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Review Article

SUBSTANTIATION OF COTTON IRRIGATION REGIME ON MEADOW-ALLUVIAL SOILS OF THE KHOREZM OASIS

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Abstract
The article provides a comparative analysis of the establishment of cotton irrigation regimes on irrigated meadow alluvial soils of the Khorezm region of Uzbekistan from a groundwater level of 2,0 - 3,0 m based on the methods of the Research Institute for Breeding, Seed and Agricultural Technology of Cotton Cultivation and FAO. Experiments on the irrigation regime of cotton were carried out with the following variants of irrigated soil moisture: 70-70-60%, 70-80-60% and 70-80-60% (increased irrigation rates by 30 %) Maximum field moisture capacity MFMC. To establish the irrigation regime for cotton according to the FAO method, the program CROPWAT and AquaCrop are used. The comparison of the results showed that, corresponding to the FAO method, the number of irrigations by 4-6 times more (given in small irrigation norm amounts that`s why numbers of watering multiplies) than by the method of the Research Institute for Breeding. The best results were obtained for creating a meliorative reclamative condition for the growth and development of cotton in the experimental plots, provided that the over-irrigation moisture in the soil was maintained at 70-80-60% of the Ultimate Field Moisture Capacity (UFMC). During the growing season, followings are necessary: light soil that was irrigated 6 times, in the cotton development phase according to the scheme 1-4-1, irrigation norms 437-825 m^3/ha, irrigation norms 3641-3676 m^3/ha, yield was 4.02 t/ha, an average mechanical structure of the soil must be irrigated 5 times, based on the 1-4-0 scheme, with irrigation norms of 494-664 m^3/ha and irrigation norms of 3090-3133 m^3/ha, yield 4.01 t/ha, heavy mechanical soil should be irrigated 4 times, corresponding to the scheme 1-3-0, with irrigation norms of 541-753 m^3/ha and irrigation norms of 2766-2786 m^3/ha, yield 3.93 t/ha. Compared with the production (control) option, the cotton yield was more than 0.98 t/ha, 0.93 t/ha and 0.88 t/ha.

Keywords: soil penetration, cotton, irrigation regime, water productivity, yield, centner.

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INTRODUCTION

Today, one of the ten global problems of the 21st century is the shortage of fresh water. Over the past 60 years, the consumption of drinking water on our planet has increased 8 times. By the middle of the century, many countries will have to import water. Water is a rather limited resource, it is now becoming an important key factor in geopolitics, and at the same time, one of the causes of global tension and conflict situations. World agriculture uses 2.8 thousand km^3 of fresh water per year. This accounts for 70 % of freshwater consumption in the world, which is 7 times more than the water used in the global industry. Most of the water in agriculture is used for irrigation. About 40% of world food and 60% of grain crops are produced on irrigated lands. According to the International Commission on Irrigation and Drainage, the world's irrigated land area is about 299.488 million hectares.

Unregulated use of water resources leads to their global deficit. The search for new sources of water resources requires large investments to maintain water management systems. Increasing the price of each cubic meter of water causes problems in the water supply of developing countries. If current patterns of water use and water consumption remain the same, then with an increase in population, water shortages will increase.

To achieve high and sustainable yields on irrigated lands, it is important to ensure timely supply of sufficient moisture required for plants, which will result in high and stable yields as a result of maintaining favorable water-nutritional, air, salt and thermal conditions through the use of scientifically-based regimes. Irrigation of major crops. The use of water-saving technologies proves high and stable yields and efficient use of water resources.

