Influence of physicochemical factors on water exchange in cotton leaves under the moisture deficit conditions

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Abstract. Presowing treatment of cotton seeds with a physical factor (low-frequency electromagnetic field - LF EMF) and a chemical compound (glycyrrhizic acid - GzA) and sowing them under conditions of optimal and limited water supply showed that different varieties of cotton, depending on their biological peculiarities and the method of seed treatment, had different parameters of water exchange in plants. The experiments were carried out in laboratory, greenhouse, lysimetric and field conditions, the indicators of the electrical resistance of leaf tissues (ERLT) of cotton plants depended on the conditions of water supply. According to this indicator, the varieties Ishonch, Gulbahor-2 and Navbahor-2 showed greater resistance to soil moisture deficiency, in comparison with the variety Tashkent-6. The plant varieties from seeds, treated with LF EMF and GzA, to a greater or lesser extent, are in the range with the lowest ERLT values, in comparison with the varieties from untreated seeds.

1. Introduction

Water stress is one of the most widespread abiotic factors, which has pernicious influence on plant organism. The development and survival of plants is much more dependent on the availability of water than on any other environmental factors [1, 2]. At present, about 1/3 of the dry lands is occupied by areas with moisture deficit, and half of this area is extremely arid. This problem has been aggravated already in the period of global warming – 1861-2005. The average global temperature on Earth has increased by 0.7°C (IPCC, 2014). It is predicted that in the next 20 years, the temperature will rise on average 0.2°C per decade, and by the end of the 21st century, the Earth’s temperature may rise from 1.8 to 4.6°C, which will lead to a significant deterioration of the climatic situation in different regions of the world, especially, in irrigated areas with lack of irrigation water. This problem is extremely acute for the arid zones of Central Asia and, especially, for Uzbekistan, with almost entirely irrigated agriculture. Insufficient efficiency of cotton growing in our country, in comparison with the leading cotton-growing countries, is mainly caused by the progressive soil drought, low adaptive potential of cultivated varieties and the narrowness of the spectrum of representatives of the genetic diversity of the species and genus involved in the breeding process.

Soil drought leads the plants with less drought resistance to wilting [3, 4], whereas the drought resistant genotypes of cotton are able to endure drought during ontogeny and grow and develop in...
these conditions [5, 6]. One of the criteria of endurance to drought is the maintenance of turgescence at high water potential (WP) [6]. The second of the criteria for drought resistance of plants is the viability of leaves during dehydration at low values of the electrical resistance of leaf tissues — ERLT [7, 8].

The limited water resources arouses the necessity of the development and implementation of fundamentally new agricultural technologies (improvement of soil conditions, the introduction of various technologies of drip irrigation, etc.), which make it possible to economically consume water while maintaining plant productivity.

In addition, the development of other activities takes on special significance – carrying out genetic selection works in creating drought-resistant varieties of agricultural crops and increasing the resistance to water deficit of already cultivated varieties using the latest achievements and approaches, which include pre-sowing seed treatment with various factors. Knowledge on the reaction rate of genotypes and the limits of their modification variability, taking into account the genetic potential and the effect of external influence, is of great importance when creating new forms with the desired traits and improving the existing forms for the period of ontogeny.

This article provides data on the effect of the electromagnetic field and glycyrrhizic acid on cotton varieties under conditions of normal water supply and simulated drought based on the electrophysiological parameters of leaves.

2. Materials and Methods

The objects of the research were medium-staple cotton varieties Gulbahor-2, Navbahor-2, Ishonch and Tashkent-6. Field experiments were carried out in the trial plots of the Zangiata experimental base of the Institute of Genetics and Plant Experimental Biology, on the backgrounds with two irrigation rates: background 1 – optimal water supply (OWS), with irrigation scheme 1-2-1; and background 2 – with insufficient water supply (simulated drought – SD), with an irrigation scheme 1-1-0. The rest of the agronomic measures were the same for both backgrounds. On the trial plot the depth of groundwater is 8.0 m or more, and the soil refers to the typical sierozem of long-time irrigation with low humus content. The bulk density of the soil is 1.32-1.33 g/cm³.

