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EFFICIENCY OF ELECTROMAGNETIC TREATMENTS IN COTTON[5]

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Abstract: *Summarized results for the effect of the pre-sowing electromagnetic treatment and the influence of the storage periods before and after treatment on the sowing qualities of seeds of five Bulgarian cotton varieties were considered. The voltage between the electrodes (U) Kv of a specialized device and the duration of exposure (t) s were perceived as controllable factors of the electromagnetic treatment. It was found stimulating effect of the energy impact on the sowing qualities of cotton seeds after their treatment in the electromagnetic field. The best variants of the controllable factors were identified - combinations of the duration of exposure (t)s and the field intensity (U)Kv determining the level of the energy portion for the highest positive stimulating effect at a specific varietals' reaction. Possibilities for using the electromagnetic treatment of cotton seeds in case of their storage in order to preserve or stimulate their sowing qualities have been discovered. A serious theoretical and practical base has been built by the research team at the University of Ruse - Ruse, scientific and professional experience has been gained, allowing further deepening of the research and more complete systematization of the obtained results.*

Keywords: *Electromagnetic Treatment, Cotton Seeds, Laboratory Germination, Root and Sprout Length, Root and Sprout Mass, Duration of Storage*

INTRODUCTION

The increase in crop yields is ensured by rapid intensification of production with high degree of chemicalization and significant investment costs. The ecological purity of production and soil is endangered, and this leads to adverse consequences for human and animal health.

Of great importance for modern agriculture is the demand for alternative, environmentally friendly methods and technologies to increase yields of major crops. Increasing attention is being paid to organic products that are the result of organic farming.

Many scientists are looking for other non-traditional ways to stimulate the genetic potential of plants, which can lead to increased yields and produce environmentally friendly agricultural products, with lower capital investments.

In recent years, many researchers, in many cultivated plant species, have experimented with the application of physical methods for pre-sowing seed treatment in order to stimulate their sowing qualities.

Physical treatments include treatments in: magnetic field; direct current field; electrostatic field; corona discharge field; electromagnetic field, laser, gamma rays, etc. (Blonskaya and Okulova, 1982; Listopad et al., 1986; Andonov et al., 1987).

It is believed that every living organism is an energy (open electrical) system and with the help of electrical influences can control its vital activity (Kalmykov, 1965; Lazarenko and Bologa, 1970).

Physical treatments using the application of magnetic fields have been studied the most. Results have been known for magnetic stimulation of the sowing qualities of peas (Iqbal et al., 2012a,b), soybean (Radhakrishnan and Kumari, 2012), triticale (Alvarez et al., 2012; Flórez et al., 2014) and many others

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(Aladjadjiyan, 2010; Pietruszewski and Martínez, 2015; Martinez et al., 2017). The disadvantage of pre-sowing magnetic treatments was that they required a long time to affect the seeds (Alvarez et al., 2012; Florez et al., 2014).

Aguilar et al. (2015) compared the effects on germination and growth of corn seeds after their treatment with magnetic, electric and electromagnetic fields. After analyzing seed germination, growth dynamics, chlorophyll a, chlorophyll b and total chlorophyll content, as well as the accumulation of fresh and dry mass of plants, they found that the best results were obtained from seeds treated in electromagnetic fields. Moreover, these results have doubled the values of most of the studied indicators.

According to Starodubtseva and Fedorishchenko (2001) after pre-sowing electromagnetic treatment of sorghum seeds, laboratory germination was increased by 6-8%, field - from 8.3 to 20.8%, yield - by 160 kg/ha, and maturation occurred by 8-11 days earlier than the control.

Positive results were obtained after treatment in electromagnetic field of corn seeds (Sirakov, 2006; Palov et al., 2001a; 2001b; 2002; 2005; Bilalis, 2012a; Aguilar et al., 2015), wheat (Sirakov et al., 2007), soybean (Đukić et al., 2017), pease (Palov et al., 2013a), vegetable seeds (Ganeva et al., 2013; 2014; Sirakov et al., 2013; 2014a; 2015; 2016a; Antonova et al., 2013; 2014; 2018; Antonova–Karacheva and Sirakov, 2020).

