Karatal" Almaty, province (KazNIIVHdata)

In USA (S.Shih), Dagestan (Musayev), Rostov oblast, Russia (V.Kostyukov) in experiments on sorgo and grass irrigation defined linear dependence of crop yield versus water consumption for these crops (table 2.2). Damage coefficient changes because of water consumption lack within very wide limits 0.9-1.83 in USA conditions and 1.14-1.5 in Russia European part conditions.

Industrial crop – cotton – differs by other characteristics of reaction on water stress. For this crop under dry mass formation there is linear dependence between biomass and water consumption described by following equation (according to dr. 2.3):

$$\mathbf{Y_{dm} = 0.01\ И - 4.15} \qquad (3.5)$$

Equation (3.5) can be expressed through the damage, then it will be the following:

$$\mathbf{1 - Y = 1.03\ (1 - И)} \qquad (3.6)$$

At the same time there is non-linear relation between raw cotton crop yield and dry mass described by equation:

$$\mathbf{Y_0 = -\ 0.009\ Y^2_{dm} + 2.15\ Y_{dm} - 71.24} \qquad (3.7)$$

Similar relations were found for cotton abroad (S.Shih, USA) which differ only by coefficients.

### 1.7.2. Water consumption influence on agricultural crops capacity and irrigation water productivity

Data represented in Chapter 2.1 show close relation of agricultural crops capacity growth versus water consumption value. For majority of clean filled and forage crops specialists of Central Asia and abroad studied and determined linear dependence between crop capacity growth and water consumption, although there are some published works on maize where non-linear dependence between them is described. Regarding industrial crops, in particular cotton, this dependence is described by parabola equation of the second power – that is explained by faster coming of phases of "obesity", i. e. intensified growth of biomass and crop yield ripening backward, on this crop after certain water consumption value. Regarding other crops there was no this limit of crop capacity growth depending on water consumption. On the other hand, agricultural crops capacity is multi-factor process and therefore it is impossible to obtain regularity of its change not only for all crops, but for one specie of crops. Results of agricultural crops capacity change field researches on pilot projects of irrigation regime and water consumption norms are considered below.

#### 1.7.2.1. Changes of cotton crop capacity and irrigation water productivity in dependence on water consumption

Information of cotton crop capacity changes depending on water consumption norms is represented on 7 pilot projects, 3 of which were fulfilled in the Republic of Tadjikistan and 4 – in the Republic of Uzbekistan.

Table 2.2

Damage coefficient K dependability on sorgo-sudan grass water consumption with regard for its yield

| Location | Yield type | Regression equation in relative units | Maximum values yield c/ha | Maximum values water consumption $m^3$/ha | K | Research data |
|---|---|---|---|---|---|---|
| Dagestan | grain | U = 1.19W- 0.19 | 39.8 | 5252 | 1.14 | M.Musayev /89/ |
| Rostov province | green mass of sorgo-sudan gibride | U = 1.5W - 0.5 | 835 | 5762 | 1.5 | V.Kostyukov /70/ |
| USA (Nebraska) | grain | U = 1.1W- 0.1 | 72 | | 1.10 | /170/ |
| USA (California) | grain | U = 0.86W + 0.05 | 99.4 | 5870 | 0.9 | /170/ |
| USA (Colorado) | grain | U = 1.06W - 0.19 | 84.5 | 4290 | 1.06 | /170/ |
| USA (Alabama) | sudan grain, dry mass | U =1.87W + 0.17 | 139.2 | 120 | 1.83 | /170/ |

Plots of the Republic of Tadjikistan are situated on authomorphous non-saline soils. Of 4 pilot plots of the Republic of Uzbekistan – 3 ones are placed in conditions of half-automorphous soils, represented by saline grounds and 1 plot (NISTO – 1.01 Uz) under automorphous conditions. Data obtained by SPA SANIIRI and KKNIIZ and study of cotton irrigation regime are attracted during data analysis.

Processed data of cotton crop capacity growth versus water consumption represented at dr. 2.9 show that crop yield change is dependent not only on water consumption, but on natural-economic conditions too as well. So, under conditions of authomorphous soil maximum cotton crop capacity within 55-58 c/ha is obtained on thick dark grey soils, which are rich with humus under water consumption about 6800-7500 cu. m/ha, while on stony grounds of low thickness under similar water consumption values 35 c/ha is obtained. At the same time on thick light grey soils of Tashkent rayon (EPP UNIIH and NISTO SPA SANIIRI) which are poor with natural humus, maximum crop capacity varies within 39-48 c/ha under irrigation norms near 7.0 th. cu. m/ha (water consumption – 7.8-8.0 th. cu. m/ha).

On saline half-automorphous soils of Karshi and Hungry steppes maximum cotton crop capacity within 32-34 c/ha is obtained under water consumption value appropriately 9000-9500 and 7800-8000 cu. m/ha. At the same time, on saline hydromorphous soils of Khorezm oblast (OPX SANIIRI and OPH KKNIIZ) maximum cotton crop capacity within 35-36 c/ha is grown under water consumption 7000-7200 cu. m/ha, of which 30-35 % are formed at the expense of groundwater use and 8-10 % of soil moisture stock.

Data processed as curves of dependence of actual cotton crop capacity change versus water consumption represented at dr. 2.10, 2.12 and 2.14 with regard to automorphous, hydromorphous and half-automorphous soils formation, show non-linear relation between cotton crop yield and water consumption. So, in automorphous regime conditions cotton crop yield growth is observed up to 60 c/ha for dark grey soils, rich with humus, and up to 50 c/ha for light grey soils, under water consumption value 7000-8000 cu. m/ha.

Water consumption norms' increase above pointed out figures causes cotton crop capacity reduction, that is explained by aggravation of water-aerial conditions of biomass formation and fruits ripening backward.

The same situation is noted in half-automorphous soil conditions (dr. 2.14). In this case maximum crop capacity equaled to 45-50 c/ha is obtained under water consumption 7-8 th. cu. m/ha as well, exceeding of which causes productivity reduction. There is different process of cotton crop capacity growth depending on water consumption. Here relation between cotton crop yield and water consumption is close to linear one. In these conditions the highest limit of crop capacity growth has not been obtained by means of experiments, depending on water consumption, after which crop capacity reduction is observed. On the other hand, in hydromorphous soil conditions water "stress" is not sensible for agricultural crops, as plants are permanently recharged from groundwater. Share of groundwater recharge, use of soil moisture and precipitation stock in hydromorphous soil conditions are 45-55 % in total water consumption, while cotton demand for water is covered at the expense of water supply. Otherwise, in hydromorphous and half-automorphous soil conditions in formation of soil water availability (water consumption) groundwater level and regime have a big importance.

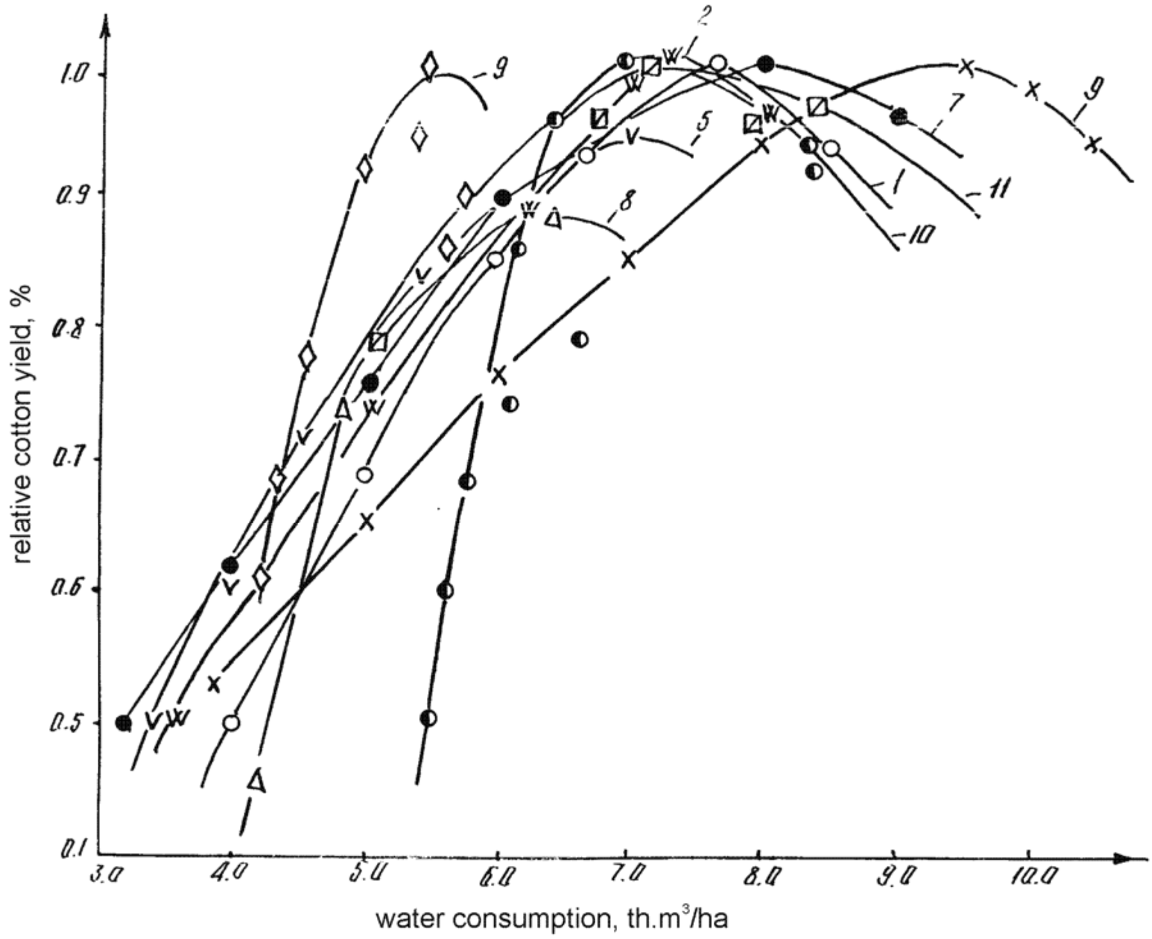
Processed vast material, collected by Central Asian scientific-research institutes, allowed to define for different intervals of groundwater depths close relation between relative cotton crop capacity and irrigation norm. Given relation could be represented as parabolic dependence of the second power:

$$\mathbf{Y/Y_{max} = b\ (M/M_{opt}) + a\ (M/M_{opt})^2 - c}$$

where: $\mathbf{Y, Y_{max}}$ – appropriately actual and potential optimal crop yield;

$\mathbf{M, M_{opt}}$ – appropriately actual and optimal irrigation norms.

$$\mathbf{M = M/M_{opt}}$$

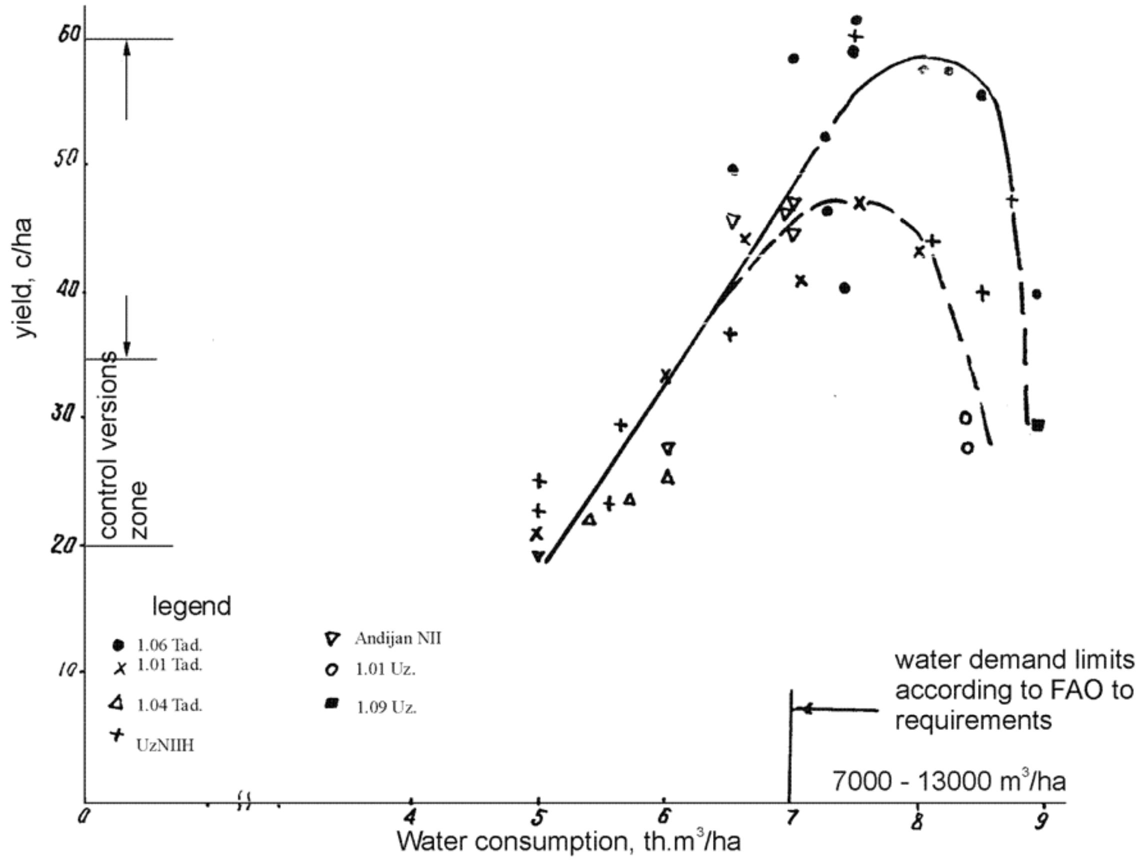



Dr.2.9. Relative cotton yield versus water consumption.