The irrigation regime of cotton in irrigated agriculture, taking into account the water and physical properties of the soil, as well as nutritional regimes for growth, development, yield and quality of cotton fiber in the Republic of Uzbekistan, were studied by scientists like: S.N.Ryzhov [1], V.E. Eremenko [2], M.P.Mednis [3, 4, 5, 6], Kh.A.Akhmedov [7], S.A. Gildiev[8], N.F. Bespalov [9, 10, 11], F.M.Rakhimbaev and others[12], K.M.Mirzajonov [13], G.A.Bezborodov[14], M.Kh.Khamidov [15, 16], A.E.Avliyaqulov [17, 18], B.S.Mambetnazarov [19], G.M. Satipov [20], Isabaev K.T. [21], B.Sh. Matyakubov [22, 23, 24, 25, 26] and studied by scientists in international: Blaine R. Hanson, Lawrence J. Schwankl, Allan Fulton [27], Beede R.H. and Goldhamer D.A.[28], Brown M.J. and Kemper W.D.[29], Coolidge P.S.[30], Guttman Joseph[31], Jeffrey T. Baker, Dennis C. Gitz, John E. Stout and Robert Joseph Lascano[32], Jing ZHANG [33], Kassam A.H. [34], Molden D. [35], Marx D. and Hutter J. [36], Mohan Reddy Junna[37], Stringham G.E. and Keller J.[38], Walker W. and Stringham J.[39], Wallender W.W. and Bautista E. [40].

Currently, there is not enough research in the country to develop and use science-based irrigation regimes for cotton due to the need to optimize and improve the efficiency of water use in a changing water use system, crop rotations, including cotton and winter wheat, with increasing water scarcity.

MATERIALS AND METHODS

When conducting research, analyzing the soil, observing cotton, measurements and analyzes were carried out according to the methods of the Institute of Cotton-growing "Methods of conducting field experiments", "Methods of agrochemical and agrophysical studies in irrigated cotton areas of field and vegetation experiments with cotton" [41], and also based on the method developed by FAO. The reliability and accuracy of the obtained data was analyzed by the generally accepted multi-factor method of B. A. Dospekhov [42], as well as using the mathematical statistical software SPSS (Statistical Package for Social Science), Statistica 7.0.

To select an experimental field site, the method was used by V.V. Shabanov [43], taking into account the natural and production conditions of the oasis, soil texture and location of the groundwater level. This method is characterized by a combination of both quantitative and qualitative characteristics of two natural systems for optimizing the experimental site: the microzone and microregion correspond to the main parameters of the experimental sites.

The main type (first testing) includes: the moisture content in the soil, moisture capacity, water permeability, soil texture, the amount of humus in the fertile layer (0-30 sm), the slope of the irrigated area. Second testing is the amount of cotton per 1 hectare, the amount of feed fertilizer and soil growth.

Comparisons using the method recommended by Shabanov, the results obtained by the Pascal program were 0.567.

The suitability of the selected pilot fields for irrigated lands in the Khorezm oasis was 56.7%. Based on this, the experimental fields were chosen correctly.

To select the experimental site, calculations were carried out, the site was determined to be representative, the widespread soil reclamation and hydrogeological conditions in the region were studied, it was 56.7%. Scientific studies at the experimental plots for a scientifically-based cotton irrigation regime were carried out in accordance with the methods adopted by the cotton-growing institute, as well as by the FAO (UN) method and corresponding to generally accepted empirical formulas. Scheme of experience to clarify the mode of irrigation of cotton is given in table 1.

Table 1. Experiment scheme for determining the mode of irrigation of cotton (2011–2013.)

Options	Pre-irrigation soil moisture (% of the maximum moisture capacity (MMC))	Irrigation rate, m^3 / ha
1	production control	actual measurements
2	70-70-60	deficiency of moisture in the layer 50-100-70 sm.
3	70-80-60	deficiency of moisture in the layer50-100-70 sm
4	70-80-60	with excess moisture deficit in the layer 50-100-70 sm. By 30%

Field experiments were made on the meadow-alluvial soils of the Bobo Omoniyo farm (light loam soils-experience 1, and medium loam soils-experiment 2) and the Abdulla farm (heavy loams soils-3) in the Yangibazar region of the Khorezm region of Uzbekistan.

The object of research is the mode of irrigation of cotton, the middle variety "Khorezm-127" on meadow-alluvial, different mechanical composition of soils at groundwater level 1.0-2.0 m and salinity 1-3 g / l in the Khorezm region.

Field experiments conducted in 4 replications. All observations, studies and calculations were carried out according to the methods adopted by the cotton research institute and the Tashkent institute of engineers of irrigation and agricultural mechanization.