The latest research in this area reveals innovative and original solutions to a number of problems and issues related to pre-sowing electrical seed treatment. Mathematical and computer modeling of the electric field has been developed, which makes it possible to visualize the equipotent lines and values of the field intensity and allows to structure and analyze the zones formed in the inter-electrode space (Palov, 2005; Zahariev, 2015; Sirakov, 2015b; Zahariev, 2014; Zahariev et al., 2014; Sirakov, 2015a; 2020a; 2020b). Laboratory devices have been developed for rapid evaluation of the efficiency of pre-sowing electrical treatment of seeds (Sirakov et al., 2014b). Mathematical models have been developed, taking into account the influence of many and individual factors on the effect of pre-sowing electrical or electromagnetic treatment (Zahariev, 2015).

The parameters of efficient electrical treatments of seeds from: maize hybrids (U = 1.65kV and τ = 10s) and wheat seeds (U = 3kV and τ = 35s) (Zahariev et al., 2013; Zahariev, 2015) were established. From production research conducted in different regions of the country, increased yields were realized, expressed as a percentage compared to the control: for maize (4.2 ... 22.5)% / k; for wheat (2.5 ... 9.1)% / k (Zahariev, 2015; Palov et al., 2013b; 2016).

The parameters of effective electromagnetic treatments of seeds of three Bulgarian triticale varieties have been established (Muhova et al., 2016; Sirakov et al., 2016b; 2016c; 2018; 2019).

The use of pulsed electromagnetic fields has also been shown to be effective in the treatment of fat-rich cotton seeds. It has been found to increase the germination of cotton seeds and improve development in the early stages of growth (Bilalis et al., 2012b).

Variants of electromagnetic treatments, in which a number of sowing qualities of cotton seeds were improved and the yields of the Bulgarian varieties Beli Izvor and Ogosta were increased, have been established (Bozhkova et al., 1993; Palov et al., 1994). An increase in earliness and yield up to 12% was achieved for the variety Chirpan-539 after pre-sowing electromagnetic treatment of seeds at initial values of controllable factors: voltage U1 = 8kV and duration of treatment = 15s (Palov et al., 2008; Stoilova et al. 2011).

Main unit of cotton growing technology is the preparation of seeds for sowing. Seed cotton yield and fiber quality largely depend on the seed sowing qualities. Seeds possessing high vitality and good germination are guarantee for well-garnished and leveled crops, good growth and development of plants.

In recent years, more intensive cotton research has been conducted to study the effect of electromagnetic treatments on seed sowing properties, with a view to stimulating them and subsequently increasing yields.

In order to establish the effect of electromagnetic treatment on the sowing properties of cotton seeds, the following approach was applied:

- Laboratory experiments were conducted to assess the effect of energy impact on the sowing properties of seeds after processing in electromagnetic field;

- The possibilities for enhancing the manifestation of the stimulating effect of electromagnetic influence after different storage periods of the treated seeds have been studied.

The research was based on the energy stimulation of seeds to improve their sowing qualities and subsequently increase the yield. Studies in this area showed different values of energy levels when using one or another physical field of impact, leading to the desired changes in plant development. On the other hand, even within one plant species, variations in energy portions were observed, causing one or another effect, depending on the specific reaction of different varieties (for a given species). It is even more complicated to determine the time and intensity of the field used, determining the level of energy portion, i.e. the same dose of energy can be obtained after different exposures as the effect on the plant object is different.

Studies have been conducted to study the effect of:

- The electromagnetic treatment and storage time after treatment of seeds on their sowing qualities;
- The electromagnetic treatment and storage time before treatment of seeds on their sowing qualities.

