Water-saving irrigation technologies for cotton in the conditions of global climate change and lack of water resources

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Abstract. The article presents the results of the experiments on the study of irrigation technologies of cotton in the conditions of grassy-alluvial, saline, and medium loam soil of the Bukhara oasis by lying black film on cotton furrows and using polymer complexes. In field experiments, irrigation technology was carried out by using the irrigation received moisture content of the soil recommended for grassy-alluvial, saline, and medium loam soil of the Bukhara oasis at 70-80-65% compared to LSMC. When the cotton was irrigated 4 times according to the scheme 1-3-0 with irrigation norms of 767, 604, 622, 644 cbm/ha and seasonal irrigation rate of 2637 cbm/ha by covering furrows with the black film and 1818 cbm/ha compared to the control option, the river water was economized and the yield was higher which was 46.8 h/ha. Even when irrigated by using polymer complexes, cotton was irrigated 4 times according to scheme 1-3-0 with irrigation norms of 779, 616, 650, 667 cbm/ha and seasonal irrigation rate of 2712 cbm/ha by using polymer complexes and in this regard, 1743 cbm/ha of the river water as compared to the control option was saved while the yield was 44.8 h/ha. Increased cotton yield by 3.0-5.0 h/ha and saving river water by up to 30-40% was achieved through the irrigation technology by using the screen, which was created by covering the black film and polymer complexes.

1. Introduction
In Uzbekistan, irrigated agriculture plays an important role in human activities. Irrigation is the basis of the agro-industrial complex, which is the basis of food security in the dry climatic conditions, the basis of the well-being of the rural population, the protection of land and its productivity, and the rapid pace of development [1].

Today the water resources have a strategic impact in the Bukhara region of Uzbekistan and about 95% of agricultural products produced in irrigated areas of the region. Conservation and efficient use of water resources are imperative [2]. As a result of the state policy in the field of rational use of water resources in Uzbekistan, the total amount of used water is 64 billion cubic meters annually compared to the average of 51 billion cubic meters diminished as in the 1991s (fig. 1). If we used water from 1 hectare irrigated area in the 1991th years to 18.0 thousand cbm/ha, today it is 10.2 thousand cbm/ha (fig. 2).
The problem of global climate change is urgent on the agenda of mankind, which means not only an increase in the average annual temperature on our planet but also the change in all the entire geotechnical system, the rise of the world's oceans, the melting of glaciers and permafrost, increase in uneven precipitation, changing of river flow regime and other changes depended on climate instability. There may be the melting of glaciers in mountainous areas, and a decrease in their volume and river flow may decrease in the next 20 years, in particular, the Amudarya and partially the Syrdarya and Zarafshan by 25-30%, which will cause serious problems in the region, and in the driest years, the average annual water mineralization in the lower part of the Amudarya will decrease by 1.5 times as a result of global warming.

Climate change causes evaporation of water from the water surface by 10-15%, water consumption by 10-20% more due to increased degradation of vegetation and irrigation rates. This leads to a sharp increase in water consumption by 18% on average, which undoubtedly hinders the further growth of agricultural production.

Cotton is currently planted on 31.8 million hectares around the world, producing more than 24.9 million tons of cotton fiber annually. One of the global challenges of the XXI century is the extreme shortage of water resources, and over the past 60 years, the consumption of potable water has increased 8 times over the world. According to the International Commission on Irrigation and Drainage, the area of irrigated land in the world is 307.955 million hectares. At the same time, 2.8 thousand cbkm of fresh water is spent on world agriculture per year, which is 70% of the available fresh water consumption.

The main water resources of the region in which we live, namely the Aral Sea basin, consist of the waters of the Amudarya and Syrdarya rivers, the average long-term volume of which is 114.4 km³, and we manage them and consume them together with our neighboring countries. In particular, only 20% of the water used in our country is formed in the territory of our republic, and the remaining 80% is formed due to snowfalls and glaciers in the territory of the neighboring countries, including Tajikistan and Kyrgyzstan. In recent years, water consumption has been declining as a result of climate change and water scarcity, agricultural diversification, the introduction of water-saving irrigation methods, and others (fig. 1). In this case, to efficiently use the water resources available in the Republic, it is necessary to develop and introduce modern resource-intensive technologies in irrigated agriculture.