Based on the experimental design, field experiments were carried out in 4 variants and 4 repetitions. The size of the experimental field is: the furrow length is 100 m, the distance between the furrows was chosen based on the mechanical composition of the soil, a = 0.6 m (light soil), a = 0.9 m (medium and heavy soil), number 8 rows, 4 of which are calculated, other protective strips and the area of one variant with light loamy soil is 8 x 0.6 x 100 = 480 m^2, with a repetition area of 480 x 4 = 1920 m^2, the total area of the experimental plot is 1920 x 4 = 7680 m^2 (Fig. 1).

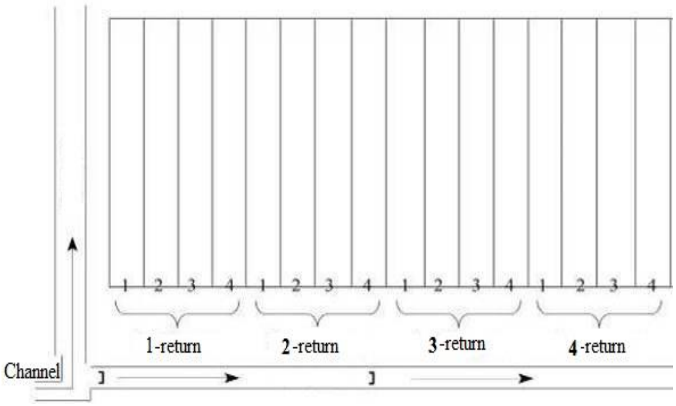

Figure 1. The scheme of the experimental plot

In the first experimental plot, the bulk soil mass at the beginning of the growing season in a layer of 0-50 sm (light loam) is (on average for three years) 1.30 gr/sm³ in a layer of 0-70 sm, 1.32 gr/sm³, and in a meter layer 1.32 gr/sm³.

In the second experimental plot, the bulk soil mass at the beginning of the growing season in the 0-50 sm layer (middle loam) is 1.37 gr/sm³ in the 0-70 sm layer: 1.38 gr/sm³, in the 0-100 sm layer: 1.35 gr/sm³.

In the third experimental plot, the bulk soil mass at the beginning of the growing season in the 0-50 sm layer (heavy loam) is 1.43 gr/sm³, in the 0-70 sm layer, 1.43 gr/sm³ and in the 0-100 sm layer, 1.41 gr/sm³. Because of agrotechnical measures carried out during the growing season, the bulk soil mass in all variants of the experimental plot increased.

The maximum field moisture capacity of the soil was: in the 0-50 layer: 19.36% (experiment 1), - 20.64% (experiment 2), and 21.69% (experiment 3); in the 0-70 sm layer: -19.41% (experiment 1) - 20.17% (experiment 2) and 21.84%

(experiment 3); in the 0-100 sm layer: -19.01% (experiment 1) - 20.32% (experiment 2) and 22.07% (experiment 3).

On the experimental plot 1 showed that the water permeability of the soil at the beginning of the growing season was 1616 m^3 or 0.449 mm/min, at the end of the growing season were: option 1: 1335 m^3 or 0.371 mm/min; option 2: 1384 m^3 or 0.384 mm/min; option 3: 1464 m3 or 0.407 mm/min; option 4: 1406 m^3 or 0.391 mm/min.

On experimental plot 2 showed that the water permeability of the soil at the beginning of the growing season was 1279 m^3 or 0.355 mm/min, and by the end of the growing season: option 1: 1012 m^3 or 0.281 mm/min; option 2: 1114 m^3 or 0.309 mm/min; option 3: 1193 m^3 or 0.331 mm/min; option 4: 1119 m^3 or 0.311 mm/min.

On experimental plot 3 showed that the water permeability of the soil at the beginning of the growing season was 791 m^3 or 0.220 mm / min, and at the end of the growing season: option 1: 641 m^3 or 0.178 mm / min; option 2: 666 m^3 or 0.185 mm / min; option 3: 719 m^3 or 0.200 mm / min; option 4: 690 m^3 or 0.192 mm / min.