Of particular interest to theory and practice was the application of pre-sowing electromagnetic treatment to energetically stimulate the sowing properties of cotton seeds to be stored, as well as cotton seeds that have been stored for one or two years. It was essential to establish the duration of storage (after and before the electromagnetic impact) of cotton seeds of Bulgarian varieties, in which it was possible to stimulate their sowing qualities using pre-sowing electromagnetic treatment. For now in the specialized literature there were insufficient data on the effect of electromagnetic treatments depending on the duration of storage of electromagnetically treated seeds, as well as the term of stored (untreated) seeds, set aside for the reserve.

The materials and methods of research were presented in detail in a number of our publications (Radevska at al., 2012; Palov at al., 2012; Stoilova at al., 2012; Koleva and Radevska, 2020).

The effect of electromagnetic field was studied for the cotton seeds stored for 40 days, one and two years after treatment. The effect of electromagnetic treatments on cotton seeds stored for one and two years before treatment was also studied. The voltage between the electrodes (U)Kv and the duration of exposure (t)s were accepted as controllable factors of the electromagnetic treatment. After one and two years of storage of cotton seeds treated in electromagnetic field, from the varieties Chirpan-539, Avangard-264 and Trakia, the laboratory germination was better than that of the control (without electromagnetic treatment) variants: for the Avangard-264 variety the increase was by 10.5% after one-year storage of seeds and by 6.1% after two-year storage; for the Chirpan-539 variety - by 5.4% and 5.6%; for Trakia variety - by 6.8% after two-year storage. The variants of treatment 1 with controllable factors [U=(9…6)kV, τ =(15…35)s] for the variety Chirpan-539, [U=(4…2)*kV*, τ =(5…25)s] for the variety Avangard-264 and [U=(9…6)kV, τ =(2…25)s] for the variety Trakia helps the most to increase laboratory germination during both storage periods (Koleva, Radevska, 2020).

Seeds having low laboratory germination for sowing in the year of treatment or for storage for one to two years must be subjected to pre-sowing electromagnetic treatment.

The total length of sprout and root for the Chirpan-539 variety was increased by 46.8-55.2% and 30.6-36.8%, respectively after one- and two-year storage, for the Avangard-264 variety - by 20.5-47.5% and 9.8-23.4%, and for the Trakia variety - by 47.9-65.5% and 10.9-21.6%. As for the Chirpan-539 variety, in case of one- and two-year storage, the processing options with controllable factors 2[U=(7…4.5)kV, τ =(15…35)s], 3[U=(9…6)kV, τ =(5…25)s] and 5[U=(5…2.5)kV, τ =(5…25)s] had the greatest effect, regarding the Avangard-264 variety - of treatment with controllable factors 3[U=(4..2)kV, τ =(2…15)s], 4[U=(3…1)kV, τ =(2…15)s] and 5[U=(2…1)kV, τ =(5…10)s] after one-year storage, 1[U=(4…2)kV, τ =(5…25)s] and 5[U=(2…1)kV, τ =(5…10)s] after two-year storage, and for the Trakia variety - variants 2[U=(4…2)kV, τ =(2…25)s] and 5[U=(2.5…2)kV, τ =(15…25)s] for one-year, 2[U=(4…2)kV, τ =(2…25)s], 4[U=(4…2)kV, τ =(1…12)s] and 5[U=(2.5…2)kV, τ =(15…25)s] for two-year storage (Figure 1.).

Positive effect of electromagnetic treatment on the total length of root and sprout was also observed for the seeds without storage for the Chirpan-539 and Avangard-264 varieties.