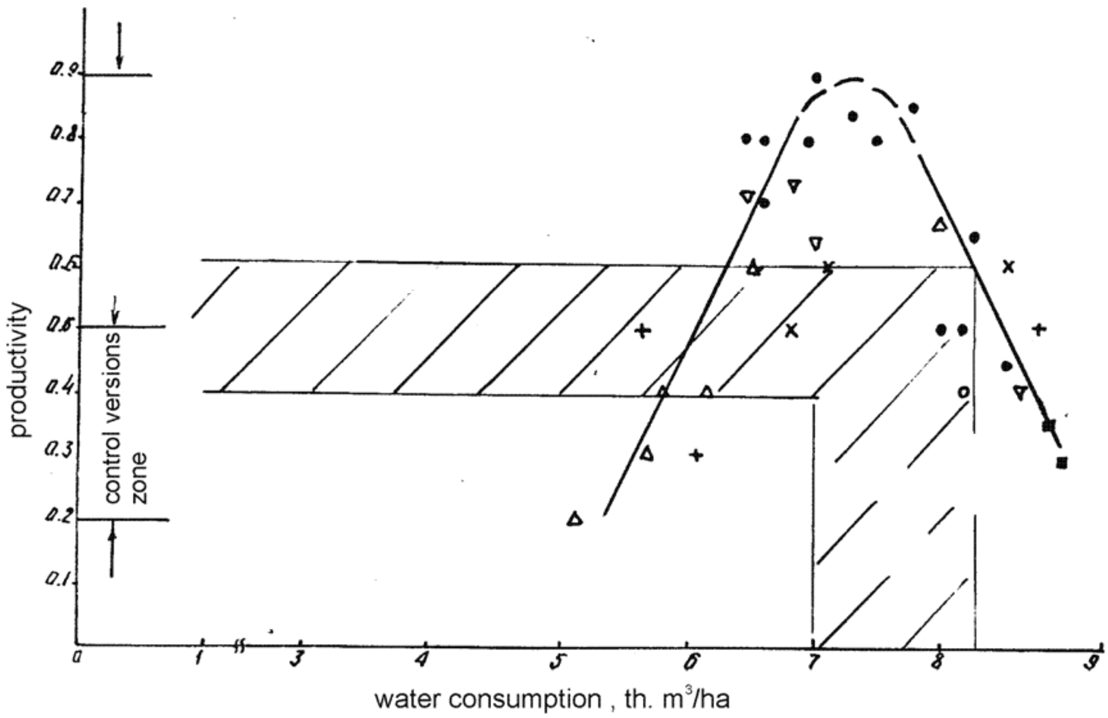
maximum yield in experiments, $Y_{max}$= 35 - 58 c/ha

Legend

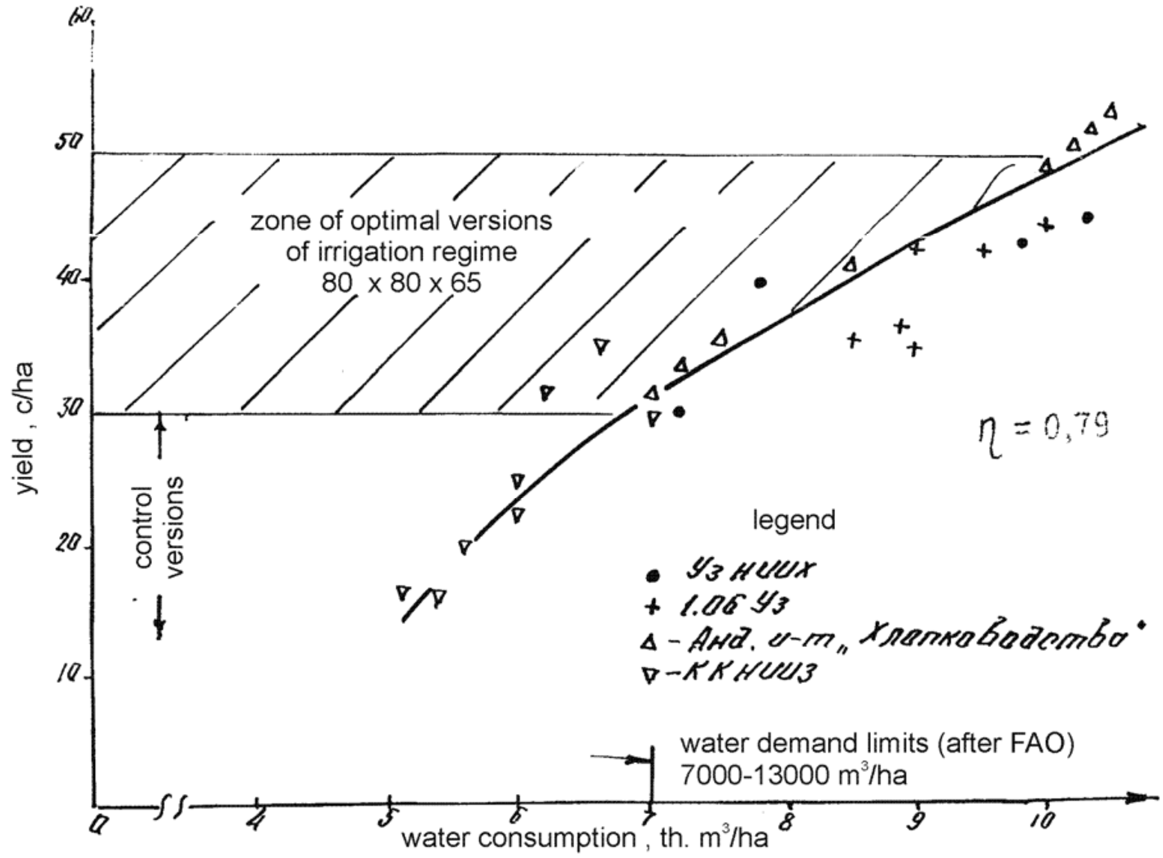
- ○ - 1 - Респ. Каракалпакстан (Чимбай КНИИЗ) Ор = 7.6 тыс. м³/га, Уmax = (32 - 35 ц/га)
- w - 2 - Харезмс. обл. (ОПХ САНИИРИ) Ор = 7.2 тыс. м³/га, Уmax = (35 - 36 ц/га)
- x - 4 - Карши (9 и 24 сов ) Ор = 9.5 тыс. м³/га, Уmax = (32 - 34 ц/га)
- v - 5 - Ташк. обл. (УзНИИХ) Ор = 7.0 тыс. м³/га, Уmax = (39 - 48 ц/га)
- ● - 7 - Сырд. обл. (г. Гулям) Ор = 8.0 тыс. м³/га, Уmax = 32 ц/га
- Δ - 8 - Ташк. обл. (НИСТО) Ор = 6.4 тыс. м³/га, Уmax = 31 ц/га
- ◇ - 9 - Харезмс. обл. (ОПУ. Халкабад) Ор = 5.5 тыс. м³/га, Уmax = 44 ц/га
- ◐ - 10 - Ленинабадск. обл. (Тадж.) Ор = 7.1 тыс. м³/га, Уmax = 35 ц/га
- ⊠ - 11 - Гиссарск. р-н (Тадж.) Ор = 7.2 тыс. м³/га, Уmax = 58 ц/га



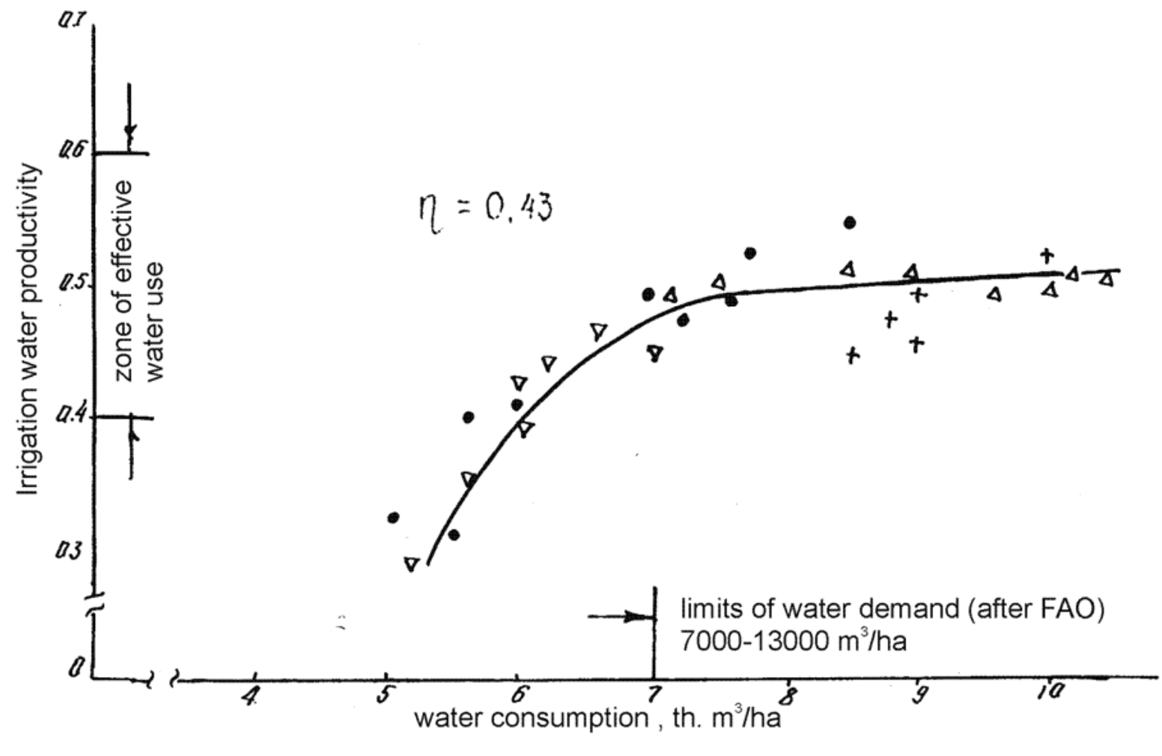

Dr. 2.10. Cotton yield versus water consumption on automorphous soils.