Before sowing, the seeds of the selected cotton varieties were treated with a low frequency electromagnetic field in an electromagnetic pulse generator with a frequency of 4 Hz and a magnetic induction of 200 - 500 nT for 30 min. The magnetic induction generated by LF EMF generator was measured at a frequency of 50 Hz with mT F 4356. The seeds were steeped with stimulator for growth in a solution of 10⁻⁷ M glycyrrhizic acid (10⁻⁷ M GzA) within 24 hours. Previously, we determined the concentration of polyethylene glycol (PEG) corresponding to the values of water potential [9]. In table 1 was brought the data of correspondence of various concentrations of PEG (molecular weight 1500) in moles (mol) with indicators of water potential in Megapascal (MPa).

| Pier | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| MPa  | -0.91 | -1.13 | -1.36 | -1.59 | -1.82 | -2.04 | -2.27 | -2.50 | -2.72 | -2.95 |

The electrical parameters of the leaves were measured using a digital measuring bridge LCRMS 5308 (Mastech, China) at a frequency of 1 kHz between needle electrodes with a distance of 10 mm between them, and a refractometer IRF-454BM. The electrical resistance of leaf tissues (ERLT) was determined on the leaves of the third layer from above. The measurements of ERLT₁ were carried out directly on the plant itself, and after an hour ERLT₂, then the difference in ERLTs was determined. In laboratory conditions, ERLT was measured on cotyledonous leaves of 14-days-old plants of the varieties Ishonch and Tashkent-6 in the following experimental combinations:

1) The control (distilled water); Seeds, treated with a low frequency electromagnetic field (LF EMF); Seeds, steeped in glycyrrhizic acid at a concentration of 10⁻⁷ M (GzA) for 24 hours;
2) Seeds, germinated in distilled water and for 24 hours before the experiment, kept in a solution of PEG (polyethylene glycol) as a factor of artificial drought at a concentration of 7.5% with a molecular weight of 1500 in the above mentioned combinations of the experiment.

3. Results and Discussions

For cotton plants, an important indicator of drought resistance is the limiting values of the water potential (VP), which is determined by the concentration of sugar in the cell. The higher the concentration, the higher the absorbing capacity of the leaves is. Water potential is measured in units of pressure (1 MPa = 1 bar ≈ 10 atm. ≈ 10 kg/cm²). A 1-molar solution of sucrose has an osmotic potential of 35.7 atm. or water potential = 3.57 MPa [7].

A definite correlation was observed between the water potential and electrical resistance of leaf tissues, i.e. plants with a lower water potential had a higher electrical resistance of tissues. Application of electrophysiological methods in assessing the content of ions in cells and tissues, resistance potential, water content in leaves, i.e. their physiological condition and the plant in whole has become quite widespread [10].

In this regard, a study was carried out on the possibility of assessing the water potential of cotton leaves by measuring their electrical conductivity on alternating current. To identify the correlation between the water potential of cotton leaves and their electrical resistance on the experimental cotton field, cotton varieties, cultivated in two regimes of water supply were explored [11]. The results of these measurements are shown in Figure 1. As shown in figure-1, the relationship between the electrical resistance of leaf tissues and water potential in the range of water potential -1.0 – -2.0 MPa is close to a straight line. This allows carrying out approximate measurements of the water potential by measuring the electroconductivity of the leaves.

![Figure 1](image)

Figure 1. The relationship between the water potential of cotton leaves and their electrical resistance

A series of experiments was carried out with two relatively contrasting varieties in conditions of simulated moisture deficit (7.5% PEG). Table 2 shows that ERLT1 indices in plants, grown on distilled water change insignificantly in the studied combinations, and when artificial drought is created, ERLT1 increases by more than 100 kΩ, and in the variety Tashkent-6 its value is higher than in the variety Ishonch. The difference of ERLT in conditions of artificial drought with PEG in the variety Ishonch in various options fluctuates from 87.4±8.5 kΩ to 171.3±10.5 kΩ, and in the variety Tashkent-6 - from 145.8±12.3 kΩ to 251.7±13.6 kΩ.
In the process of the study, the following patterns were observed: the higher the values of ERLT₁ and the greater the difference between ERLT, the less resistant the plant to conditions of water deficit (PEG). When creating an artificial drought, the values of the VP of cotyledonous leaves in seedlings, whose seeds were treated with LF EMF and GzA, were lower than in untreated samples. The vegetation experiment was carried out in vessels with 5 kg of absolutely dry soil. Irrigation was carried out by weight with bringing the soil moisture to 70% of the maximum field water capacity (FWC) – optimal water supply (OWS) and 30% of FWC – simulated drought (SD). Measurement of ERLT was carried out on natural leaves (1st leaf) on 30-day-old seedlings of the varieties Ishonch and Tashkent-6 in the same experimental combinations as on cotyledonous leaves (Table 3).