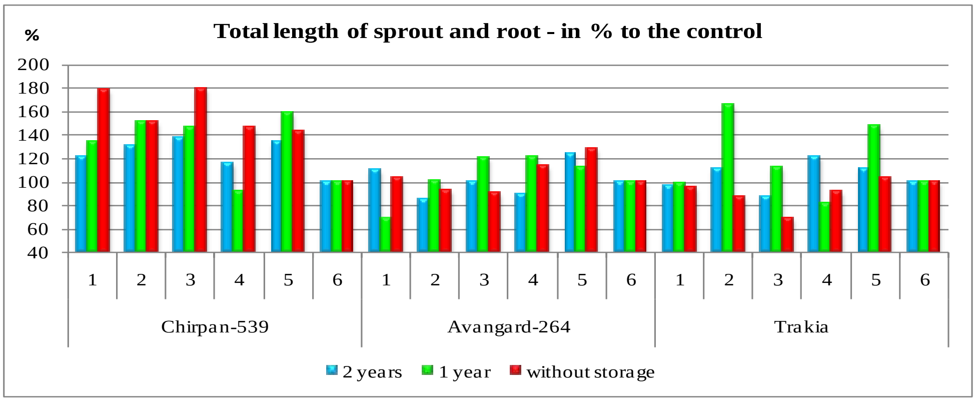

Fig. 1. Effect of electromagnetic treatment on the total length of sprout and root

The total mass of root and sprout, after electromagnetic treatment of seeds, for the variety Chirpan-539 was increased by 36.3% to 59.7% (at option 1[U=(9…6)kV, τ=(15…35)s]) without storage and by 27.3% to 63.2% (at option 5[U=(5…2.5)kV, τ=(5…25)s]) after one year of storage, for the variety Avangard-264 - by 20.4% without storage (in case of option 5[U=(2…1)kV, τ=(5…10)s]) and by 16.7% to 44.8% (in case of option 4[U=(3…1)kV, τ=(2…15)s]) after one year of storage, and as for the variety Trakia - by 17.4% (in case of option 5[U=(2.5…2)kV, τ=(15…25)s]) and 17.7-34.7%, respectively (at options [2U=(4…2)kV, τ=(2…25)s] and 5[U=(2.5…2)kV, τ=(15…25)s]) (Figure 2).

Based on the increased total mass of root and sprout as a complex result, the most suitable processing options were: for the variety Chirpan-539 - option 1[U=(9…6)kV, τ =(15…35)s] without storage and option 5[U=(5…2.5)kV, τ =(5…25)s] after one year of storage; for the variety Avangard-264 - variant 5[U=(2…1)kV, τ =(5…10)s] without storage and variant 4[U=(3…1)kV, τ =(2…15)s] after one year of storage; for the variety Trakia - variant 5[U=(2.5…2)kV, τ =(15…25)s] without storage and variants 2[U=(4…2)kV, τ =(2…25)s] and 5[U=(2.5…2)kV и τ =(15…25)s] after one-year storage.

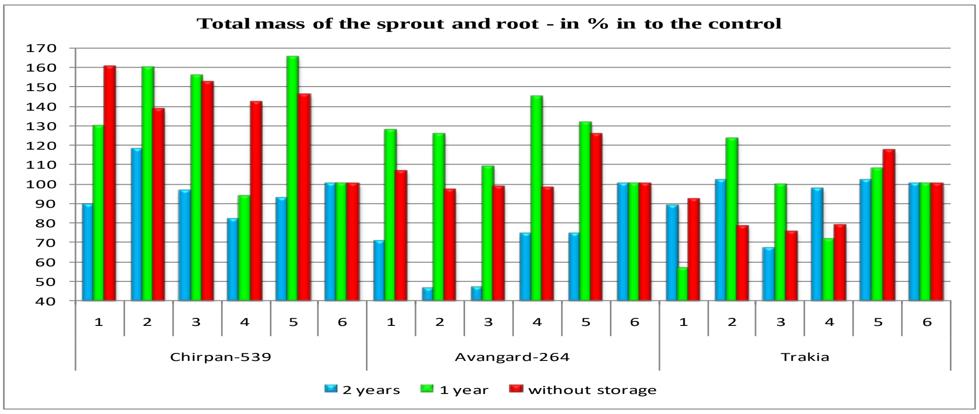

Fig. 2. Effect of electromagnetic treatment on the total mass of sprout and root

After pre-sowing electromagnetic treatment of cotton seeds of the varieties Chirpan-539, Trakia, Helius, Natalia and Nelina, stored one and two years before treatment, the selected values of controllable factors had stimulating effect on:

- the germination energy and laboratory germination - compared to the untreated control the increase of the two indicators was respectively by 7.3 - 9.9% at option 3[U=(8…5)kV, τ =(5…25)s]; and 5.6 - 6.4% as the best options were 2[U=(6…3)kV, τ =(15…35)s] and 4[U=(6…3)kV, τ=(5…25)s] (Figure 3);
- the length of sprout and root - by 10.2 - 15.3% as the best processing options were 1[U=(8…5)kV, τ =(15…35)s] and 4[U=(6…3)kV, τ =(5…25)s]; 6.0 - 17.5% at option 4[U=(6…3)kV и τ=(5…25)s];

- the total length of sprout and root - by 7.5 - 16.4% as the best results were obtained after processing according to variants 4[U=(6…3)kV, τ =(5…25)s] and 1[U=(8…5)kV, τ =(15…35)s] (Figure 4);
- the mass of sprout and root - the mass of sprout was increased by 8.9 - 13.8% and the best processing options were 1[U=(8…5)kV, τ =(15…35)s] and 4[U=(6…3)kV, τ =(5…25)s], the mass of root was increased by 3.5 -11.3%, as the best options are the same processing;
- the total mass of sprout and root - by 7.8 - 12.7%, the best processing options were 1[U=(8…5)kV, τ =(15…35)s] and 4[U=(6…3)kV, τ =(5…25)s], (Figure 5).

From the obtained results and their analysis it turns out that the variants of pre-sowing electromagnetic treatment 1[U=(8…5)kV, τ =(15…35)s] and 4[U=(6…3)kV, τ =(5…25)s] appeared to be very good for all indicators

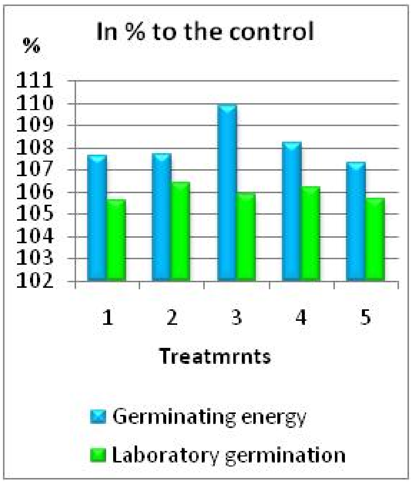

Fig. 3. Effect of electromagnetic treatment on the germinating energy and laboratory germination

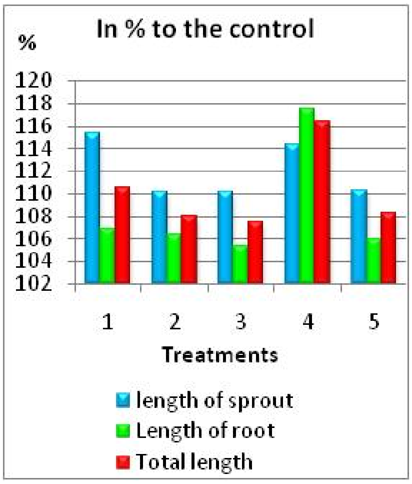

Fig. 4. Effect of electromagnetic treatment on the length of sprout, length of root and the total length of sprout and root

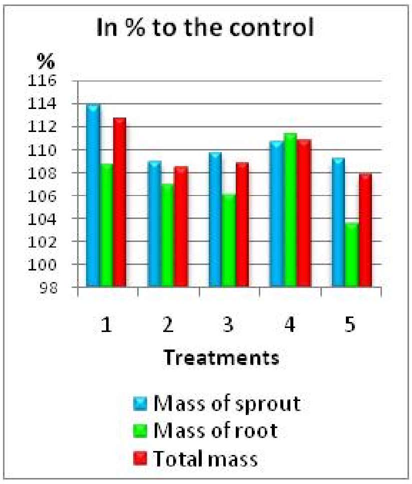

Fig. 5. Effect of electromagnetic treatment on the mass of sprout, mass of root and the total mass of sprout and root

Electromagnetic treatment as an individual factor had a proven stimulating effect on all reported indicators related to the seeds sowing qualities. All treatment options had positive impact.