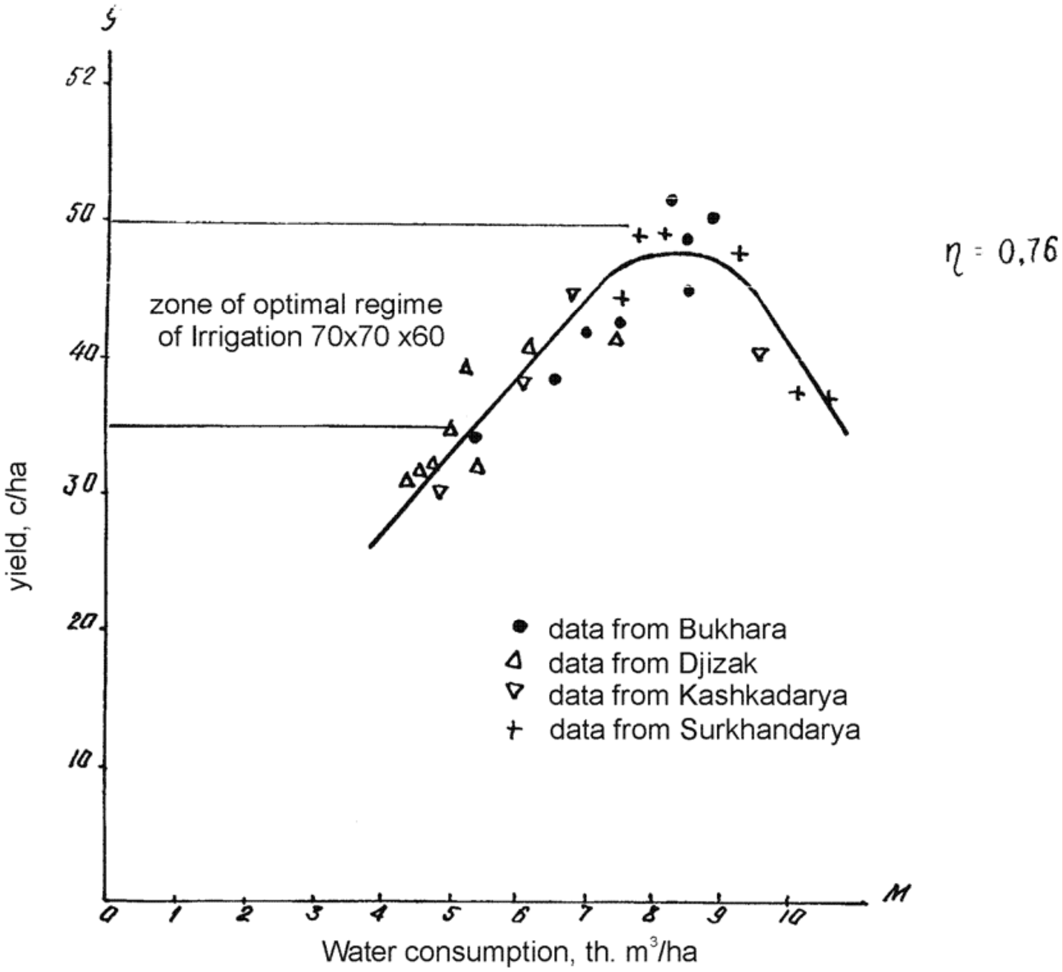

Dr. 2.11. Irrigation water productivity versus cotton water consumption.



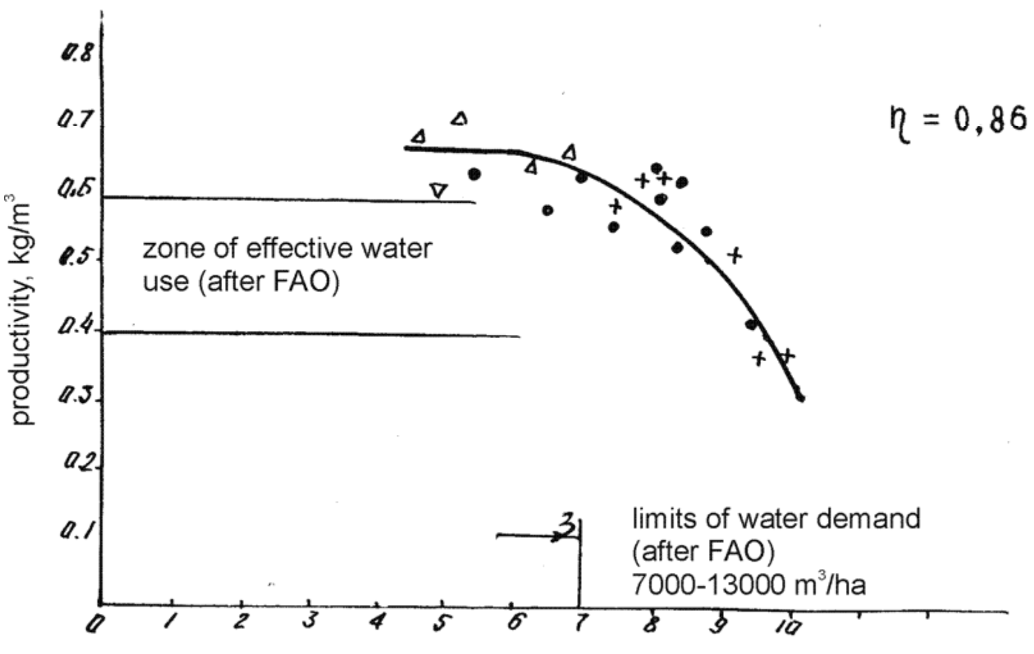

Dr. 2.12. Cotton yield versus water consumption norm on hydromorphous soils.




Dr. 2.13. Irrigation water productivity versus cotton water consumption on hydromorphous soils (ground water table 0,5-2,0 m).




Dr. 2.14. Cotton yield versus water consumption norm on half-automorphous soils (ground water table 2-3 m.).




Dr. 2.15. Irrigation water productivity versus cotton water consumption on half-automorphous coils (ground water table 2-3 m).

Equation parameters under different groundwater table are given below in table 2.3.

Table 2.3

| Depth range, m | $Y/Y_{max} = f(M_i/M_{opt})$ | Regression coefficient | | | Correlation coefficient |
|---|---|---|---|---|---|
| | | a | b | c | |
| 0.5-1.0 | $Y = -0.808M^2 + 1.86M - 0.0267$ | 0.808 | 1.861 | 0.0267 | 0.92 $\pm$0.01 |
| 1.0-2.0 | $Y = -1.0716M^2 + 2.245M - 0.165$ | 1.0716 | 2.245 | 0.165 | 0.93 $\pm$0.01 |
| 2.0-3.0 | $Y = -1.438M^2 + 2.981M - 0.528$ | 1.438 | 2.981 | 0.528 | 0.91 $\pm$0.01 |
| > 3.0 | $Y = -2.13M^2 + 3.971M - 0.858$ | 2.13 | 3.971 | 0.858 | 0.90 $\pm$0.01 |
| 0.0-3.0 | $Y = -0.582M^2 + 1.67M - 0.0913$ | 0.522 | 1.674 | 0.0613 | 0.88 $\pm$0.3 |

Given relation may be used during schedule calculations of cotton water consumption norms taking into account covering of cotton demand for water and groundwater table (GWT). GWT itself is the result of non-growing and growing periods irrigation, because GWT increases at once after one irrigation.

On the other hand, comparison of water consumption values, obtained during experiments on irrigation regime in Central Asia, with similar ones obtained by FAO, shows that actual values of cotton total evaporation for all conditions of soil formation are within demand for water limits according to FAO or lower. So, on FAO recommendation, to obtain 35-50 c/ha of cotton crop yield in hydromorphous soil conditions and 45-50 c/ha and more in automorphous ones water consumption within 7000-13000 cu. m/ha is supposed. With regard to cotton irrigation regime experiments to achieve pointed out values of crop yield moisture, discharge per total evaporation does not exceed 7000-8000 cu. m/ha. Within limits recommended by FAO cotton demand for water 7000-13000 cu. m/ha is estimated as effectively used irrigation water, while cotton 1 kg yield growing takes 0.4-0.6 cu. m of water. From this point of view during all cotton irrigation regime experiments, conducted in Central Asia, effective use of irrigation water was obtained (table 2.4, dr. 2.11, 2.13 and 2.15). So, in optimal options of irrigation regimes for automorphous, half-automorphous and hydromorphous regimes of soil formation irrigation water productivity changes within 0.4-0.7 kg/cu. m, i. e. is within limits recommended by FAO.

So, data analysis represented at dr. 2.10-2.15 and tables 2.4, 2.5 show that certain water consumption value corresponds to each level of crop capacity. Otherwise there is exact "limit" of cotton crop capacity growth depending on water consumption volume, above which sharp reduction of crop yield or negligible "increment" per "unit" of total evaporation (tables 2.4 and 2.5).

Table 2.4

## Assessment of irrigation water use productivity

| Pilot plot index | Soil-climatic zone | Water allowance rayon | Salinity degree | Ground-water table, m | Agricul-tural crop | Informa-tion type | Water consumption during growing pe-riod. per., m3/ha | | Limits of water consumption (after FAO) m3/ha | Actual water consumption or ex-ceeding or arriers compared with FAO (m3/ha) ( % ) | Yield kg/ha | Irrigation water productivity (efficiency), kg/m3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | total | at expen-ses of water consum. | | | | after FAO | actual 12:8 | exceed-ing FAO % |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1.01. Uz. | Ц-П-В | Ш | NS | 5 | cotton | ОП | 9080 | 7275 | 7000 - 13000 | -1920 (19) | 3100 | 0.4 - 0.6 | 0.35 | -20 |
| | | | | | | К | 9575 | 7500 | 7000 - 13000 | -425 (4.2) | 2600 | 0.4 - 0.6 | 0.3 | -40 |
| 1.02. Uz. | Ц-П-Б | 1У-У | MS | 1.5-3 | cotton | ОП | 8170 | 4000 | 7000 - 13000 | -5100 (51) | 3200 | 0.4 - 0.6 | 0.6 | 20 |
| | | | | | | К | 7830 | 4700 | 7000 - 13000 | -5300 (53) | 2600 | 0.4 - 0.6 | 0.3 | -4 |
| 1.06. Uz. | Ц-1-А | У1-УП | MS | 0.5-1.5 | cotton | ОП | 5370 | 4081 | 7000 - 13000 | -4302 (43) | 4430 | 0.4 - 0.6 | 0.6 | 4 |
| | | | | | | К | 5618 | 4275.3 | 7000 - 13000 | -4302 (43) | 3550 | 0.4 - 0.6 | 0.6 | 2 |
| 1.08. Uz. | Ю-1-Б | 1У | MS | 2-3 | cotton | ОП | 9350 | 8050 | 7000 - 13000 | -1950 (19.5) | 2800 | 0.4 - 0.6 | 0.3 | -4 |
| 1.01. Tad. | Ю-П-Б | Ш | NS | 10 | cotton | ОП | 10653 | 10415 | 7000 - 13000 | 415 (4.15 | 4270 | 0.4 - 0.6 | 0.4 | -2 |
| | | | | | | К | 9791 | 9321 | 7000 - 13000 | -679 (6.8) | 3340 | 0.4 - 0.6 | 0.3 | -4 |
| 1.04. Tad. | Ц-П-А | Ш | NS | 5 | cotton | ОП | 6821 | 6260 | 7000 - 13000 | -3740 (37.4) | 8520 | 0.4 - 0.6 | 0.5 | 0 |
| | | | | | | К | 8556 | 8213.7 | 7000 - 13000 | -1786 (17.8) | 3230 | 0.4-0.6 | 0.4 | -2 |
| 1.06. Tad. | Ю-1-Г | Ш | NS | 10 | cotton | ОП | 6584 | | 7000 - 13000 | -3416 (34.1) | 5800 | 0.4 - 0.6 | 0.9 | 80 |
| | | | | | | К | 7349 | | 7000 - 13000 | -2651 (26.5) | 4870 | 0.4 - 0.6 | 0.66 | 3 |
| Exp. base KKNIIZ | Ц-1-А | 1У | WS MS | 1.5-2.0 | cotton | ОП | 6780 | 2361 | 7000 - 13000 | -3220 | 3640 | 0.4 - 0.6 | 0.53 | 6 |
| -”- | Ц-1-А | 1У | WS, MS | 1.5-2.0 | cotton | ОП | 6270 | 2651 | 7000 - 13000 | -3730 | 3200 | 0.4 - 0.6 | 0.51 | 1 |
| -”- | Ц-1-А | 1У | WS, MS | 1.5-2.2 | cotton | ОП | 5820 | 1924 | 7000 - 13000 | -4180 | 2940 | 0.4 - 0.6 | 0.5 | 0 |

Legende: NS - non-saline; WS - weakly saline; MS - medium saline.

