Operational responsibility and operational reliability of cotton drip irrigation systems

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Abstract. The article deals with the introduction and operation of drip irrigation systems using water-saving technologies for the cultivation of "Sultan" cotton in the Jarqurghon massif of the Denau branch of "Surkhan Sifat Tekstil" LLC in Jarqurghon district of Surkhandarya region. The results of theoretical and field experimental studies conducted in 2018-2019 are presented. In changing the natural climate and economic conditions of the region under consideration, the authors first determined the values of reliability and operational reliability of the main joints and the entire drip irrigation system. High efficiency and reliability of drip irrigation systems are ensured due to their high design and high-quality construction and installation work. The operation of the system is constantly monitored for the implementation of all activities provided for in the business plan of farms. Therefore, the work on ensuring the technical and working condition of drip irrigation systems, improving the reclamation of lands, maximizing productivity and operation has helped

1. Introduction
In Uzbekistan, innovative resource-saving techniques and technologies for irrigation of cotton, orchards and vineyards, vegetables, and other agricultural crops are being rapidly introduced. According to the Ministry of Water Resources of the Republic of Uzbekistan, the area of drip irrigation is currently planned at ~ 4045 ha, including the area of cotton 2075 ha, orchards, and vineyards in 2010 and others ~ 188 ha [21, 22]. Since 2018-19. Theoretical and field experimental studies were conducted in the Dzharkurgan massif in the Dzharkurgan district of the Surkhandarya region. This region is the southernmost region of the Republic of Uzbekistan, where there is an acute shortage of irrigation water. Over the past three years, due to global climate change and abnormal heat during the growing season, the total water consumption of cotton and the size of the irrigation and irrigation rates have sharply changed [18].

The problem of reliability and uptime is becoming a priority with drip irrigation. Planned water use and round-the-clock use of water for irrigation depend on the reliable operation of canals, hydraulic structures, pumping stations, pipelines, transport pipelines, droppers [7, 8, 11].

The object of the research.
The experimental plot with a drip irrigation area of 60 ha is located on the Dzharkurgan massif. The source of irrigation is the main canal “Amu-Sang”, which takes irrigation water from the river Amudarya. The surface of the experimental plot has a slope of i = 0.003 – 0.004, the soils are light in terms of mechanical composition, bulk density is 1.1-1.26 t / m³, sandy loam, and light loam, not saline, are widespread, the depth of groundwater during the year varies from 2.6 – 2.8 to 3.1 – 3.5 m.
The components of the irrigation system are shown.

Table 1. The climatic characteristics of the experimental site of the Surkhandarya region for 2019 are shown

| Indicators                  | I   | II  | III | IV  | V   | VI  | VII | VIII | IX  | X   | XI  | XII | Average per year | Amount for the year |
|-----------------------------|-----|-----|-----|-----|-----|-----|-----|-------|-----|-----|-----|-----|------------------|----------------------|
| Air temperature, °C         | 6.2 | 8.9 | 18.0| 19.4| 24.5| 30.9| 33.2| 29.2  | 24.4| 16.7| 10.1| 8.6 | 19.1             | 230.1                |
| Relative humidity, %        | 66  | 63  | 59  | 53  | 51  | 38  | 37  | 41    | 45  | 53  | 69  | 71  | 53.83            | 646                  |
| Moisture deficit, mm        | 4.2 | 5.0 | 10  | 12.9| 17.2| 29.6| 34.3| 25.5  | 18.6| 11.0| 4.3 | 5.0 | 14.8             | 177.6                |
| Precipitation, mm           | 8.8 | 22.6| 15.8| 12.9| 29.4| -   | -   | -     | -   | 14.0| 18.5| 24.9| 10.7             | 128.4                |

The experimental plot is typical for climatic, soil, geological, hydrogeological, hydrological, and economic conditions of the Dzharkurgan irrigation massif; it was selected based on the methods of V.V. Shabanov and E.P. Rudashenko [5, 6].

In case of drip irrigation, cotton irrigation was carried out through an extensive network of pipelines through special micro-outlets directly to the root zone, maintaining soil moisture throughout the growing season at a level close to the calculated one, while this created the possibility of a continuous supply of water to plants and nutrients.
2. Methods
The main methodological provisions are based on theoretical and experimental studies, a broad generalization of the practice of drip irrigation of cotton by the research of TIIIMSKH, NISSAVKH, NIIIVP, TashSAU, VNIIGIM named after A.N. Kostyakov, Volgograd State Autonomous Institution, Moscow State Agrarian University named after Timiryazeva et al. Field studies were carried out using standard and specially developed methods, the reliability of the results was evaluated by verifying the results of theoretical and field studies.

In conditions of deficit of irrigation water, variegated climatic conditions and the cultivation of crops without predictive regulation of water reserves in the soil stratum throughout the growing season is impossible. Such regulation is possible only when choosing a resource-saving method and irrigation technologies, which should complement each other and provide a predictable crop.

3. Results
Reliability is the likelihood of ensuring the design characteristics of drip irrigation systems and achieving high stable operating efficiency on time. Reliability criteria - failure-free good operation of devices and readiness for work.

Failures - deviations from the calculated values are more than permissible, interruptions in work for various reasons. Depending on the cause of the failure, there are three types of failures: during the development of drip irrigation systems at the beginning of the operation, they are eliminated upon commissioning due to wear of the elements (aging), eliminated by replacing the elements; accidental failures due to variable conditions and loads.

Reliability indicators include the probability of uptime for the growing season, MTBF, failure rate, technical resource, system utilization rate. \( \lambda \) - The probability of failure-free operation of the drip irrigation system during the growing season in most cases complies with the law.

\[
P = e^{-\lambda t}; \quad [4]
\]
Where $P$ is reliability (probability), in fractions of a unit; $e$ is the number 2.71; $\lambda$ is the failure rate; $t$ is the duration of the system.