The longer two-year storage period of seeds has led to lowering of all sowing qualities compared to the shorter one-year storage period.

The interaction of treatments × storage periods determined higher indicators of the sowing qualities of seeds after their one-year storage.

The varieties reacted differently to the two storage periods. In most cases, with lowering the sowing qualities of seeds after their two-year storage, in some cases they had the same indicators after the two storage periods.

The electromagnetic impact had stimulating effect in both storage periods compared to the untreated relevant control:

- for the germination energy by 6.8–9.1% at option 4[U=(6…3)kV, τ =(5…25)s] and 6.7– 8.8% at option 2[U=(6…3)kV, τ =(15…35)s] and for laboratory germination by 5.3–6.4% at option 4[U=(6…3)kV, τ =(5…25)s] and 5.2–7.6% at option 2[U=(6…3)kV, τ =(15…35)s];
- the length of sprout was higher by 11.3–18.6% at variant 4[U=(6…3)kV, τ =(5…25)s] and by 5.2–12.4% at variant 1[U=(8…5)kV, τ =(15…35)s]; the length of the root - by 8.3–22.8% and 4.5–11.3% at option 4[U=(6…3)kV, τ =(5…25)s]; the total length of sprout and root - by 7.6–21.1% and 2.3–11.0% at option 4[U=(6…3)kV, τ =(5…25)s];
- the sprout mass was increased by 11.4–16.8% at option 1[U=(8…5)kV, τ =(15…35)s] and 5.3–10.4% at options 1[U=(8…5)kV, τ=(15…35)s] and 4[U=(6…3)kV, τ =(5…25)s]; the root mass - by 5.1–16.1% at options 1[U=(8…5)kV, τ =(15…35)s] and 4[U=(6…3)kV, τ =(5…25)s] and 2.7–8.1% at

option 4[U=(6…3)kV, τ =(5…25)s]; the total mass of sprout and root - by 10.8–16.5% at option 1[U=(8…5)kV, τ =(15…35)s] and 4.5–9.1% at option 4[U=(6…3)kV, τ =(5…25)s].

The interaction of varieties × treatments had the most significant impact on the root mass.

As a result of the three main factors interaction, variants with significant higher values than the control variant for the experiment - Chirpan-539 variety, one-year storage, untreated seeds, were reported only for one-year storage of seeds.

Compared to the untreated control corresponding to each variety and storage period, the stimulating effect of the pre-sowing electromagnetic treatment was observed for all varieties, at both storage periods.

The Helius variety was most responsive to electromagnetic impact. This variety responded with the strongest stimulating effect for many of the indicators. For this variety, at most after electromagnetic treatment increased:

- the germination energy - from 23.1% to 26.5% and from 19.0% to 21.5%, respectively, after one and two years of storage;
- the laboratory germination - from 18.5% to 20.0% and from 12.3% to 19.5%;
- the sprout length, after one-year storage - by 44.5-48.8% at variants 1[U=(8…5)kV, τ=(15…35)s], 2[U=(6…3)kV, τ=(15…35)s] and 4[U=(6…3)kV, τ=(5…25)s], after two-year storage - by 27.4% at variant 4[U=(6…3)kV, τ=(5…25)s];
- the root length after one-year storage - by 36.5 and 43.5% at variants 2[U=(6…3)kV, τ=(15…35)s] and 4[U=(6…3)kV, τ=(5…25)s];
- the sprout and root total length, in case of one-year storage - by 34.8–43.9% in variants 1 [U=(8…5)kV, τ=(15…35)s], 2[U=(6…3)kV, τ=(15…35)s] and 4[U=(6…3)kV, τ=(5…25)s]
- the sprout mass after one-year storage - by 36.0% to 57.1% at variant 1[U=(8…5)kV, τ=(15…35)s], after two-year storage - by 8.3 to 23.3% at variant 4[U=(6…3)kV, τ=(5…25)s].
- the sprout and root total mass after one-year storage - by 48.5% at option 1[U=(8…5)kV, τ=(15…35)s].