**Purpose:** The purpose of this work is to develop water-saving irrigation technologies that ensure a high and high yield of cotton by studying cotton irrigation technologies in the grassy-alluvial, saline,
and medium loam soil of the Bukhara oasis, economizing river water due to global climate change and increasing water scarcity.

**Scientific novelty of applied research:** Save of water resources, reduction of agro-technical measures, prevention of deterioration of the ecological reclamation situation of the environment, reduction of irrigation waterways, improvement of economic efficiency of farmer farms have been achieved by studying the impact of irrigation technologies on the growth, development, fertility, land reclamation under the conditions of the grassy-alluvial, saline and medium loam soil of the Bukhara oasis, where the water level is 1.5-2.0 m, mineralization is 1-3 g/l, the influence of the first time irrigation by using polymer complexes and lying black film on the furrows.

Jiangtao Wang et al and Zhenyu Zhang et al researched that mulched drip irrigation is a common water-saving irrigation technology that can improve water resource utilization efficiency in arid areas affect evapotranspiration (ET) processes while conserving water [3, 4].

Changjian et al conducted researches on irrigation and fertilizer management for sustainable development of agriculture in the arid and semiarid regions [5].

There are numerous sources of water-saving irrigation technology. Guang Yang et al, Hong Wang et al, Lujun Ding and Yuhong Liu, Biao Zhang et al, Xiuzhi Chen et al, Di Wu et al, and Yanhua Zhuang et al conducted researches on water-saving irrigation technologies under different conditions [6,7,8,9,10,11,12]. A couple of researches have studied film mulching (plastic film) effects on soil water dynamics in irrigated fields and researched water use efficiency, growth, yield, and quality of different agricultural crops in deficit irrigation conditions [13, 14, 15, 16, 17].

On meadow-alluvial, on the mechanical composition of medium loamy, medium-saline soils of the Bukhara region, with leaching irrigation using the chemical compound Biosolvent at the rate of 8.0 l/ha ensures not high efficiency of washing water, but also saving river water by 30 % [18, 19].

Role of polymer complexes in saving water resources: P.V. Krotov learned about the effects of hydrogels on the hydrological properties and the crop rotation of rich nutritious crops. For the conditions of the area to be studied, the rational dose of hydrogel for the exchange of v was proposed (for 3 years 2000 kg /ha), while the constant consumption of mineral fertilizers was introduced unchanged, the yield of the exchange crops (barley + perennial grasses) without regard to climatic conditions ensures an increase of 2.2-2.5 t/ha. When hydrogel is used in crop rotation, water-physical properties of light soils are improved: the optimal volume of soil is reached 1.35-1.40 g/cbcm (1.51 g/cbcm control variant) [20].

According to P.V. Krotov when the hydrogel is introduced, inefficient moisture consumption is reduced by 30-50%. The optimal water balance is achieved when the hydrogel dose is 2000 kg/ha. Polymer hydrogel reduces the rate of water filtration in soil by 15-35%. Moisture evaporation from the hydrogel surface is 25% less than from the water surface. When the number of hydrogels was introduced into the barley sowing area at 2000-3000 kg/ha and the amount of precipitation was up to 160 mm, the microflora activity was high. As humidity increases, it decreases [20].

According to Yu.G. Bezborodov, water resources of 1153 cbm/ha or 24% in the cultivation of cotton, or 1920 cbm/ha or 28% in the cultivation of beetroots are economized by covering the furrows with the screen (polyethylene film, kraft paper, straw), which is water-saving, soil-protecting and environmentally safe ploughing [21].

As a result of the research, it was shown that there was an increase in the yield of agricultural crops as follows: 1.1 t/ha (29.4%) for cotton; 0.16 t/ha (3%) for maize grain; 11.9 t/ha (15.3%) for beetroot. Together with the Research Institute for mechanization and electrification of agriculture, the design “film stacker” was developed to draw a screen on the racks, and it was tested. Calculations showed that the irrigation of crops on screened furrows is more energy-efficient and cost-effective than the traditional method.

N.B. Sadovnikova studied the water retention ability of polymer hydrogels with high swelling in light loam soil, their influence on the structure of water permeability, and soil porosity by using modern instrumental methods. When the amount 0.1-0.2% of highly swollen polymer clay is given,
the filtration coefficient decreases and makes the permeability closer to the saturation level of loam soil, and also increases the permeability of capillary and pleural moisture in an unsaturated state. Also, a polymer with high swelling ability increases the water retention capacity [22].