It was shown, that the values of ERLT₁ under simulated drought significantly increase in comparison with the optimal water supply. On the background of the simulated drought in the plants of the variety Ishonch, the seeds of which were treated and GzA values were lower and made up 525.4±16.6 and 540.5±13.5 kΩ, than the untreated version with 561.6±17.3 kΩ. In the control plants of the variety Tashkent-6 – 621.4±19.9 kΩ, and in the plants, whose seeds were treated with GzK and LF EMF – 559.1±17.2 and 598.7±16.7 kΩ, respectively. With the optimal water supply in the variety Ishonch in different combinations the indication values ranged from 180.7±8.8 kΩ to 225.3±9.8 kΩ; in the variety Tashkent-6 from 293.6±11.4 kΩ to 339.1±10.1 kΩ. In case of insufficient water supply the difference of ERLT in the variety Ishonch the same combinations varies from 220.3±6.8 kΩ to 279.5±8.3 kΩ (Table 3).

| Variety     | Distilled water | PEG, 7.5% |
|-------------|----------------|-----------|
|             | ERLT₁, kΩ      | Difference ERLT, kΩ | VP, MPa | ERLT₁, kΩ | Difference ERLT, kΩ | VP, MPa |
| Ishonch     | 237.5±10.3     | 185.1±9.6  | -0.27±0.03 | 350.4±13.5 | 171.3±10.5 | -0.35±0.02 |
| Tashkent-6  | 260.7±15.4     | 262.3±8.5  | -0.24±0.02 | 428.1±12.7 | 251.7±13.6 | -0.32±0.03 |
| Ishonch LF EMF | 240.3±9.3   | 102±7.3   | -0.33±0.05 | 366.8±18.7 | 103.5±11.2 | -0.37±0.01 |
| Tashkent-6 LF EMF | 293.5±13.7 | 215±8.8   | -0.28±0.04 | 454.0±17.3 | 156.2±15.7 | -0.36±0.06 |
| Ishonch GzA  | 279.7±12.8     | 95.9±10.6  | -0.30±0.03 | 337.9±24.6 | 87.4±8.5   | -0.41±0.04 |
| Tashkent-6 GzA | 267.5±14.7   | 221±12.74  | -0.25±0.02 | 371.3±10.9 | 145.8±12.3 | -0.34±0.01 |

Table 2. Determination of ECLT on cotyledonous leaves of cotton

| Variety     | OWS       | SD       | OWS       | SD       |
|-------------|-----------|----------|-----------|----------|
|             | ERLT₁, kΩ | Difference ERLT, kΩ | ERLT₁, kΩ | Difference ERLT, kΩ | VP, MPa | VP, MPa |
| Ishonch     | 276.6±19.8 | 225.3±9.8  | 561.6±17.3 | 279.5±8.3 | -0.46±0.01 | -0.58±0.01 |
| Tashkent-6  | 297.9±21.3 | 339.1±10.1 | 621.4±19.9 | 386.2±7.2 | -0.43±0.02 | -0.54±0.01 |
| Ishonch LF EMF | 223.5±14.7 | 180.7±8.8  | 583.8±14.8 | 220.3±6.8 | -0.57±0.01 | -0.79±0.035 |
| Tashkent-6 LF EMF | 269.2±10.5 | 284.3±7.3  | 598.7±16.7 | 319.5±5.5 | -0.55±0.01 | -0.62±0.02 |
| Ishonch GzA  | 176.4±13.6 | 212.9±9.4  | 540.5±13.5 | 261.8±6.4 | -0.53±0.06 | -0.75±0.05 |
| Tashkent-6 GzA | 253.1±18.1 | 325.4±7.7  | 559.1±17.2 | 300.6±8.1 | -0.62±0.08 | -0.70±0.06 |