Such patterns were in all experiments and variants. Experiments were carried out during three years of observations 2011-2013 by using programs CROPWAT and Aquacrop. These programs required data of meteorologic stations (temperature, precipitation, moisture capacity, velocity of wind), mechanical structure of the soil, level of groundwaters, water mineralization in order to determine evapotranspiration. As a result, were calculated regime, norms, quantity and terms of irrigation.

From the point of view, the initial water permeability of soils based on V.A.Kovda [44] was satisfactory, and according to S.V.Astanov [44] from medium to weak.

RESULTS

In field studies, the deviation of the actual soil moisture from the target was ± 2.0 % of MMC (lowest humidity). During production control (option 1), the actual soil moisture before cotton irrigation in the years of research was 53.1-67.3 % of MMC.

The study found that the actual depth of soil wetting after irrigation depends on a given regime of pre-irrigation moisture and irrigation rate. In option 1, where irrigation was carried out with large norms up to 1308 m^3/ha (at the production control), the wetting depth reached 120-130 sm. In versions where irrigation was carried out with irrigation norms calculated from a moisture deficit of the layer 0-100 sm, the average wetting depth was 70 - 90 sm.

The highest yield of raw cotton was obtained in option 3, where irrigation was carried out at a pre-irrigation soil moisture of 70-70-60% of HB.

$$m = (W_{HB} - W_{\Phi}) \cdot 100 \cdot \delta \cdot h + k$$

In this version, with an irrigation rate of 4800-6000 m3 / ha, the research years are 41.1 c / ha of raw cotton with a variation in years from 37.1 (1994) to 45.1 (1997) centners per hectare. The lowest yield was obtained in production control, with an irrigation rate of 5400-7050 m^3 / ha, an average of 29.5 kg / ha was obtained over the years of research. In the "hard" mode of pre-irrigation soil moisture (60-70-60% of HB), a crop of raw cotton was obtained over an average of ten years studying the irrigation rate of 4300 - 4900 m3 / ha. Maintaining an optimal regime of pre-irrigation soil moisture provides a somewhat ripened.

The calculation of irrigation water was accomplished using a water-measuring device "Chipolleti". The findings of the study are given below. Maintain the pre-irrigation soil moisture at 70-80-60% of MMC (option 3), the first experiment required 6 irrigations based on the scheme 1-4-1, irrigation rates 437-825 m^3 / ha and the irrigation rate average - 3658 m^3 / ha. The irrigation period ranged from 15 to 24 days.

To maintain pre-irrigated soil moisture at 70-80-60 % of MMC (option 3), the second experiment required 5 irrigations corresponding to the 1-4-0 scheme, irrigation rates of 494-664 m^3 / ha, and an average irrigation rate of 3115 m^3 / ha of the irrigation period was 20-23 days.

At the 3rd experimental plot, to maintain pre-irrigation soil moisture at a level of 70-80-60 % of MMC (option 3), it was necessary to conduct 4 irrigations according to the 1-3-0 pattern, irrigation norms 541-753 m^3 / ha and the irrigation rate average - 2779 m^3 / ha. The irrigation period was 26-29 days (Table 2).

Table 2 Cotton Irrigation Regime

Experienced plot	Options	Irrigation rates, m^3 / ha	Irrigation sxems	Irrigation norms, m^3 / ha	The irrigation period, day	Cotton yield, tonn / ha
1	1	1205 - 1308	1-2-1	4967 – 5099	23-35	3.04
	2	439 - 882	1-3-1	3874 – 3903	21-29	3.22
	3	437 - 825	1-4-1	3641 – 3676	15-24	4.02
	4	576 - 1078	1-3-1	3967 – 4005	19-26	3.55
2	1	1196 - 1300	1-2-1	4999 – 5015	27-35	3.08
	2	491 - 980	1-3-1	4271 – 4319	22-27	3.31
	3	494 - 664	1-4-0	3090 – 3133	20-23	4.01
	4	642 - 1173	1-3-1	4344 – 4427	23-28	3.62
3	1	1144 - 1293	1-2-1	4777 – 4895	28-33	3.05
	2	542 - 1107	1-2-1	3705 – 3782	27-30	3.11
	3	541 - 753	1-3-0	2766 – 2786	24-26	3.93
	4	696 - 1319	1-2-1	3901 – 3997	26-31	3.76

The lowest yields of raw cotton were obtained in the production control (option 1), where the irrigation rate was 4967-5099 m^3/ha, and the average yield was 3.04 tonn/ha (experiment 1).