Table 2.5.

Cotton and cotton field water consumption versus its yield and irrigation technique efficiency

| Cotton yield, C/ha | Average water consump tion, m3/ha | Water consumption (m3/ha) at expense of: | | | Leaching coeffi-cient K | Mnet for vegeta-tion | Irrigation tech-nique effi-ciency | Mgross for vegeta-tion | M for non-vegeta-tion | M annual | Perspective | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | precipi-tation | soil mois-ture use before 1st irrigation | ground-water use | | | | | | | Irrigation tech-nique effi-ciency xxxx) | M vegeta-tion | M annual |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Automorphous regime. Low thickness top soil, underlaid by pebble and sand | | | | | | | | | | | | | |
| 25-30 | 5700 | 600xx) | - | - | 1 | 5100 | 0.55 | 9350 | 500xxx) + | 10350 | 0.85 | 6000 | 7000 |
| 20-25 | 5200 | -”- | - | - | 1 | 4800 | -”- | 8750 | 500+500 | 9750 | 0.85 | 5670 | 6670 |
| Automorphous regime. Light loamy soils, thickness 1.5-2.0 m underlaid by sand | | | | | | | | | | | | | |
| 35-40 | 7500 | 500 | 1050 | - | 1 | 5450 | 0.65 | 8400 | 900 | 9300 | 0.75 | 7300 | 8200 |
| 30-35 | 6200 | -”- | -”- | - | 1 | 4150 | -”- | 6400 | -”- | 7300 | -”- | 5530 | 6430 |
| 25-30 | 5700 | -”- | -”- | - | 1 | 3650 | -”- | 5600 | -”- | 6500 | -”- | 4800 | 5780 |
| 20-25 | 5200 | -”- | -”- | - | 1 | 3150 | -”- | 4850 | -”- | 5750 | -”- | 4200 | 5100 |
| Automorphous regime. Non-saline big thickness loamy deposits. I water allowance rayon | | | | | | | | | | | | | |
| 40-50 | 8500 | 350 | 1650 | 260 | 1 | 6240 | 0.70 | 8900 | 700 | 9600 | 0.75 | 8320 | 9020 |
| 35-40 | 6800 | -”- | -”- | -”- | 1 | 4500 | -”- | 6500x) | -”- | 7200 | 0.75 | 6040 | 6740 |
| 30-35 | 6200 | -”- | -”- | -”- | 1 | 3940 | -”- | 5640 | -”- | 6340 | -”- | 5250 | 6950 |
| 25-30 | 5700 | -”- | -”- | -”- | 1 | 3440 | -”- | 4920 | -”- | 5620 | -”- | 4600 | 5300 |
| 20-25 | 5200 | -”- | -”- | -”- | 1 | 2980 | -”- | 4280 | 800 | 5080 | -”- | 3950 | 4750 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Half-automorphous regime. Non-saline loamy soils. IV water allowance rayon | | | | | | | | | | | | | |
| 40-48 | 8200 | 300 | 1600 | 650 | 1 | 5650 | 0/75 | 7580 | 700 | 8280 | 0.80 | 7050 | 7750 |
| 35-40 | 6900 | -”- | -”- | -”- | 1 | 4350 | -”- | 5800 | -”- | 6850 | -”- | 5450 | 6150 |
| 30-35 | 6250 | -”- | -”- | -”- | 1 | 3700 | -”- | 5000 | -”- | 5700 | -”- | 4630 | 5330 |
| 25-30 | 5700 | -”- | -”- | -”- | 1 | 3150 | -”- | 4230 | -”- | 4930 | -”- | 3950 | 4650 |
| 20-25 | 5200 | -”- | -”- | -”- | 1 | 2800 | -”- | 3750 | 800 | 4550 | -”- | 3500 | 4300 |
| Hydromorphous regime. Meadow and marshy-meadow soils. VI water allowance rayon. Weakly saline soils | | | | | | | | | | | | | |
| 45-50 | 8700 | 250 | 1500 | 1000 | 1 | 5950 | 0.80 | 7400 | 2000 | 9400 | 0.85 | 7030 | 9030 |
| 4045 | 7750 | -”- | -”- | -”- | 1.05 | 5250 | -”- | 6600 | -”- | 8600 | -”- | 6170 | 8170 |
| 35-40 | 6750 | -”- | -”- | -”- | 1.10 | 4400 | -”- | 5500 | -”- | 7500 | -”- | 5180 | 7180 |
| 30-35 | 6200 | -”- | -”- | -”- | 1.15 | 3980 | -”- | 5000 | -”- | 7000 | -”- | 4680 | 6680 |
| 25-30 | 5700 | -”- | -”- | -”- | 1.20 | 3560 | -”- | 4480 | 2500 | 6980 | -”- | 4200 | 6700 |
| Hydromorphous regime. Meadow and marshy -meadow soils. Saline in different degree | | | | | | | | | | | | | |
| 45-50 | 8700 | 200 | 1200 | 1790 | 1.15 | 6300 | 0.84 | 7550 | 4000 | 11550 | 0.85 | 7400 | 11400 |
| 4045 | 7750 | -”- | -”- | -”- | 1.20 | 5500 | -”- | 6550 | -”- | 10550 | -”- | 6480 | 10480 |
| 35-40 | 6750 | -”- | -”- | -”- | 1.25 | 4050 | -”- | 5470 | -”- | 9470 | -”- | 5410 | 9410 |
| 30-35 | 6200 | -”- | -”- | -”- | 1.30 | 3960 | -”- | 4740 | -”- | 8740 | -”- | 4650 | 8650 |
| 25-30 | 5700 | -”- | -”- | -”- | 1.35 | 3430 | -”- | 4100 | -”- | 8100 | -”- | 4030 | 8030 |
| 20-25 | 5150 | -”- | -”- | -”- | 1.40 | 2780 | -”- | 3300 | 4500 | 7800 | -”- | 3260 | 7760 |

Notes: õ) - only for saline and subjected to salinization soils;
õõ) - precipitation of 75 % availability (April, May);
õõõ) - pre-ploughing, pre-sowing and pre-sporuting irrigations;
õõõõ) - it means sprinkler irrigation introduction.

### *1.7.3. Wheat and barley crops capacity change depending on water consumption norms*

With regard to these crops on 5 pilot projects (experimental plots) is represented in IPTRID register, on one of which – in the collective farm named after Karl Marx of Gissar rayon of Tadjikistan (1.05 Tad) barley was grown. Of 5 plots – 2 plots 1.04 Uz and 1.08 Uz belong to the Republic of Uzbekistan and 3 plots – to the Republic of Tadjikistan. With regard to environmental conditions 4 pilot plots are placed within automorphous and 1 – half-automorphous soils.

Irrigation regime of industrial and other kinds of clean filled crops differ from wheat and barley irrigation regime. Vegetation period irrigation wheat and barley are carried out in autumn-winter and, especially, spring periods of the year, when precipitation is high and water discharge per total evaporation is minimum because of low temperatures and high air humidity. Processing of information on wheat and barley winter crops show strict connection between their crop yield and water consumption, which is described by parabola of the second power, but not by linear dependence. Under this crop capacity level (50 c/ha) there is a proportional growth of crop yield versus water consumption above which crop yield increment reduction is noted. At the same time relatively high wheat crop yields within 40-60 c/ha are grown under optimal irrigation regime options near 70x70x60 and 70x70x70 of full field water capacity (FFC), under which water consumption varied within 4500-6500 cu. m/ha (dr. 2.16). Of general water consumption within 4500-6500 cu. m/ha water supply is 2500-4500 cu. m/ha and precipitation and soil moisture cover the rest.

Irrigation water productivity varies within wide limits 0.4-1.0 kg/cu. m of water. At the same time according to FAO limit of irrigation water use could be considered as effective, if productivity is within 0.8-1.0 kg/cu. m and water consumption value is within 4500-6500 cu. m/ha. Comparison of experimental data with FAO requirements shows that in optimal options of irrigation regime with keeping pre-irrigation soil moisture 70x70x70 of FFC irrigation water productivity is within 0.8-1.0 kg/cu. m (table 2.6), i. e. FAO requirement is kept (dr. 2.17).

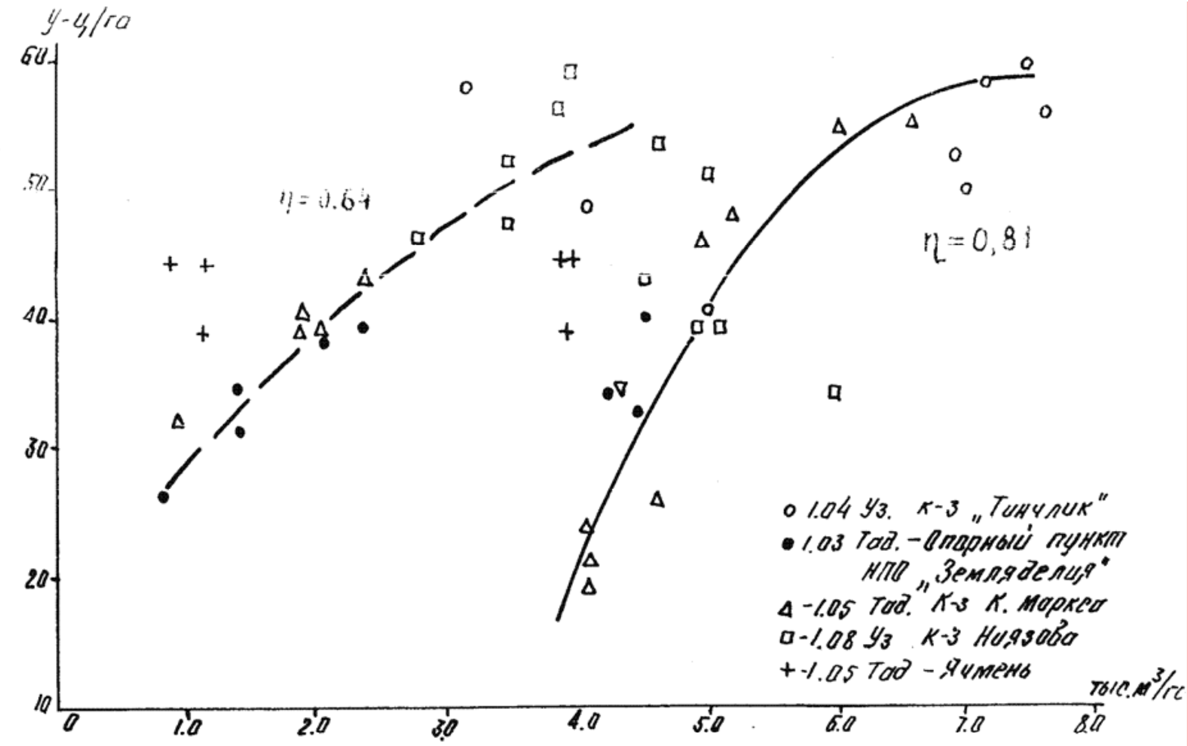
### 1.7.4. Maize crop capacity change in dependence on water consumption norms

The most full information concerning maize for grain and dry mass crop capacity changes are represented on 5 pilot projects (over the Republic of Tadjikistan – 3 objects, and over the Republic of Uzbekistan – 2 ones). Over the Kyrgyz Republic incomplete information is presented as schedules of relation between actual crop yield and water consumption, as well as between relative crop capacity value and water consumption (water availability). During data processing curve of relation between actual crop yield and water consumption, obtained on Kyrgyzstan data, was supplemented with data of pilot projects over Tadjikistan objects – 1.05 Tad and 1.02 Tad, and over Uzbekistan – 1.04 Uz (dr. 2.18 and 2.19). Further information on 5 pilot projects of register was processed with attraction of field researches data, obtained on pilot plots of irrigation regime of maize for grain of Karakalpak Scientific-Research Institute of Farming and Kashkadarya Branch of Uzbek Scientific-Research Institute of Cotton-Growing (UzNIIH). According to R.Gorbacheva (Kyrgyzstan) investigations relation