Table 3. ERLT and WP on natural leaves in a greenhouse experiment under different conditions of water availability

Thus, in the variety Ishonch the difference in ERLT is less than in the variety Tashkent-6, which can be suggested, that Ishonch, as a drought-resistant variety, maintains a greater viability of leaves under extreme conditions of insufficient water supply. Secondly, plants, whose seeds were treated with LF EMFs and GzA, are in the range with the lowest ERLT values, in a greater or lesser extent, in
The values of WP of leaves in seedlings of the varieties Ishonch and Tashkent-6, the seeds of which were treated with LF EMF and GzA, were lower in comparison with the control variants under two water regimes. The studies on ERLT of plants, grown in lysimeters at 70% soil moisture in optimal water supply (OWS) and at 30% soil moisture in the simulated drought (SD) of the maximum field water capacity (FWC) of the soil, showed the following: the difference in ERLT under optimum irrigation conditions – in the variety Ishonch 145.2±8.4, in the variety Tashkent-6 194.3±7.6 kΩ, under the conditions of insufficient water availability – in the variety Ishonch 176.8±6.7, in the variety Tashkent-6 260.7±9.5 kΩ, respectively (Table 4). Plants of the varieties Ishonch and Tashkent-6, whose seeds were treated with LF EMF, have the following values for the difference in ERLT: with optimal water supply in the variety Ishonch within the following combinations (LF EMF), the values were – 135.1±7.8: 120.9±6.5 kΩ; in the variety Tashkent-6 – 183.4±7.3: 170.1±11.4 kΩ, respectively. With insufficient water supply for the variety Ishonch – 160.5±9.8: 147.1±10.3 kΩ; Tashkent-6 – 253.4±10.5: 230.7±11.3 kΩ.

**Table 4. Determination of ERLT and WP of leaves during budding under different conditions of water supply (lysimeter)**

| Variety          | OWS ERLT, kΩ | Difference in ERLT, kΩ | SD ERLT, kΩ | Difference in ERLT, kΩ | OWS WP, MPa | SD WP, MPa |
|------------------|--------------|------------------------|-------------|------------------------|-------------|------------|
| Ishonch control  | 267.2±12.5   | 145.2±8.4              | 350.3±14.1  | 176.8±6.7              | -1.81±0.02  | -2.52±0.05 |
| Tashkent-6 control | 238.5±9.6   | 194.3±7.6              | 312.5±8.7   | 260.7±9.5              | -1.74±0.04  | -2.26±0.01 |
| Ishonch LF EMF   | 254.6±10.1   | 135.1±7.8              | 340.1±13.9  | 160.5±9.8              | -2.02±0.03  | -2.58±0.01 |
| Tashkent-6 LF EMF | 272.3±7.4   | 183.4±7.3              | 360.8±9.5   | 253.4±10.5             | -1.95±0.03  | -2.34±0.05 |

As shown in Table 4, the values of WP of leaves with insufficient water supply have lower values than with optimal water supply. Based on the data obtained (laboratory, greenhouse and lysimeter experiments), it can be stated that the value of the WP of the leaves in the studied samples decreases with the increase of the age of the cotton.

In field experiments, the drought resistance of cotton varieties Ishonch, Gulbahor-2, Navbahor-2 and Tashkent-6 was assessed depending on the water supply (soil moisture 70% with optimal water supply (OWS) and 50% with simulated drought (SD) from the maximum field water capacity of the soil (FWC)) during flowering and fruit formation.

Under field conditions the measurement ERLT1 in control variants showed the following: the optimal conditions of water regime in the variety Ishonch – 271.3±10.6 kΩ; in the variety Gulbahor-2 – 267.2±12.5 kΩ; in the variety Navbahor-2 – 272.3±7.4 kΩ; in the variety Tashkent-6 – 280.4±14.6 kΩ, in the condition with insufficient water supply in the variety Ishonch – 356.4±13.3 kΩ; in the variety Gulbahor-2 – 350.3±14.1 kΩ; in the variety Navbahor-2 – 360.8±9.5 kΩ; in the variety Tashkent-6 – 400.5±16.7 kΩ, respectively (Table 5).