MTBF is the average uptime, $T = 1 / \lambda$. The failure rate is the average number of failures per unit time, $\lambda = 1 / T$. Technical resource is the total duration without failure of the system from the start of the operation to the limit state (wear), $T$.

The coefficient of technical use of the drip irrigation system (the ratio of the technical resource to the sum of the terms - the technical resource, the duration of repairs and adjustments);

$$K_i = \frac{T_t}{(T_t + T_p + T_p)}$$

When organizing the operation of the drip irrigation system, it is necessary to determine for each element and the system as a whole: [10] [20]. The average duration of running-in and commissioning; failure rates, average uptime, nature of failures and elimination of failures; average durability (technical resource); the duration and intensity of failures during the period of wear. Reliability during normal operation is achieved by running in all the elements during the initial operation; prevention and replacement of individual elements during wear; clarification of the operating rules after the average life of the elements (in the period of wear).

The system works reliably with the continuous organization; operation monitoring the operation of drip systems according to the constituent elements of the main version; based on tests of constituent elements and refinement of reliability indicators.

The main provisions of the theory of reliability of drip irrigation systems are as follows; system reliability is equal to the product of system reliability.

$$P_c = P_1 \cdot P_2 \cdot P_3 \cdot P_{in}; [9]$$

System reliability decreases as the number of links increases. With the nodal diagram of the system, reliability is higher; system reliability improves when connecting redundant links.

$$P_c = \{1 - (1 - P)^n\} = (1 - (1 - P_i)m)^n \quad [15]$$

Where $n$ is the number of links; $(m - 1)$ is the number of backup elements; $P_1$ is the reliability of one link.

With reserves, it is possible to ensure the stable operation of the system. [16]. The capital costs of improving the links (C) and the reliability of the system (P) are estimated by the ratios (in relation to machines):

$$C_1 = C \cdot \frac{1 - P}{P} \cdot \frac{P_1}{1 - P_1} \quad [17]$$

*Figure 3. Photographs of cotton irrigation systems for drip irrigation.*
The values of the operational reliability of the links of the cotton irrigation drip irrigation system located in the Dzharkurgan massif of the Surkhandarya region for the years of research 2018 - 2019 are shown in the table.

| № Links | The value of operational reliability ($P$) | № links | The value of operational reliability ($P$) | Note |
|---------|------------------------------------------|---------|------------------------------------------|------|
| 1       | 1.0                                      | 6       | 1.0                                      | The cotton drip irrigation system was put into operation in 2017. |
| 2       | 1.0                                      | 7       | 1.0                                      |      |
| 3       | 0.99                                     | 8       | 1.0                                      |      |
| 4       | 0.98                                     | 9       | 1.0                                      |      |
| 5       | 0.98                                     | 10      | 1.0                                      |      |

as can be seen from graphs 4 and 5 in Table, the connection of this drip irrigation system is weak.

$P_{eff} = P_1 \cdot P_2 \cdot P_3 \cdot P_4 \cdot P_6 \cdot P_9 \cdot P_{10} = 1.0 \cdot 1.0 \cdot 0.99 \cdot 0.98 \cdot 0.98 \cdot 1.0 \cdot 1.0 \cdot 1.0 = 0.95$. High values of operational reliability and reliability of all links of drip irrigation systems are ensured due to the high-quality implementation of design and construction works [12, 13, 19]. The operation of the system is brought under constant control of the implementation of all work provided for in the business plan of farms. The maintenance and maintenance in good technical and working condition of irrigation systems were also facilitated by the established work on reclamation and operational monitoring. In 2019, with the drip irrigation of the cotton plant of the Sultan variety, the irrigation norm was $M = 1880$ m$^3$/ha, the number of irrigations was 6. The values of the elementary irrigation norm during the growing season, depending on the development phase and climatic changes during the growing season, were $M = 290 – 316$ m$^3$/ha.

The efficiency value of drip irrigation systems amounted to 0.98, against the value of the efficiency of existing open irrigation systems - 0.76. The value of the coefficient of land use (CIU) increased from 0.89 to 0.99. The coefficient of utilization of water (CUW) increased to 0.99, against 0.90 in the control array.

In the control plot with furrow irrigation, the irrigation rate was $M = 6960$ m$^3$/ha, the number of irrigations was 6. Irrigation rates, depending on the development phase and climatic changes, were $m = 950 – 1100$ m$^3$/ha. The water-saving during drip irrigation of cotton cultivar “Sultan” amounted to 5100 m$^3$/ha. The yield of cotton under drip irrigation was $Y = 41.7$ c / ha, and in the control plot, the yield was 32.8 c / ha. The productivity of one cubic meter of water during drip irrigation was 0.02 c/ha and in the control version 0.025 c/ha.
4. Conclusions

1. The irrigation system of drip irrigation of cotton of the Dzharkurgan massif, Dzharkurgan district of Surkhandarya region over the years of field research due to the choral quality of the "design" and "construction" works, as well as their coordinated operation, ensured a high-reliability value - P = 0.95%.

2. The efficiency value of drip irrigation systems amounted to 0.98% against the value of the efficiency of existing open irrigation systems - 0.76%. The value of the coefficient of land use (CIU) increased from 0.89% to 0.99%. The coefficient of utilization of water (CUW) increased to 0.99%, against 0.90% in the control array.

3. High and stable operational reliability, the Sultan variety cotton irrigation drip irrigation system provides a steady increase in yield and water savings. The cotton yield in the experimental plot in 2019 was 41.7 sent / ha, and in the control variant - 32.80 sent / ha.

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