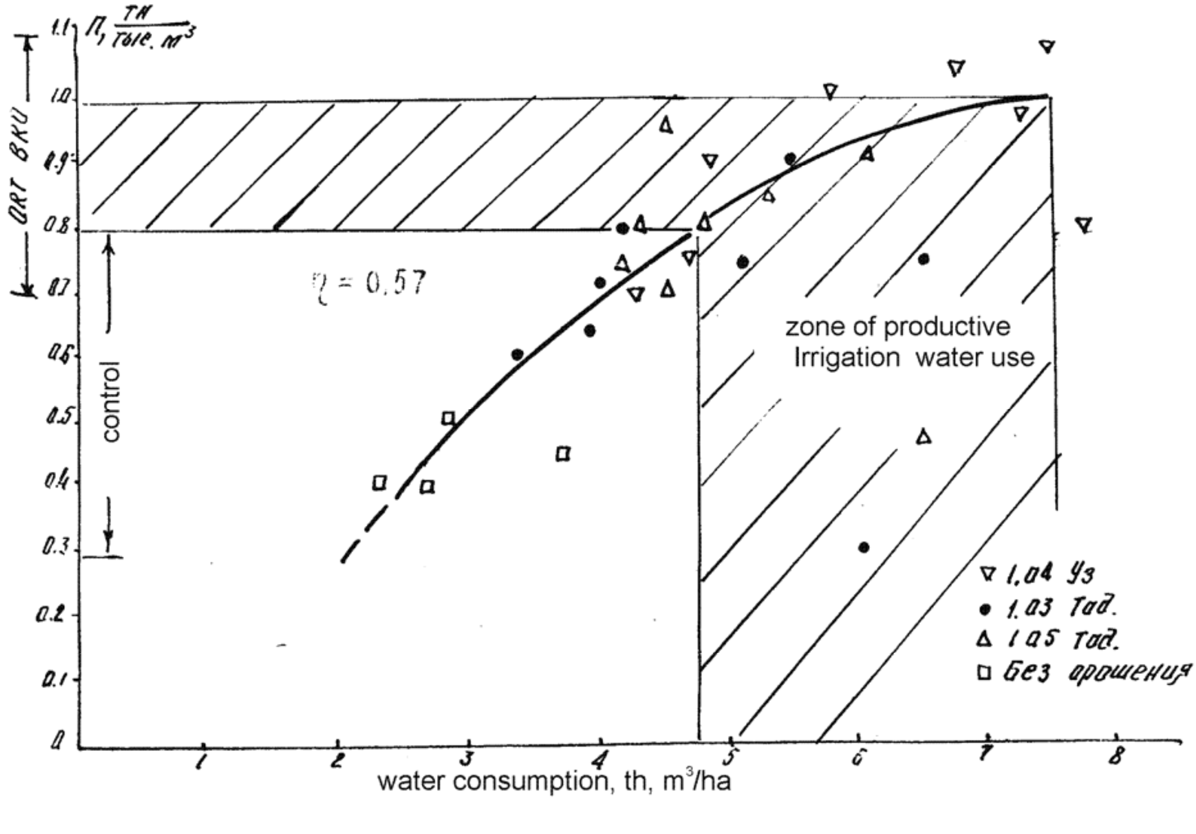
Table 2.6

Assessment of irrigation water use efficiency for winter wheat and winter barley

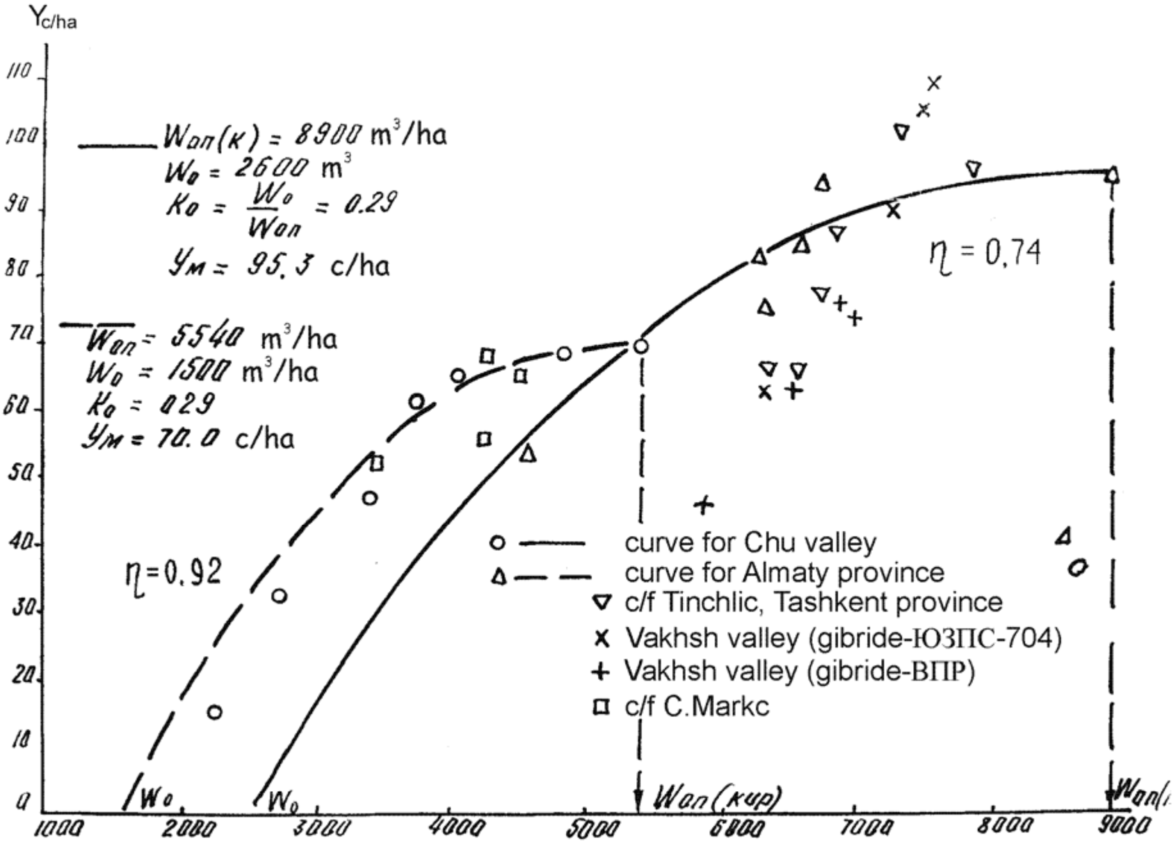
| Pilot plot index | Soil-climatic zone | Water allo-wance rayon | Salinity degree | Groundwater table, m | Agricultural crop | Information type | Water consumption during veg. per. m3/ha | | Water consumption limits after FAO (average), m3/ha | Water consumption exceeding or arriers to compare with FAO (average) | Yield, kg/ha | Irrigation water productivity (efficiency), kg/m3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | total | incl. at expense of water supply | | | | after FAO | actual | FAO exceeding % |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1.05. Tad. | Ю-П-Г | Ш | non-saline | 10 | winter barley | ОП | 3848 | 1110 | 4500-6500 | -1752(32) | 4450 | 0.8-1.0 | 1.1 | 122 |
| | | | | | | К | 3901 | 1375 | 4500-6500 | -2000(36) | 3410 | 0.8-1.0 | 1.0 | 111 |
| 1.04. Uz. | Ц-П-В | Ш | non-saline | 5-10 | winter wheat | ОП | 6500 | 3650 | 4500-6500 | | 5830 | 0.8-1.0 | 11.0 | 117 |
| | | | | | | К | 7768 | 4090 | 4500-6500 | 2268(42) | 4840 | 0.8-1.0 | 0.62 | -132 |
| 1.03. Tad. | Ц-П-Б | Ш | non-saline | 5 | -"- | ОП | 4885 | 2090 | 4500-6500 | -615(11) | 4210 | 0.8-1.0 | 0.9 | 0 |
| | | | | | | К | 6046 | 2952 | 4500-6500 | 596(8.4) | 1900 | 0.8-1.0 | 0.3 | -70 |
| 1.05. Tad. | Ю-1-Г | Ш | non-saline | 10 | -"- | ОП | 4492 | 1922 | 4500-6500 | -1008(18.3) | 4320 | 0.8-1.0 | 0.96 | 106 |
| | | | | | | К | 5070 | 2065 | 4500-6500 | -430(7.8) | 3800 | 0.8-1.0 | 0.7 | -123 |
| 1.08. Uz. | Ц-П-А | 1У | medium saline | 2-3 | -"- | ОП | 3286 | 2753 | 4500-6500 | -2215(40.2) | 5900 | 0.8-1.0 | 1.8 | 200 |
| | | | | | | К | 4500 | 3720 | 4500-6500 | -1000(18) | 4820 | 0.8-1.0 | 1.1 | 122 |



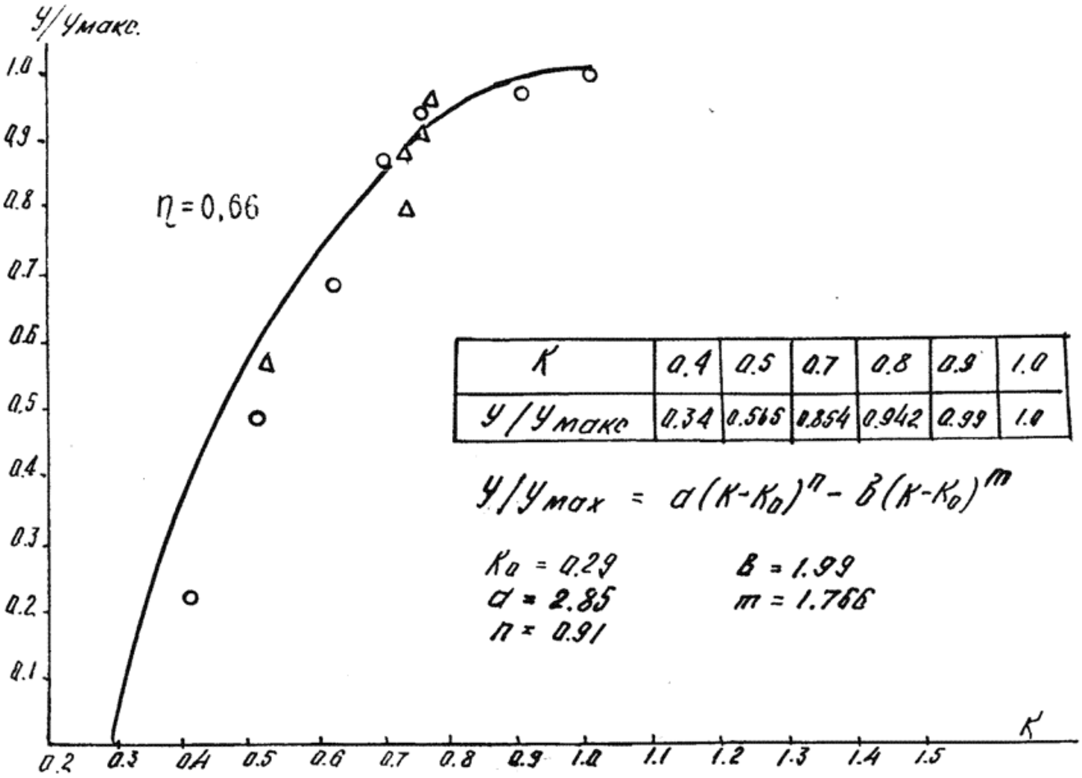

Dr. 2.16. Winter wheat and barley yield versus Irrigation norms and water consumption




Dr. 2.17. Winter wheat productivity versus water consumption in zone of automorphous soils.