Thus, with sufficient watering, the ERLT1 changes insignificantly in the studied varieties. With insufficient watering, the ERLT1 values increase, especially in the variety Tashkent-6 the values are higher than in the varieties Ishonch, Gulbahor-2 and Navbahor-2. It can be assumed that drought-resistant varieties retain high leaf viability under extreme conditions with insufficient water supply. Secondly, the plants in which the seeds were treated with LF EMF and GzA, to a greater or lesser extent, are in the range with the lowest values in comparison with the control variants.
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Table 5. Determination of ERLT and WP of leaves during the flowering - fruit formation period under different water supply conditions (field experiment)

| Variety       | OWS ECTL1, kΩ | Difference in ERLT, kΩ | OWS ECTL1, kΩ | Difference in ERLT, kΩ | WP, MPa | WP, MPa |
|---------------|--------------|-----------------------|--------------|-----------------------|---------|---------|
| Gulbahor-2    | 267.2±12.5   | 127.6±8.5             | 350.3±14.1   | 139.5±13.6            | -2.18±0.07 | -2.72±0.06 |
| Gulbahor-2 LF EMF | 238.5±9.6    | 116.8±7.3             | 312.5±8.7    | 122.3±11.8            | -2.29±0.05 | -2.85±0.04 |
| Gulbahor-2 GzA | 254.6±10.1   | 120.4±6.4             | 340.1±13.9   | 131.3±12.9            | -2.06±0.06 | -2.76±0.08 |
| Navbahor-2    | 272.3±7.4    | 119.2±9.1             | 360.8±9.5    | 127.5±14.6            | -2.06±0.07 | -2.67±0.09 |
| Navbahor-2 LF EMF | 263.0±8.2    | 109.5±7.9             | 334.6±10.6   | 118.1±7.6             | -2.59±0.09 | -2.81±0.07 |
| Navbahor-2 GzA | 270.3±11.3   | 110.8±8.3             | 368.5±11.2   | 133.3±11.3            | -2.72±0.08 | -2.94±0.06 |
| Isonch        | 271.3±10.6   | 141.7±7.8             | 356.4±13.3   | 150.8±8.3             | -2.42±0.06 | -2.90±0.08 |
| Isonch LF EMP | 264.1±9.7    | 111.9±5.4             | 329.8±9.8    | 120.5±14.4            | -2.49±0.03 | -2.94±0.06 |
| Isonch GzA    | 254.6±12.5   | 133.6±4.9             | 351.2±10.3   | 140.5±9.1             | -2.50±0.04 | -2.99±0.09 |
| Tashkent-6    | 280.4±14.6   | 157.6±6.1             | 400.5±16.7   | 241.4±19.2            | -1.82±0.04 | -2.33±0.05 |
| Tashkent-6 LF EMF | 262.7±7.4    | 133.2±9.6             | 380.0±15.5   | 196.7±10.8            | -2.10±0.07 | -2.42±0.05 |
| Tashkent GzA  | 276.4±11.3   | 127.6±7.7             | 364.1±11.3   | 190.1±8.2             | -2.18±0.09 | -2.76±0.08 |

The signs of drought resistance are lower values of the water potential, which is an indirect characteristic of the drought resistance of the varieties Gulbahor-2, Isonch and Navbahor-2. In the growing experiment, all physicochemical factors had positive effects on the varieties Isonch and Tashkent-6. Correlation between cotton productivity and ERLT/difference ERLT was (r=0.52)/(r=0.55) under simulated drought conditions. Changes in the value of WP in leaves under field conditions revealed the same regularities as in the above experiments – the value of WP increases both with the age of the plant and under insufficient water supply. The lowest values observed in the varieties Isonch (-2.90±0.08 MPa), Gulbahor-2 (-2.72±0.06 MPa) and Navbahor-2 (-2.67±0.09 MPa). The values of WP in the variety Isonch in LF EMF:GzA combinations, under SD were -2.94±0.06: -2.99±0.09: -3.04±0.03 MPa; in the variety Tashkent-6 -2.42±0.05: -2.76±0.08: -2.65±0.06 MPa; in the variety Gulbahor-2 (LF EMF:GzA) the values were -2.85±0.04: -2.76±0.08 MPa; in the variety Navbahor-2 (LF EMF:GzA) -2.81±0.07: -2.94±0.06 MPa. The results of the comparative study of the influence of physicochemical factors on the physiological condition of leaves under simulated drought are shown in Tables 5 and 6.