In addition to reducing water absorption into the soil, it creates a screen that stops the capillary absorption of the soil and prevents the salinity of soluble salts, thus preventing secondary salinization. The technological method for the introduction of a strong swollen polymer has been scientifically justified.

D.G.Akhmedjonov found a significant increase in water saving and cotton yield as a result of research using polymer-polymer complex (PPC) in the brown soils with deep groundwater. He came to the conclusion that the yield per hectare is 7.8 hundredweight when irrigated through an elevated screen, which is formed using a water-saving PPC, and when irrigated through an underground screen, 8.3 hundredweight per hectare [23].

D.G.Akhmedzhonov conducted a lysimetric survey to determine the irrigation standards for cotton irrigation on the screen of the inter-polymer complex containing mineral fertilizers. In this regard, it was reported that underground water absorption was reduced by 33-36% compared with irrigation norms, the number of mineral fertilizers in the active soil layer retained 25% more nitrogen than in the control in the experimental lysimeter [24].

According to A.Shamsiev, in typical gray and low-saline and saline sulphate soil, intermittent irrigation of cotton during the growing season, the seasonal water content in the 0–50 cm compact layer of the soil root system: mechanical composition on medium-sized loam soil 450-500 cbm/ha and meadow soil of moderate loamy meadow soil with the mechanical content of 350-400 cbm/ha and pre-irrigation moisture content of the soil in the order of 65-65-60% and 70-70-60% compared to LSMC and it is noted that the highest yields of cotton are obtained from covering with inter-row polyethylene film and mulching with straw, and the additional cotton yield is 4.9-6.8 and 6.1-8.1 h/ha, respectively [25].

2. Methods

Scientific-research works were carried out on irrigated lands of the “Educational-Scientific Center” of the Bukhara branch of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, situated in the Khodja Yakshaba RCG, Kagan district in Bukhara region. The educational and scientific center specializes in cotton growing, grain, and gardening. On the lands of the educational and scientific center, collector-trench networks have been restored, it includes an open trench 4.7 km long and irrigation networks with an engineering feature. Water for crops is delivered to the fields through horns and ditches, and crops are furrowed and irrigated. The farm's soil is moderately saline.

Field experiments were conducted to study the growth and yield of the “Bukhara-6” variety of cotton on grassy-alluvial soil (87.7%), which makes up the largest area on the irrigated lands of the region and in conditions where the depth of settlement of gray water is 1.5- 2.0 m. The experiments were carried out on the following systems.

| №  | Irrigation technologies                              | Pre-irrigation soil moisture, in % compared to LSMC | Computation layer |
|----|-------------------------------------------------------|----------------------------------------------------|-------------------|
| 1. | furrow irrigation (control)                           | factual measurements                                | factual measurements |
| 2. | irrigation with covering black film on furrows        | 70-80-65 %                                         | according to the moisture deficit in the layer 0-100-70 sm |
| 3. | irrigation with using polymer complexes for furrows   |                                                    |                    |
Field experiments were conducted with the same fertilizing norms and varieties in three repetitions. The options consist of 8 rows with a furrow spacing of 90 cm, from which all the calculation work was carried out on the four furrows in the middle, two rows on the side are protective rows.

Field, laboratory experiments, and phenological observations were conducted on the basis of “Methods of Conduction of Field experiments” (Cotton breeding, seed production, and cultivation agrotechnologies research institute. 2007). The following observations and studies were conducted in the field of cotton:
- Study of soil conditions of the experimental field. For this purpose, a complete soil section was dug up to the depth of groundwater in the experimental field prior to sowing, soil samples were extracted from the genetic layers, and laboratory conditions revealed its mechanical composition, humus, nitrogen, phosphorus and potassium salts, and soil salts;
- the volume of the soil of the experimental field was determined annually by a roller of 10 cm height on layer 0-100 cm at the beginning and end of vegetation;
- permeability of water of the experimental field soil was determined annually by the cylindrical circle based on the Nesterov method at the beginning and end of vegetation;
- field moisture capacity of the experimental field was determined before the start of the experiment, with a depth of 0–100 cm each 10 cm by pumping 2000–3000 cbm of water to a 2x2 m area according to the Rozov method;
- study of the depth and mineralization of the groundwater level in the experimental field. For this purpose, observation wells were installed in all versions of the second turn. Each time before and after irrigation, groundwater samples were taken from observation wells using special devices, and the amount of salt in them was measured by a condenser. The depth of groundwater in monitoring wells was measured every 10 days;
- changes in soil moisture content at the beginning and end of the growing season were detected in digital laboratory equipment that measures humidity at a depth of 0-100 cm before and after an irrigation (3 days);
- water consumption in the experimental and control fields was measured using a “Chippoletti” water measurement device (0.50 m) and calculated according to the schedule;
- measurements were conducted by conductometer for 0–100 cm of soil at the beginning and end of the vegetation period at each and every 10–10 cm for all soil samples to determine the salinity of the experimental field soil;
- growth and development of the cotton grown on experimental fields were carried out according to the methodology adopted by the Research Institute of agrotechnologies of cotton selection, seed cultivation.