In option 2, where the pre-irrigation soil moisture was maintained at 70-70-60 % of MMC (hard mode), the average yield for all experimental research sites was 3.11-3.31 tonn / ha with an irrigation rate of 3705-4319 m^3/ha.

Relatively high yields of cotton were obtained in option 3, where pre-irrigation soil moisture was maintained at a level of 70-80-60 % of MMC 3.93-4.02 tonn/ha with an irrigation rate of 2766-3676 m^3/ha.

In the 4th variant, where the pre-irrigation soil moisture was maintained at 70-80-60% of MMC (irrigation rate, increased by 30%), the average yield for the experimental plots was 3.55-3.76 tonn/ha at the irrigation rate 3901- 4427 m^3/ha.

The analysis of the above results leads to the following, in all experiments and options, the highest yield of raw cotton was obtained in option 3, where irrigation was carried out at a pre-irrigation soil moisture of 70-80-60% of HB. In this version, with an irrigation rate of 2766-3676 m^3/ha, an average of 3.93-4.02 t/ha of raw cotton was obtained on average over the years of research.

The lowest yield was obtained in production control, with an irrigation rate of 4967-5099 m^3/ha, an average of 3.04 t/ha was obtained over the years of research.

In addition, Water consumption and cotton irrigation regime were determined by the FAO method and empirical formulas.

When making more exact the regime of irrigation of cotton by the FAO method, the following factors were taken into account [30]:

1. Climatic conditions of the experimental site: air temperature, amount of precipitation and their distribution by months; humidity and evaporation; wind speed, direction and repetition.
2. Soil conditions: soil texture, water-physical properties, type and degree of salinity.
3. Hydrogeological conditions: groundwater depth, water salinity, changes in groundwater level.
4. Economic and economic conditions: agricultural technology, soil fertility, cotton productivity.
5. The biological properties of cotton.
6. Accepted irrigation methods and irrigation techniques.

Water consumption and irrigation regime of cotton according to the method developed by the International Food and Agriculture Organization (FAO), based on the analysis of uncontrolled climatic factors and AquaCrop computer programs.

The water balance of the calculated soil layer under these programs is determined by the dependence:

$$W_{r,t+1} = W_{r,t} + (P-RO) + I + CR - E - T_r - DP$$

where P - precipitation;

RO - precipitation loss due to surface outflow;
I - irrigation rate;

CR - capillary raising of groundwater;
E - soil evaporation;

T_r - plant transpiration;

DP - depth filtering;

$W_{r,t}$ - water volume in the active soil layer.

Evapotranspiration in the program is determined by the formula Penman-Monteith:

$$E = E_0 \cdot K$$

where, E - evapotranspiration, mm;
K - coefficient depending on the type of culture, K = 0,6–0,8;

$$E_0 = \frac{H \cdot \Delta + \gamma \cdot E_y}{\Delta + \gamma}$$

where, H - the amount of energy absorbed by the soil;

Δ – maximum vapor pressure;
γ - constant value, γ = 0,48-0,50;

E_y - possibility of air conditioning.

The results of cotton irrigation regime data (experiment 1, light loamy soil) are shown in Figure 2.

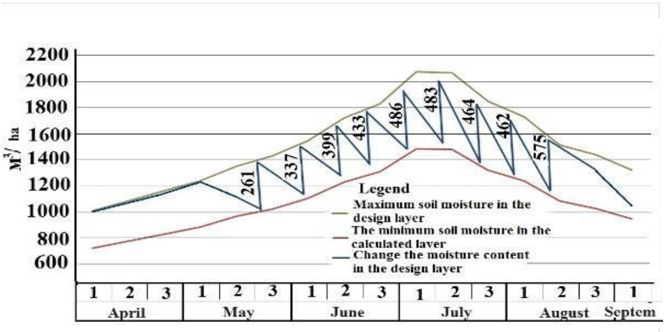

Figure 2. Irrigation regime of cotton according to the FAO method (experiment 1).