The results of the conducted experiments present a positive effect of LF EMF and GzA on cotton, regardless of the variety. The stimulating effect on the germination, growth and development of cereals has the influence on the seeds with a frequency of about 10 Hz of intensity gradients, which appears under favorable environmental conditions. Weak stimulation is detected at 230 gradients of the magnetic field strength and at 460 gradients it is lost. Similar to the post-radiation effect, the stimulating effect of the magnetic field remains in seeds for a limited time [12].

Much information can be found about the neutral and negative effects of EMF on plant organs. In the study carried out by Shashurin (2016) [13] showed the effect of various exposures of pre-sowing treatment of seeds of Allium fistulosum L. with combined constant magnetic field (CCMF) on the physiological and biochemical parameters of its seedlings. It was revealed that the pre-sowing treatment of seeds in the conditions of the author’s experiment (exposure, combined constant magnetic field) caused negative geotropism in seedlings. The influence of magnetic field on the seeds resulted in a strong reduction in peroxidase activity and low-molecular content of antioxidants under the background of lipid peroxidation intensity increase in their seedlings. According to the results of our researches, when creating an artificial drought in laboratory conditions, it was shown that the varieties with drought-resistant traits are less susceptible to the negative effects of a high concentration of osmolytes (PEG), which appears in the preservation of the ability to germinate seeds and in decreasing in the inhibition of root growth.
The results obtained by us and many other researchers indicate the influence of the studied factors on the mechanisms of a general biological nature. It should be taken into consideration that the magnetic field accompanied the emergence and development of all living substance from the earliest stages, beginning from primary, primitive organisms to higher eukaryotic organisms, including plants, animals and humans. Naturally, the electromagnetic background changed many times, to which organisms, in particular, plants, have developed mechanisms for optimal response to these changes. As in all cases of fluctuations in environmental conditions, the primary reaction of the organism’s response includes the reception of a signal, whether it is chemical compound, temperature, or some other agent. As for the magnetic field, in determining magnetic reception the difficulty was in the lack of clear relationships of stimulus-response, in most cases. Perception of the magnetic field by animals and plants is currently being discussed within the framework of the mechanism of radical pairs based on cryptochrome [14]. In order to determine the sensitivity of seedlings *A. thaliana* to weak static magnetic fields, the authors constructed curved stimulus-response between ca zero and 188 µT, for the levels of transcripts of genes *rbcl, cab4, pal4* and *efl*. Moderate magnetic sensitivity of the seedlings, grown in the dark, was significantly enhanced by blue light, and for *rbcl* and *pal4* also under red light. Stimulus response curves obtained under blue light at a constant photon flow rate showed multiple maxima. The double mutant lacking cryptochromes 1 and 2 showed altered stimulus-response curves without completely losing magnetoreactivity. The change in the direction of the magnetic field significantly influenced the gene expression and the amount of CAB protein (chlorophyll a, b-binding protein).

The research conducted by Pushkin (2016) [15] showed that the treatment of corn seeds with microwave EMF in the frequency range 53-78 GHz leads to an increase in the dynamics and energy of