Dr. 2.18. Maize for grain yield versus water availability (water consumption ).




| K | 0.4 | 0.5 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|
| У/Умакс | 0.34 | 0.565 | 0.854 | 0.942 | 0.99 | 1.0 |

$$У/У_{max} = a(K-K_0)^n - b(K-K_0)^m$$

$K_0 = 0.29$  $b = 1.99$

$a = 2.85$  $m = 1.766$

$n = 0.91$

Dr. 2.19. Maise for grain yield versus water availability in relative units.

between crop yield and water consumption is described by non-linear dependence (parabola of the second power) as equation (3.4) (dr. 2.18 and 2.19). Maximum maize for grain crop capacity within 80-100 c/ha was obtained under water consumption within 7500-9000 cu. m/ha (dr. 2.18), that corresponds to optimal pre-irrigation soil moisture for this crop 80x80x80 of FFC. At the same time on grey soils of the Republic of Uzbekistan and the Republic of Tadjikistan under optimal pre-irrigation soil moisture 80x80x70 crop capacity changed within 90-110 c/ha, and water consumption was equal to 6500-7400 cu. m/ha (dr. 2.18). Of this water consumption volume water supply is 75-80 % in automorphous soil conditions and 40-50 % in hydromorphous soil conditions. Comparing actual norms of water consumption of maize for grain with similar ones according to FAO, it is clear that in Central Asian conditions under optimal irrigation regime high yields of this crop may be grown under total evaporation values, which are lower than FAO limits. So, under maize for grain crop capacity equaled to 90-110 c/ha in experiments of the Republic of Uzbekistan and the Republic of Tadjikistan water consumption value 5000-7400 cu. m/ha was obtained, while according to FAO it is enough 5000-8000 cu. m/ha. At the same time on all Central Asian pilot plots on irrigation regime of maize for grain the highest productivity was achieved under optimal pre-irrigation soil moisture of FFC of irrigation water. Irrigation water productivity on pilot projects and experimental plots of KKNIIZ and UzNIIH branches changed within 1.0-1.98 kg/cu. m, while according to FAO estimation of water use effectiveness limit productivity is equal to 0.8-1.6 kg/cu. m (table 2.7, dr. 2.20). In experiments, even on lands, which are subjected to salinization, irrigation water productivity turned out high and equal to 1.2-1.9 kg/cu. m.

### *1.7.5. Changes of rice crop capacity in dependence of water consumption*

Rice development physiology sharply differs from other agricultural crops. Water-aerial, nutrient exchange and vegetation regime of rice crop proceed in permanently flooded surrounding. In connection with that rice water consumption by 2-2.5 times higher than cotton, maize and other clean filled crops. With regard to IPTRID register information rice water consumption is from 40 to 50 % of water supply to the field and changes within 7250 (1.02 Kaz) – 14600 cu. m/ha (1.09 Uzb), and water supply to the field on these plots is appropriately equal to 26000 and 31000 cu. m/ha.

According to KazNIIVH data of total water consumption volume transpiration is 30-45 % and changes within 3200-7500 cu. m/ha (table 2.8).

Processing of data on rice did not allow to determine certain conformity to laws of relation between water consumption and crop yield. High crop yield of rice near 60-62 c/ha corresponds to water consumption level 13626 cu. m/ha and 8950 cu. m/ha, and crop yield 45-50 c/ha appropriately to 7250 and 11052 cu. m/ha. The lowest crop yield (32.3 and 37.4 c/ha) was achieved under water consumption value 14600-14000 cu. m/ha.

At the same time balance researches in connection with rice yield change in Central Asia, Krasnodar region and Japan determined close relation between rice crop yield growth and vertical filtration rate, which is described by equation:

$$\mathbf{Y = a_1 + b_1V + c_1V^2 + d_1V^3} \qquad (3.8)$$

where: $\mathbf{a_1, b_1, c_1, d_1}$ – empirical coefficients;

Table 2.7

Assessment of irrigation water use efficiency under maize

| Pilot plot index | Soil-climatic zone | Water allowance rayon | Salinity degree | Groundwater table, m | Agricultural crop | Information type | Water consumption during veg. per., m3/ha | | Water consumption limits after FAO (average), m3/ha | Water consumption exceeding or arriers to compare with FAO (average) | Yield, kg/ha | Irrigation water productivity (efficiency), kg/m3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | total | incl. at expense of water supply | | | | after FAO | actual |
| 1.04. Uz. | Ц-П-В | III | NS | 10 | maize for grain | ОП | 4800 | 3600 | 5000-8000 | -700(9) | 9516 | 0.8-1.6 | 1.98 |
| | | | | | | К | 5200 | 4000 | 5000-8000 | -300(4.0) | 6713 | 0.8-1.6 | 1.3 |
| 1.05. Tad. | Ю-П-Г | III | NS | 5 | -"- | ОП | 4254 | 4275 | 5000-8000 | -1275(17.2) | 6740 | 0.8-1.6 | 1.6 |
| | | | | | | К | 4333 | 3262 | 5000-8000 | -2238(29.8) | 5800 | 0.8-1.6 | 1.34 |
| 1.02. Tad. | Ю-П-Б | III | NS | 5-10 | -"- | ОП | 7414 | 6057 | 5000-8000 | -86(1.1) | 10500 | 0.8-1.6 | 1.4 |
| | | | | | | К | 6345 | 6087 | 5000-8000 | -1455(15.4) | 6300 | 0.8-1.6 | 0.99 |
| 1.02. Tad. | Ю-П-Б | III | NS | 5 | -"- | ОП | 7414 | 5654 | 5000-8000 | -86(1.2) | 7600 | 0.8-1.6 | 1.02 |
| | | | | | | К | 6345 | 4416 | 5000-8000 | -1155(15.4) | 4670 | 0.8-1.6 | 0.74 |
| Exp. base KKNIIZ | Ц-1-А | IV | WS | 1.5-2.0 | maize | ОП | 7550 | 3418 | 5000-8000 | - | 8940 | 0.8-1.6 | 1.18 |
| Exp. base KKNIIZ | Ц-1-А | IV | WS | 1.5-2.0 | -"- | ОП | 6370 | 2504 | 5000-8000 | - | 9360 | 0.8-1.6 | 1.45 |
| Kashkadarya branch | Ю-1-Б | | WS | | -"- | ОП | 7000 | 5400 | 5000-8000 | - | 8450 | 0.8-1.6 | 1.2 |
| UzNIIHL | | II | WS | 2-2.3 | ВИР | ОП | 7100 | 5110 | 5000-8000 | - | 9140 | 0.8-1.6 | 1.9 |
| Kashkadarya branch | | | | | maize for grain | ОП | 6100 | 4350 | 5000-8000 | - | 7810 | 0.8-1.6 | 1.8 |
| UzNIIHL | Ю-1-Б | | WS | 2-2-3 | | ОП | 7370 | 5360 | 5000-8000 | - | 8660 | 0.8-1.6 | 1.6 |

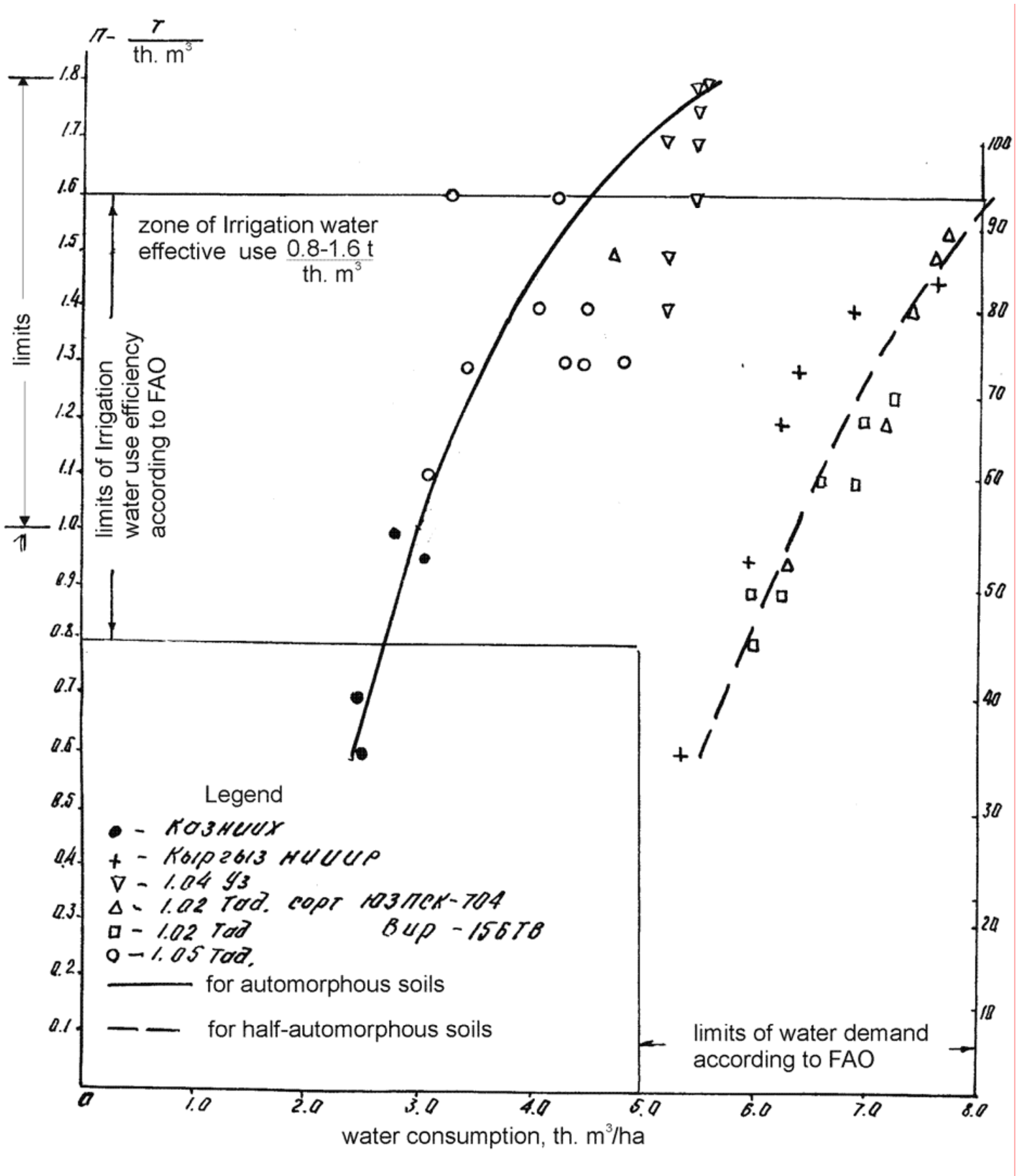
Note: NS - non-saline, WS - slightly

Table 2.8

Assessment of irrigation water use efficiency under rice

| Pilot plot index | Soil-climatic zone | Water allowance rayon | Salinity degree | Groundwater table, m | Information type | Water consumption during veg. per., m3/ha | | Water consumption limits after FAO (average), m3/ha | Water consumption exceeding or arriers to compare with FAO (average) | Yield, kg/ha | Irrigation water productivity (efficiency), kg/m3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | total | incl. at exp. of water supply | | | | after FAO | actual |
| 1.02. Kaz. | С-П-А | У1 | NS | 1-2.5 | ОП | 7250 | 26000 | 3500-7000 | | 4516 | 0.7-1.1 | 0.62 |
| | | | | | К | 8250 | 28160 | 3500-7000 | | 4016 | 0.7-1.1 | 0.48 |
| 1.03. Kaz. | С-П-А | У1 | MS | 1-3 | ОП | 9750 | 25000 | 3500-7000 | | 2750 | 0.7-1.1 | 0.28 |
| | | | | | К | 10500 | 23000 | 3500-7000 | | 1800 | 0.7-1.1 | 0.17 |
| 1.04. Kaz. | Ц-1-А | 1У | MS | 1-2.5 | ОП | 13626 | 24596 | 3500-7000 | | 6200 | 0.7-1.1 | 0.45 |
| | | | | | К | 11052 | 20605 | 3500-7000 | | 5000 | 0.7-1.1 | 0.45 |
| 1.05. Kaz. | Ц-1-А | 1У | MS | 1-2.5 | ОП | 8950 | 21672 | 3500-7000 | | 6000 | 0.7-1.1 | 0.67 |
| | | | | | К | 10700 | 20605 | 3500-7000 | | 5000 | 0.7-1.1 | 0.46 |
| 1.08. Kaz. | С-1-А | УП | MS | 1-3 | ОП | 9750 | 20620 | 3500-7000 | | 4800 | 0.7-1.1 | 0.49 |
| | | | | | К | 10344 | 29820 | 3500-7000 | | 4390 | 0.7-1.1 | 0.41 |
| 1.09. Uz. | Ц-П-Б | У1 | MS | 0.5-2.0 | ОП | 12800 | 21700 | 3500-7000 | | 4740 | 0.7-1.1 | 0.37 |
| | | | | | К | 13900 | 30900 | 3500-7000 | | 4000 | 0.7-1.1 | 0.28 |
| 1.09. Uz. | Ц-П-Б | У1 | MS | 0.5-2 | ОП | 12350 | 18862 | 3500-7000 | | 4880 | 0.7-1.1 | 0.40 |
| | | | | | К | 14000 | 29700 | 3500-7000 | | 3740 | 0.7-1.1 | 0.26 |
| 1.09. Uz. | Ц-П-Б | У1 | MS | 0.5-2 | ОП | 12870 | 18261 | 3500-7000 | | 4330 | 0.7-1.1 | 0.36 |
| | | | | | К | 14600 | 31650 | 3500-7000 | | 3230 | 0.7-1.1 | 0.22 |