The results obtained by the FAO method and field research based on the methodology of the Institute of Cotton Industry showed that when using the FAO method, the number of irrigations is 3-5 more than the number of irrigations established in field experiments, and irrigation rates are small (261-575 m^3/ha) compared with field data. Such irrigation norms can provide uniform field moistening and can be used with water-saving irrigation methods, such as sprinkling, drip irrigation, etc.

The use of this software and computer technologies in establishing scientifically based irrigation regimes for agricultural crops is highly efficient. The program used Aquacrop gave the degree of accuracy of 5-8 %.

The regime of irrigation of cotton primarily depends on the characteristics of water consumption. The water consumption of the irrigated field is determined by a number of factors - climatic, soil-reclamation, hydrogeological conditions, the type and age of the cultivated crop, soil moisture and agricultural practices.

In the practice of irrigated agriculture, there are two groups of methods for determining the total water consumption, based on the direct measurement of the total water consumption in the field (according to the water balance in the calculated soil layer or lysimeters) and on the experimental establishment of the relationship between the total water consumption of crops with climatic, meteorological and agricultural conditions, expressed in the form of indicators and ratios. These methods are represented by the formulas of two design groups. The parameters of the first group do not reflect a direct connection with the laws of physical evaporation, and the parameters of the second group, on the contrary, are direct indicators of the laws of physical evaporation.

The methods of the first group allow the most accurate determination of the total water consumption in relation to specific natural and agricultural conditions of crop cultivation. However, they require the organization of pilot studies preceding the design and construction of irrigation systems, long-term research, high costs of funds and labor.

The methods of the second group, in principle, are also based on pilot studies, which establish the dependence of the total water consumption of crops on certain indicators. However, the volume of research is reduced, since their duration is determined by the time necessary to substantiate the calculated dependence. Such dependencies are recommended to be used under conditions similar to those in which they were obtained. Currently, when establishing the calculated irrigation regimes in the world practice of irrigated agriculture of the second method, represented by empirical dependencies, they have become more widespread.

The research used the formula proposed by the scientists of the Uzdavsuvloiha design institute (Schroeder, Safonov and Parenchik, [31]). When designing various water management facilities, it uses the method of calculating irrigation norms of crops by evaporation. The irrigation rate in this case is calculated by the formula:

$$M = 10 * (E - O) * K_1 * K_2 * K_3 \text{ , m}^3\text{/ha}$$

where, M - irrigation rate, m³ / ha;

E - evaporation, mm;

O - amount of precipitation, mm;

K_1 - coefficient depending on the type of cultivated crop: for cotton - 0.63;

K_2 - coefficient depending on the length of the irrigation period;

K_3 - coefficient used to differentiate irrigation norm by hydromodular areas.

The total value of volatility (E) for the warm half-year (IV-IX) is determined by direct observation according to the empirical formula of N. N. Ivanov [13] with the introduction of the coefficient = 0.8:

$$E = 0{,}0018 * 0{,}8 * (25 + t)^2 * (100 - a), \text{ mm}$$

where, E - evaporation, mm;

t - monthly average air temperature, 0C;

a - monthly average relative humidity.

For the best option, based on the above field studies, the water consumption of cotton was determined by the first method, as well as by the first group of calculation formulas for determining evapotranspiration.

The results obtained are summarized and analyzed below.

On the basis of the water ball of the irrigated field, the water consumption of the cotton plant at the experimental plots was determined; on average, in 2011-2013, it was estimated. 5940-9355 m³/ha, including the irrigation rate of 2779-5034 m³/ha or 47-54%, groundwater use 1445-2619 m³/ha or 24-28%, use of soil moisture reserves 909-1493 m³/ha or 12.6-16.5% and due to precipitation 491 m³/ha or 5.3-8.3%. Water consumption and irrigation norms of cotton have also been determined based on empirical formulas (Figure 3 and 4).