### Table 6. Influence of physicochemical factors on the physiological condition of leaves under simulated drought

| Variety          | ERLT₁, kΩ | Difference in ERLT, kΩ | ERLT₁, kΩ | Difference in ERLT, kΩ |
|------------------|-----------|------------------------|-----------|------------------------|
| **Laboratory**   | Control   | PEG, 7.5%              | Control   | PEG, 7.5%              |
| Ishonch          | 237.5±10.3| 185.1±9.6              | 350.4±13.5| 171.3±10.5             |
| Tashkent-6       | 260.7±15.4| 262.3±8.5              | 428.1±12.7| 251.7±13.6             |
| Ishonch LF EMP   | 240.3±9.3 | 102±7.3                | 366.8±18.7| 103.5±11.2             |
| Tashkent-6 LF EMF| 293.5±13.7| 215±8.8                | 454.0±17.3| 156.2±15.7             |
| Ishonch GzA      | 279.7±12.8| 95.9±10.6              | 337.9±24.6| 87.4±8.5               |
| Tashkent-6 GzA   | 267.5±14.7| 221±12.7               | 371.3±10.9| 145.8±12.3             |

| **Greenhouse**   | OWS       | SD                     | OWS       | SD                     |
|------------------|-----------|------------------------|-----------|------------------------|
| Ishonch          | 276.6±19.8| 225.3±9.8              | 561.6±17.3| 279.5±8.3              |
| Tashkent-6       | 297.9±21.3| 339.1±10.1             | 621.4±19.9| 386.2±7.2              |
| Ishonch LF EMP   | 223.5±14.7| 180.7±8.8              | 583.8±14.8| 220.3±6.8              |
| Tashkent-6 LF EMF| 269.2±10.5| 284.3±7.3              | 598.7±16.7| 319.5±5.5              |
| Ishonch GzA      | 176.4±13.6| 212.9±9.4              | 540.5±13.5| 261.8±6.4              |
| Tashkent-6 GzA   | 253.1±18.1| 325.4±7.7              | 559.1±17.2| 300.6±8.1              |

| **Field**        | OWS       | SD                     | OWS       | SD                     |
|------------------|-----------|------------------------|-----------|------------------------|
| Navbahor-2       | 304±11.2 | 154±10.1               | 395±12.3  | 242±10.0               |
| Navbahor-2 LF EMF| 280±10.6 | 136±15.4               | 376±9.8   | 215±11.2               |
| Navbahor-2 GzA   | 295±9.1  | 147±11.3               | 384±13.7  | 235±9.6                |
| Navbahor-2 GzA + LF EMF | 300±8.6 | 149±9.7                | 368±8.6   | 190±10.4               |
| Tashkent-6       | 307±10.3 | 202±8.6                | 545±13.4  | 311±9.6                |
| Tashkent-6 LF EMF| 275±8.8  | 177±12.5               | 487±10.1  | 276±10.8               |
| Tashkent-6 GzA   | 291±9.4  | 184±13.0               | 472±12.3  | 281±13.9               |
| Tashkent-6 GzA + LF EMF | 266±12.5| 192±7.9                | 530±11.7  | 302±11.3               |
emergence, as well as the germination of plants in laboratory experiments, and it is noted that such changes (activation of growth processes after treatment of seeds of various hybrids corn with microwave EMF) fit into the concept of G. Selye about stress. In response to a strong and long-term adverse influence, nonspecific reactions are induced in the plant organism, which appears in the form of a generalized adaptation syndrome, which consists of three stages: alarm reaction, adaptation stage, and exhaustion stage.

Weak physiological stresses caused by microwave EMF do not reach critical values for maize plants. In this regard, switching of metabolism into a new regime of functioning occurs, which is realized thanks to the intracellular and extracellular regulatory systems – the perception, transmission and transformation of external signals.

The effect of low-energy radiation of an electromagnetic field in the millimeter wavelength range on corn seeds after their emergence can affect the initial stages of ontogenesis. As a result of a series of experiments, the authors have shown a stimulating effect of pre-sowing treatment of seeds with a frequency of 64.0–66.0 GHz for 8 and 12 minutes with microwave EMF – stimulating field germination, plant height and yield. It is also noted that the positive effect of pre-sowing treatment depends not only on the treatment regime, but also on the initial moisture content of the seeds.

Research data of Kim et al. (2016) [16] have shown that the application of a static magnetic field increases the germination rate and the initial growth rate of some cultivated plant species. These results indicate that the static magnetic field has a significant effect on plant growth, especially on germination and root growth of plants. Previous studies have shown that the maximum germination rate was 20% higher when the frequency of the magnetic field was approximately 10 Hz 5-6. In just 4 days of application of the magnetic field, the stem and root length increased. The group exposed to the magnetic field showed 1.4 times higher growth rate than the control group in just 8 days.