Field, laboratory experiments, and phenological observations were conducted on the basis of “Methods of Conduction of Field experiments” (Cotton breeding, seed production and cultivation agrotechnologies research institute 2007).

Furrows were covered with black film prior to the first irrigation (Pic. 1), and then any agricultural vehicles did not enter the experiment field.

The composition of the polymer complex: it consists of water 470 l/ha + nitrogen (urea) 40 kg / ha + phosphorus (superphosphate) 20 kg/ha + MFS 2% 8 kg/ha + Na-KMTs 2% 8 kg/ha + OFC 800 g/ha. These polymer complexes are prepared in experiments before every irrigation and sprinkled on furrows (fig. 2).

3. Results and Discussion
The order of irrigation in the cultivation of agricultural crops should provide for the necessary water regime for each type of plant in certain climatic conditions.

The purpose of scientific observations is to change the irrigation regime of the cotton and determine its optimal type depending on the water-physical properties of the soil and the method of irrigation of the soil near 1.5-2.0 m, mineralization 1-3 g/l, and medium-coarse soils. The experiments were carried
out in two fields with the same mechanical composition. When studying irrigation procedures, the norms, terms, and amount of each water supply were determined, as well as seasonal irrigation methods, which depend on the level of soil moisture and specific climatic indicators. Once, the irrigation rate was measured using a “Chipoletti” water measurement device. When calculating the rate of irrigation, taking into account the water-physical properties of the soil and the depth of moisture, according to the specified rate, soil moisture was calculated by the formula of S.N. Ryjov (1948).

\[ m = 100 \cdot h \cdot J \cdot (W_{LSMC} - W_{AH}) + K \text{ cm}^3/\text{ha} \]  

(1)

\[ W_{LSMC} \] is the limited moisture capacity of the field compared with the mass of soil, %; 
\[ W_{AH} \] is the actual humidity before irrigation compared with the mass of soil, %; 
\[ J \] is the volume soil weight, g/cm³; 
\[ h \] is the value of the computation layer, m; 
\[ k \] is the water consumption for evaporation in irrigation, cm³/ha (10% of moisture insufficient in the calculation layer)

| Variants | Indicators | Irrigations 1 (灌溉日期) | Irrigations 2 (灌溉间隔, 日) | Irrigations 3 (灌溉标准) | Seasonal irrigation standard (灌溉标准, cm³/ha) |
|----------|------------|------------------------|--------------------------|------------------------|------------------------------------------|
| 1        | irrigation date | 12.06                  | 24                       | 23                     | 24.08                                    |
|          | irrigation interval, day |                  |                          |                        |                                          |
|          | irrigation standards | cm³/ha               |                          |                        |                                          |
|          | irrigation date | 1226                   | 1171                     | 992                    | 1066                                    |
|          | irrigation interval, day |                  |                          |                        |                                          |
|          | irrigation standards | cm³/ha               |                          |                        |                                          |
| 2        | irrigation date | 17.06                  | 08.07                    | 31.07                  | 23.08                                    |
|          | irrigation interval, day |                  |                          |                        |                                          |
|          | irrigation standards | cm³/ha               |                          |                        |                                          |
|          | irrigation date | 767                    | 604                      | 622                    | 644                                     |
|          | irrigation interval, day |                  |                          |                        |                                          |
|          | irrigation standards | cm³/ha               |                          |                        |                                          |
| 3        | irrigation date | 18.06                  | 07.07                    | 28.07                  | 19.08                                    |
|          | irrigation interval, day |                  |                          |                        |                                          |
|          | irrigation standards | cm³/ha               |                          |                        |                                          |

In the first variant of production control, the irrigation scheme during the growing season was 1-3-0, the cotton was watered three times with watering up to 1226 cm³/h in the phase of flower germination, at the end of flowering, up to 992-1171 cm³/h, and the seasonal rate irrigation was 4455 cm³/h.