As for the Nelina variety, in case of one-year storage, at processing variants 1[U=(8…5)kV, τ=(15…35)s], 2[U=(6…3)kV, τ=(15…35)s] and 3[U=(8…5)kV, τ=(5…25)s], the root mass was increased by 41.8–51.8% in compared to the corresponding untreated control.

Studies conducted in our country (Palov et al., 2013a) showed that after pre-sowing electromagnetic treatment (with a voltage frequency of 50 Hz) of pea seeds germination increased by 2.6%, the length of sprout - by 5.5% and root - by 18.6%, and the mass as a whole - by 6.9% compared to the untreated control.

After electromagnetic treatment of Triticale seeds, the variety Boomerang, germination energy was increased to 3.0% and laboratory germination - up to 6.0%, the number and lengths of roots, respectively 9.4% and 33.0%, germ lengths up to 7.6%, green and dry masses of plants up to 35.6% and 37.0%, respectively, compared to the untreated control (Sirakov et al., 2019).

The obtained results for the laboratory germination, total length and total mass of root and sprout, as complex indicators, comfired the positive energy impact found by other authors in other crops, and give grounds to recommend pre-sowing electromagnetic treatment of cotton seeds for sowing as effective method for improving their sowing qualities.

In case of one- or two-year storage, the cotton seeds could be subjected to electromagnetic impact before storage to improve or preserve their sowing qualities.

When cotton seeds were stored for a period of one or two years, the pre-sowing electromagnetic treatment with the selected values of the controllable factors stimulated their sowing qualities and thus greatly improved their biological value.

The mechanisms of physical field action on living biological systems, such as seeds, are not yet well known. Some authors suggest that they act on the course of physiological and biochemical processes in the seed, the activation of proteins and enzymes, which leads to increased vitality and improved plant development at later stages (Carbonell et al., 2000; García et al., 2002). Bilalis et al. (2013) associated positive changes with the accumulation of chemical elements in cotton (using pulsed electromagnetic fields).

The conducted researches and obtained positive results proved the benefit of electromagnetic treatments for stimulating the sowing qualities of cotton seeds. Improved germination energy, laboratory germination, sprout and root length, sprout and root mass, sprout and root total length and sprout and root total mass, indicated that the electromagnetic field could be used as an effective means of improving cotton seed viability and accelerating plant growth and their development in the early stages.

Electromagnetic treatments are performed in a very short time, and the effect after treatment can be maintained after sufficiently long storage of treated seeds. According to Kostov et al. (2014) in case of pre-sowing electric treatments of seeds, the duration of impact can be perceived in the order of

The results of the study also showed that electromagnetic treatments increased the viability of long enough stored cotton seeds. Stored cotton seeds often lose germination and the use of electromagnetic impact can be an effective way to restore it.

Electromagnetic stimulation does not pollute the environment and can be a very good alternative to some traditional pre-sowing treatments, such as treating cotton seeds with pesticides.

A specialized modified screw device was used for the proposed electromagnetic treatments. It is simple, consumes little energy and has an environmentally friendly impact.

The achieved results show that pre-sowing electromagnetic treatments could be used in conventional and organic agriculture to improve the sowing qualities of seeds, and subsequently to accelerate the growth and development of plants, and increase crop yields.

The proposed method is also valuable in that it can also be used to improve the sowing qualities of already stored (reserve) seeds for sowing and of seeds from genetic resources that have largely lost their germination.

- In the preparation of seed for sowing for cotton production to improve the seed sowing qualities and subsequent increase in yields;
- Defining the setting parameters (the exposures) in laboratory and industrial facilities for processing in electric or electromagnetic fields of sowing material;
- In organic farming to stimulate the emergence, growth and development of plants, and improve productivity.

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