Note: NS - non-saline, WS - medium saline




Dr. 2.20. Irrigation water productivity versus maize for grain water consumption.

**$Y = Y_i/Y_{max}$** – relative crop capacity;
**$V = V_i/V_{opt}$** – relative vertical filtration;
where: **$Y_{max}$, $V_{opt}$** – maximum crop capacity and filtration corresponding to it.

**Value of empirical coefficients, defining rice crop capacity dependence on filtration rate**

| No. | Object title | Coefficients | | | |
|---|---|---|---|---|---|
| | | $a_1$ | $b_1$ | $c_1$ | $d_1$ |
| 1 | Central Asia and South Kazakhstan | 0.337 | 1.17 | -0.583 | 0.018 |
| 2 | Krasnodar region | 0.67 | 0.623 | -0.371 | 0.0604 |
| 3 | Japan | 0.746 | 0.587 | -0.404 | 0.0698 |

For these three continents which sharply differ by natural conditions and rice growing technology, this crop capacity, vertical filtration rate are characterized by 3 curves (dr. 2.21).

However, for SyrDarya lower reaches conditions crop yield growth depending on filtration rate is described by non-linear dependence such as:

$$\mathbf{Y = 4.20 + 0.48\ F - 0.03\ F^2} \qquad (3.9)$$
$$\mathbf{K = 0.72}$$

where: **F** – vertical filtration rate, mm/day.

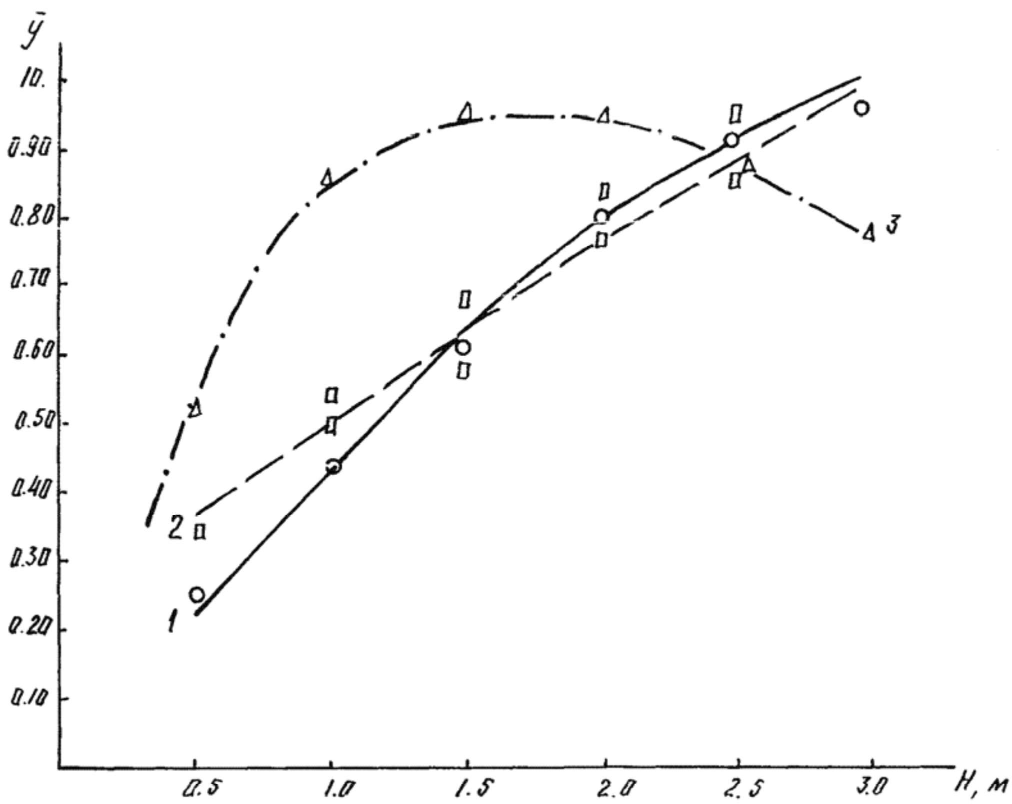
The highest rice crop capacity near 58-62 c/ha corresponds to vertical filtration value 8-12 mm/day (dr. 2.22).

Other rice crop capacity dependence on groundwater table was determined for the South Ukraine conditions (dr. 2.23 – curve 1), Krasnodar region (dr. 2.23 – curve 2) and Central Asia (dr. 2.23 – curve 3).

Meanwhile, over all pilot plots irrigation water productivity on rice fields is lower than FAO criteria lower limit and varies within 0.22 kg/cu. m up to 0.67-0.7 kg/cu. m, while according to FAO it is effective, if water productivity varies within 0.7-1.1 kg/cu. m (table 2.8). In order to obtain this productivity limits according to FAO water consumption near 3500-7000 cu. m/ha is enough. Given FAO water consumption volume is too reduced. If they are counted as share of transpiration, so everything turns understandable. Then almost on all pilot projects on rice in Central Asia under optimal irrigation regimes high irrigation water productivity 0.7-1.7 kg/cu. m is obtained, what is some more than on FAO criteria (dr. 2.24 and 2.25).

### *1.7.6. Alfalfa crop capacity changes depending on water consumption*

IPTRID registers, concerning alfalfa water consumption, are represented in three pilot projects: over Kazakhstan, located in SyrDarya river lower reaches (1.01 Kaz, 1.02 Kaz and 1.03 Kaz). All pilot plots are represented by shallow groundwater table and soils subjected to salinization. During information processing UzNIIH Khorezm Branch and KKNIIZ additional data was attracted corresponding to above-mentioned natural conditions for Kazakhstan pilot plots. Beside that, alfalfa irrigation regime data over Pakhtaaral state farm were used. Result of data processing are represented in table 2.9 and at dr. 2.26, which characterize existence of crop capacity regularity change in dependence on water consumption.




Dr.2.23. Rice yield versus ground water table during growing period.