The work of Efthimiadou et al. (2014) [17] also showed the positive effect of the pulsed magnetic field on the growth and yield of tomatoes. Qualitative changes in the content of lycopene were also noted. In this regard, we should pay our attention on, that such a stimulating effect of the magnetic field is universal for all types of living organisms. Of course, this can be said taking into account the specifics of the object, as well as the dose and duration of exposure. The study implemented by Klyuev et al. (2016) [18] showed the effect of a weak low-frequency pulsed magnetic field on the growth of biomass and the growth rate of fungal colonies, and the effect of MF on the growth of biomass was ambiguous. For Penicillium cyclopium, there was a decrease in the growth of biomass relative to the control in all variants of the experiment (30-210 minutes). For Aspergillus niger niger, short-term exposure (30 minutes) resulted in an increase in biomass, while longer exposure times (150 and 210 minutes) inhibited the growth of its biomass.

It should be noted that EMF affects plant organisms in different ways. Under the exposure of a weak constant magnetic field (CMF) with a strength of ~400 A/m on the composition and content of lipids in the leaves of adult plants and seeds of magnetic-orientation types (MOT) of radish (Raphanus sativus L. varradica DC.), it was shown that the composition and content of lipids in the leaves of adult plants and in seeds of different varieties do not change in the same way, often in the opposite way. The authors suggest that this effect is due to their different sensitivity to the action of the field, and as a stress factor is related to the characteristics of their physiological status [19].

Sleptsov et al. (2019) [20] carried out physiological, morphological and biochemical studies on seedlings of Amaranthus retroflexus L., Agastacherugosa and Thlaspi arvense L. after 6-hour exposure to a constant magnetic field on their germinating seeds, with inductions of 50, 80, 100 and 120 μT. The conducted researches have shown that the studied range of magnetic field intensities do not affect on the length of the sprout and root of seedlings in comparison with the control values. An undulation change of biochemical indices (concentration of flavonoids, malondialdehyde (MDA), the amount of low molecular weight antioxidants, the amount of saturated and unsaturated fatty acids, the activity of peroxidase and superoxide dismutase enzymes) in seedlings of the three studied plants was shown when their seeds were treated with a constant magnetic field for six hours.
It is known that the preparation used in our experiments based on glycyrrhizic acid (GzA) with a concentration of $10^{-8} - 10^{-8}$ M significantly increases the degree of germination of cotton seeds [21]. A number of GzA derivatives have also shown themselves to stimulate the growth and development of many plants. These data became the basis for studying the effect of GzA and a number of its salts on the germination, growth and development of wheat. In our experiments, we also obtained data on the positive effect of the use of the preparation based on glycyrrhizic acid on cotton.

4. Conclusions

Abiotic stressors (drought, salinity, extreme temperatures, etc.) are the main constraints on productivity in global agriculture - they are responsible for the loss of 50-82% of the potential yield. It is known that only about 10% of arable land in the world is free from stress factors, and their impact is the main reason for 2-3 and more fold differences between the potential and real crop yields.

With the constant growth of stress on agroecosystems, the leading role in the creation of new integrated systems for the production of cotton products belongs to breeding. The successful solution of the problems facing breeders, along with the optimal selection of the source material, is inextricably linked with the optimization and use in practical work of the most effective methods for assessing the genetic potential of the source forms for economic characteristics, as well as increasing resistance to abiotic stressors, in particular, to water shortage with the help of various influences of physical and chemical nature.

The positive effect of the low frequency electromagnetic field and glycerrhizic acid on cotton under water stress conditions, regardless of the variety, is shown, which indicates the influence of these factors on the mechanisms of a general biological nature. It should be borne in mind that the magnetic field accompanied the emergence and development of all living things from the earliest stages, from primary, primitive organisms to highly organized eukaryotic organisms, including plants, animals and humans.

Our data indicate the possibility of using the electrophysiological parameters of the leaf in assessing the genotypes for the tolerance of cotton varieties to water deficit, as well as the effectiveness of pre-sowing treatment of cotton seeds to increase the adaptive potential under stress conditions.

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