In the 2nd variant, the irrigation scheme with irrigation technology lying the black film on the furrow was 1-3-0, once when watering the standard at 767 cm³/h in the flowering phase, the cotton was irrigated three times when watering the standard at 604-644 cm³/h in the flowering phase, and the standard of seasonal watering was 2637 cm³/in comparison with the control. In the 3rd variant, the irrigation scheme for each furrow with a polymer complex is 1–3–0, with one irrigation rate of 779 cm³/ha in the flowering phase, with three irrigation standards for the flowering sprouts at 616–667 cm³/ha. Irrigation and seasonal irrigation standard is 2712 cm³/ha, which was 1743 cm less than the control option.
The influence of all agrotechnical measures used in the experiments is measured by the cotton yield. In the course of research in the conditions of meadow-alluvial soil of the Kagan district of the Bukhara region, the influence of the “Bukhara-6” variety of cotton on fertility indicators in various agricultural technologies was established (Table 3).

**Table 3. Impact of irrigation technologies on the productivity of cotton**

| Variants | Irrigation technologies                          | Fertilizer norms, kg/ha | Repetitions | Average productivity, (h/ha) |
|----------|--------------------------------------------------|-------------------------|-------------|-----------------------------|
|          |                                                  | N  | P  | K  | I   | II  | III |                     |
| 1        | furrow irrigation (control)                       | 250| 175| 100| 42.3 | 41.6| 41.5| 41.8                 |
| 2        | irrigation with covering the black film on furrows |                |             | 46.6 | 47.4 | 46.3| 46.8                 |
| 3        | irrigation with using polymer complexes for furrows|                |             | 45.3 | 44.9 | 44.2| 44.8                 |
In the course of our experiments, the cotton yield productivity in the 1st variant, which was grown under the conditions of the “Bukhara-6” variety of cotton amounted to 42.3; 41.6 and 41.5 kg/ha, an average of 41.8 kg/ha. During the observations, the cotton yield was 46.6; 47.4 and 46.3 kg/ha, the average yield was 46.8 kg/ha and was 5.0 kg/ha higher than the control when it was irrigated with lying the black film. Productivity in the technology of irrigation from screen furrows from polymer complexes was equal to an average of 44.8 hundredweight in repetitions and was higher for 3.0 hundredweight than in the control variant. The results of the study showed that the highest yield in the experimental plot was 46.8 kg/ha when lying with black film and 44.8 kg/ha when irrigated with a screen from polymer complexes, and the cotton yield (production control) was 3-5 kg/ha more than the yield of cotton (production control) grown in the household.

4. Conclusions
Due to global climate change and increasing lack of water resources, as a result of the use of water-saving irrigation technologies and procedures to mitigate water shortages in the condition of the grassy-alluvial, saline and medium loam soil of the Bukhara oasis, to save water resources:
- with a black film on the furrow and the pre-irrigation moisture content of the soil is maintained at 70-80-65% based on LSMC, when irrigated with cotton irrigation scheme 1-3-0, with irrigation rates of 604-767 cbm/ha and seasonal irrigation rate of 2637 cbm/ha, river water saving is 1818 cbm/ha as compared to the control option and cotton produces 46.8 h/ha, that is, 5.0 h/ha more than control;
- when in irrigation technology of furrows formed by screening polymer complexes, the pre-irrigation soil moisture content is 70-80-65% based on LSMC, in cotton irrigation scheme 1-3-0, with irrigation standards of 616-779 cbm/ha and seasonal irrigation of 2712 cbm/ha, river water saving is 1743 cbm/ha compared to the control option and cotton yields 44.8 h/ha, that is, 3.0 h/ha additional cotton yield;
- when the irrigation technology with the black film and making the screen from polymer complexes on furrow irrigation is used, the environmental pollution is avoided, and in the case of water scarcity, irrigation of river water by 30-40% economizes. At the same time, it is possible to obtain 3-5 hundredweight extra cotton.

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