1. South Ukrane;
2. Krasnodar province;
3. Central Asia and the Republic Kazakhstan;

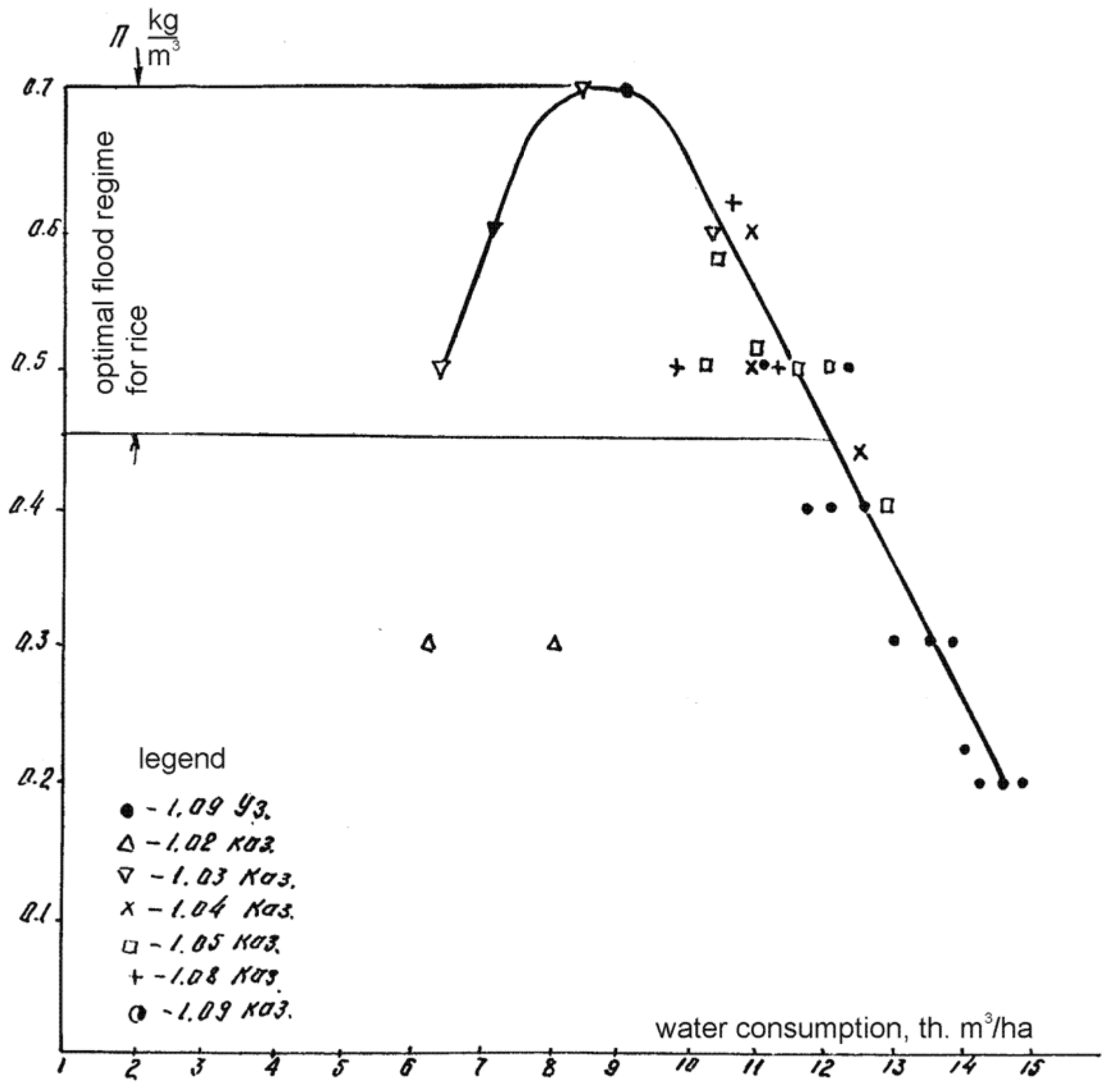
$$y'' = a'' + b''H + c''H^2 + d''H^3$$

4 $a'', b'', c'', d''$ – empirical coefficients

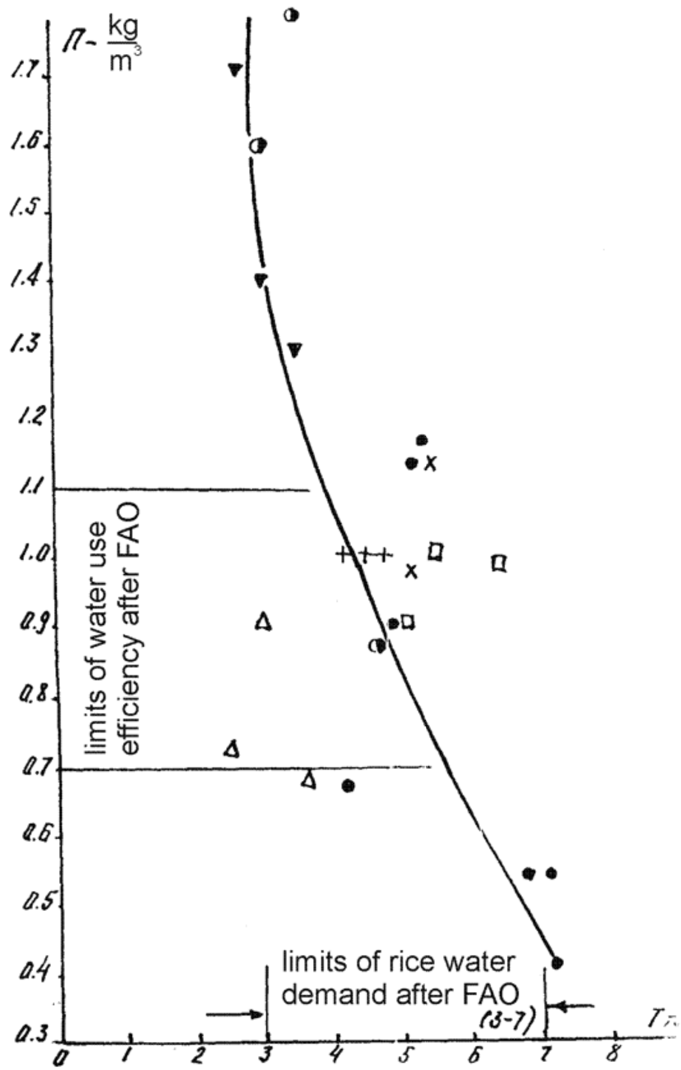
5 $H$ – ground water table, m

Values of empirical coefficients

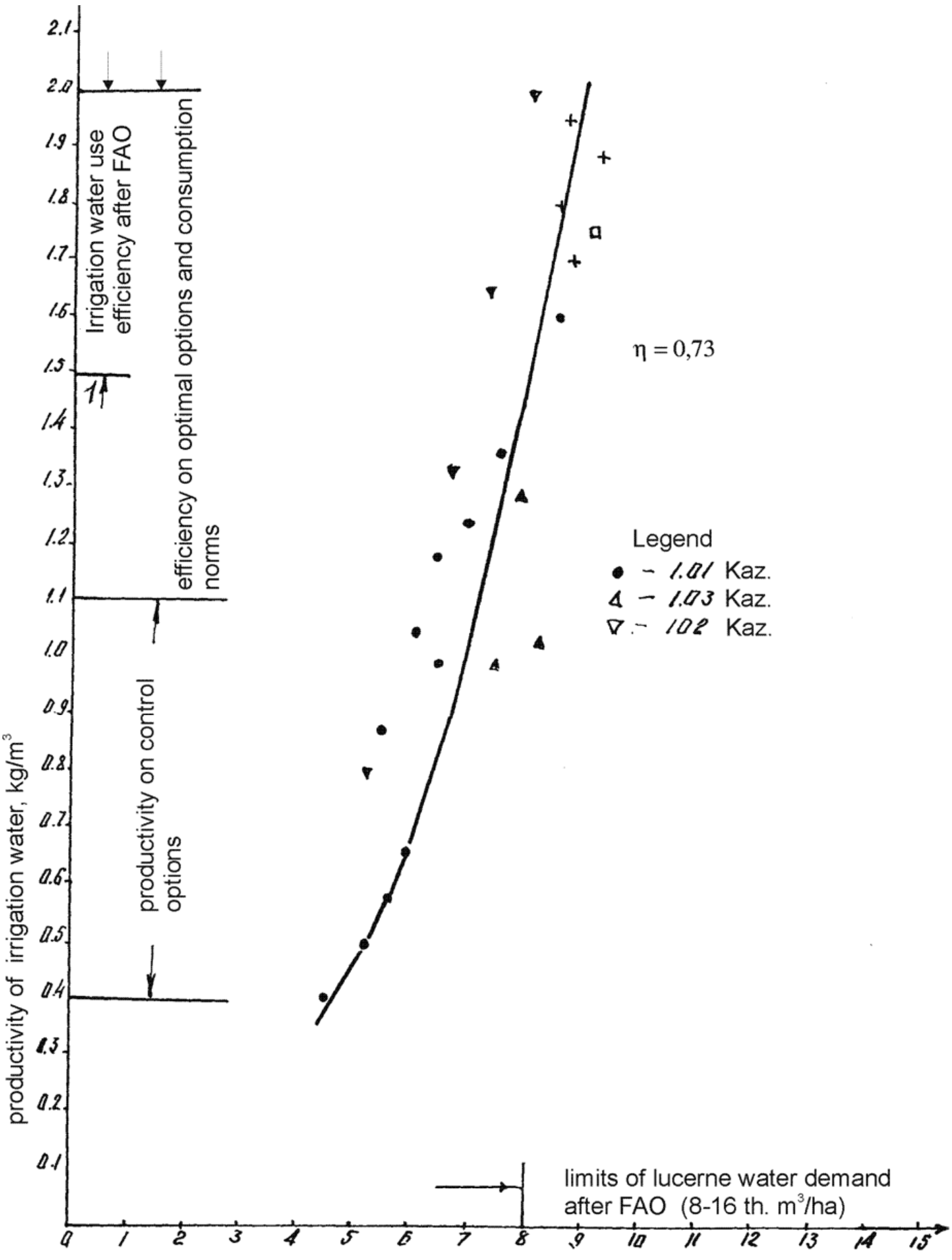
| № | Object | Correlation coefficient | Values of empirical coefficients | | | |
|---|---|---|---|---|---|---|
| | | | $a''$ | $b''$ | $c''$ | $d''$ |
| 1 | South Ukrane | 0.99 | -0,065 | 0,61 | -0,106 | 0,0073 |
| 2 | Krasnodar province | 0.97 | 0,216 | 0.31 | -0.0137 | -0.00057 |
| 3 | Central Asia | 0.96 | -0.11 | 1,58 | -0,722 | -0,099 |




Dr. 2.24. Irrigation water productivity versus rice water consumption.




Dr. 2.25. Irrigation water productivity versus transpiration "T".




Dr. 2.26. Irrigation water use efficiency for lucerne.

On all pilot plots of irrigation regime under optimal pre-irrigation soil moisture of FFC – 80x80x80 and 90x90x90 – the highest alfalfa crop yield near 180-250 c/ha was achieved. Such crop capacity formation took moisture in volume of 9000-10000 cu. m/ha. Good alfalfa crop yield near 150-180 c/ha was achieved under water consumption 8000-9000 cu. m/ha. The lowest alfalfa crop yields (60-70 c/ha) were obtained under water consumption near 6500-7500 cu. m/ha.

It worth to note, that alfalfa growing on the second and the third year in hydromorphous soil conditions in water consumption total volume water supply is 30-55 %, and the rest part is formed at the expense of groundwater inflow and soil moisture use (80-100 %). In half-automorphous soil conditions water supply is more than 65-70 %. In all options of optimal alfalfa irrigation regime with keeping pre-irrigation soil moisture 80x80x80 and 90x90x90 high irrigation water use effectiveness was obtained. On pilot objects of state farm Pahtaaral, 1.02 Kaz, UzNIIH Khorezm Branch and KKNIIZ irrigation water productivity varies within 1.9-2.5 kg/cu. m, so it is higher than upper limit according to FAO effectiveness estimation criteria (table 2.9 and dr. 2.26), while in control options irrigation water productivity is much lower than lower limit and was 0.7-1.3 kg/cu. m.

Data, represented at dr. 2.26, characterize crop capacity change versus water consumption, described by linear dependence. However, gradient differs from such dependence line, obtained by Begishev (Yuzhkazvodproekt) for Toguzken massif (dr. 2.26).

The lowest alfalfa crop yields (60-70 c/ha) were grown under water consumption equaled to 6500-7500 cu. m/ha.

Table 2.9

Assessment of irrigation water use efficiency under lucerne

| Pilot plot index | Soil-climatic zone | Water allowance rayon | Salinity degree | Groundwater table, m | Agricultural crop | Information type | Water consumption during veg. per., m3/ha | | Water consumption limits after FAO (average), m3/ha | Water consump. exceeding or arr. to comp with FAO (average) | Yield, kg/ha | Irrigation water productivity (efficiency), kg/m3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | total | incl. at expense of water supply | | | | after FAO | actual |
| 1.01. Kaz. | Ц-1-А | 1У | MS | 0.5-2.5 | lucerne of 1 year | ОВРО 80x80 | 7500 | 1950 | 8000-16000 | 7660 | 1.5-2.0 | 1.02 | -41.7 |
| | | | | | | К | 6500 | 3750 | 8000-16000 | 6060 | 1.5-2.0 | 0.93 | -47 |
| 1.01. Kaz. | Ц-1-А | 1У | MS | 0.5-2.5 | lucerne of 2 year | ОВРО 90x90 | 8900 | 4620 | 8000-16000 | 14400 | 1.5-2.0 | 1.73 | -3 |
| | | | | | | К | 8800 | 6680 | 8000-16000 | 16880 | 1.5-2.0 | 1.92 | +9.7 |
| 1.02. Kaz. | С-П-А | У1 | WS | 1-2.5 | lucerne of 2 year | ОВРО 80x80 | 7880 | 1600 | 8000-16000 | 15900 | 1.5-2.0 | 2.0 | +14.3 |
| | | | | | | К | 7300 | 1800 | 8000-16000 | 14900 | 1.5-2.0 | 2.04 | +16.6 |
| 1.03. Kaz. | С-П-А | У1 | MS | 0.5-2.5 | lucerne | ОВРО | 7900 | 2100 | 8000-16000 | 10200 | 1.5-2.0 | 1.3 | -2.6 |
| | | | | | | К | 8200 | 2400 | 8000-16000 | 8500 | 1.5-2.0 | 1.04 | -40 |
| KKNIIZ | С-П-А | 1У | MS | 1-2.5 | lucerne of 2 year | ПО | 8780 | 6789 | 8000-16000 | 16830 | 1.5-2.0 | 1.9 | +8.5 |
| KKNIIZ | С-П-А | 1У | MS | 1-2.5 | | ПО | 8320 | 5623 | 8000-16000 | 15300 | 1.5-2.0 | 1.84 | +5.1 |
| Pakhta | Ц-П-Б | 1У | WS | 2-3.5 | lucerne | ОВРО | 9980 | 6500 | 8000-16000 | 25000 | 1.5-2.0 | 2.5 | +43 |

| Pilot plot index | Soil-climatic zone | Water allowance rayon | Salinity degree | Groundwater table, m | Agricultural crop | Information type | Water consumption during veg. per., m3/ha | | Water consumption limits after FAO (average), m3/ha | Water consump. exceeding or arr. to comp with FAO (average) | Yield, kg/ha | Irrigation water productivity (efficiency), kg/m3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | total | incl. at expense of water supply | | | | after FAO | actual |
| aral | | | | | | 90x90 К | 8500 | 7000 | 8000-16000 | 17600 | 1.5-2.0 | 2.1 | +20 |
| Khorezm branch | С-П-А | 1У | WS | 1.5-2.0 | lucerne 80x80 | ПО | 8920 | 5189 | 8000-16000 | 17750 | 1.5-2.0 | 1.99 | +20 |
| UNIIHL | С-П-А | 1У | MS | 1.5-2.0 | 80x80 | ПО | 7250 | 2400 | 8000-16000 | 4900 | 1.5-2.0 | 0.1 | -60 |
| | С-П-А | 1У | WS | 1.5-2.5 | lucerne 80x80 | ПО | 9270 | 4560 | 8000-16000 | 19860 | 1.5-2.0 | 2.14 | 22.3 |

Note: WS - weakly saline, MS - medium saline