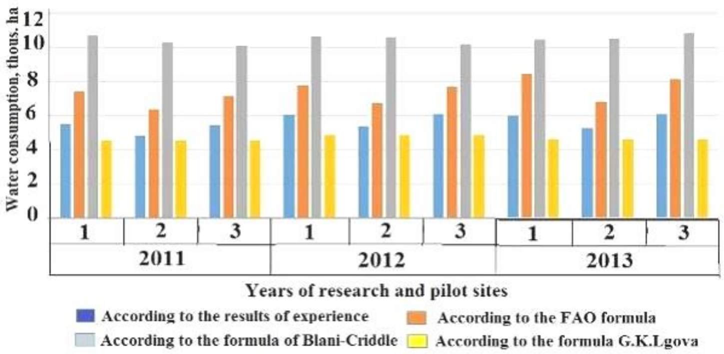

Figure 3. Change in water consumption by year.

In all experimental plots the best option was option 3, where the pre-irrigated soil moisture was at the level of 70-80-60% of MMC. To obtain 1 tonn of raw cotton, 708 m³ was used (experiment 3) - 910 m³ (experiment 1). In the production control (option 1), this indicator was 1591 m³ (experiment 3) - 1647 m³ (experiment 1), which is 737-883 m³/tons more than in the optimal variant 3 (Figure 3).

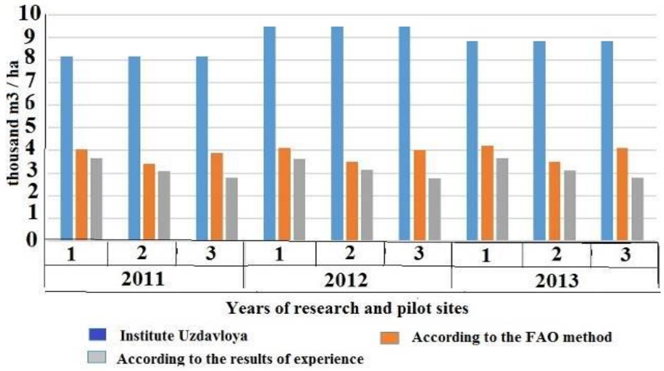

Figure 4. Changes in the irrigation rate by year.

To determine the irrigation rate, the indicators of field experiments and the FAO methodology were closed. The correlation coefficient for the calculation of irrigation rates was 0.71-0.80.

For the calculation of water consumption, the correlation coefficient: the FAO method and the results of the experiment 0.47-0.60; Formula G.K. Lgova and the results of the experiment 0.76-0.94. In this regard, it can be concluded that the FAO method can be used in the calculation of the irrigation norm, and the formula of G.K. Lgova in the calculation of water consumption.

CONCLUSIONS

1. The most favorable ameliorative conditions for the growth and development of cotton in the experimental plots are created during irrigation with a front-irrigated soil moisture of 70-80-60% of MMC. Followings are necessary:

- on light loamy soils, to conduct 6 irrigations according to the scheme 1-4-1, irrigation norms 437-825 m^3 / ha and irrigation norms 3641-3676 m^3 / ha;
- on medium loamy soils, to accomplish 5 irrigations based on the scheme 1-4-0, irrigation norms 494-664 m^3/ha and irrigation norms 3090-3133 m^3/ha;
- on heavy loamy soils, conduct 4 irrigations, corresponding to the scheme 1-3-0, with irrigation rates of 541-753 m^3/ha and irrigation rates of 2766-2786 m^3/ha.

2. The total evaporation, irrigation and irrigation norms of cotton are established according to the method developed by the International Food and Agriculture Organization (FAO), based on the analysis of uncontrolled climatic factors and AquaCrop computer programs. Comparison of the results obtained by the FAO method and field studies according to the methods of the Institute of Cotton-growing showed that when using the FAO method, the number of irrigations is 3-5 times more than the number of irrigations established in field experiments, and the irrigation rates are small (261-575 m^3 / ha) compared to field data. Such irrigation rates with a superficial irrigation method do not provide uniform field moistening and can be used with water-saving irrigation methods, such as sprinkling and drip irrigation, and others. The use of this software and computer technologies in establishing scientifically based irrigation regimes for agricultural crops is highly efficient. Used program AquaCrop 5-8%.

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