Influence of duration of storage and pre-sowing electromagnetic treatment on the sowing qualities of cotton seeds I. Germination energy and laboratory germination

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Abstract

Effect of pre-sowing electromagnetic treatments on seeds of 5 Bulgarian cotton varieties - Chirpan-539, Helius, Trakia, Natalia and Nelina on germination energy and laboratory germination of seeds stored one and two years before treatment was studied. It was found that for all tested varieties, in both seed storage periods, and in almost all variants of pre-sowing electromagnetic treatment, germination energy and laboratory germination were higher than the corresponding controls for each variety and storage period. In one- and two-year storage, the highest percentage of germination energy and laboratory germination was reported for the Helius variety and variant of treatment 1[U = (8… 5) kV and τ = (15… 35) s]. Laboratory germination increased by 19.5% compared to the relevant control, and germination energy increased by 24%.

Key words: pre-sowing electromagnetic treatment; cotton seeds; germination; germination energy

INTRODUCTION

The sowing qualities of cotton seeds are of great importance for the mass and timely germination of cotton. The seeds of high vitality and germination are a guarantee for good garnish of the cotton crops, passing of the different phonological phases of development in the respective most appropriate terms and obtaining optimal yields. At low laboratory germination, seed germination is difficult and crops remain sparse, poorly garnished with plants inside the row. This leads to strong branching of cotton plants in the empty spaces, lower setting of fruit branches, delayed ripening, strong reduction in seed cotton yield. Of great importance for modern intensive agriculture is the demand for alternative, environmentally friendly methods and technologies to increase yields of major crops. In recent years application of physical fields for pre-sowing treatment of seeds in order to stimulate their sowing qualities have experimented with many cultivated plant species. A number of authors observed an increase in yield after pre-sowing electromagnetic exposure for some crops. The use of electromagnetic field for energy stimulating effect on the sowing qualities of cotton seeds and subsequent increase of seed cotton yield is an alternative possibility for ecologically cleaner cotton production. After pre-sowing electromagnetic treatment of cotton seeds, an increase in yields was found for the Bulgarian varieties “Beli izvor” and “Ogosta” (Bozhkova et al., 1993; Palov et al., 1994). An increase in earliness and yield up to 12.0% was achieved in the variety Chirpan-539 (Palov et al., 2008). Studies conducted in Bulgaria (Palov et al., 2013) show that after pre-sowing electromagnetic treatment (applying a voltage frequency of 50 Hz) of pea seeds germination increased by 2.6%, length of sprout - by 5.5% and root - by 18.6 %, and the mass as a whole - by 6.9% compared to the control.

The aim of this research was to study the effect of terms of storage and pre-sowing electromagnetic treatment on germination energy and laboratory germination of cotton seeds.

MATERIAL AND METHODS

Seeds of five cotton varieties - Chirpan-539, Helius, Trakia, Natalia and Nelina were the object of the study. Chirpan-539 variety was obtained trough intraspecific origin *Gossypium hirsutum* L. This variety is early ripening and highly productive and possess high lint percentage. It is a national standard for productivity in the IASAS system (Exclusive Agency for Variety Testing, Approbation and Seed Control). The Helius and Trakia varieties were created by applying the method of experimental mutagenesis and are characterized by very high productivity and large bolls. The Natalia and Nelina varieties were obtained from the combination of the interspecific *G. hirsutum* L. × *G. barbadense* L. hybridization with intraspecific *G. hirsutum* L. The variety Natalia is of very high fiber quality, and the variety Nelina is highly productive possessing high lint percentage.

Seeds of all varieties were stored for one and two years, after which they were subjected to pre-sowing electromagnetic treatment. The seeds of each variety were treated in 5 different (applied to all varieties) electromagnetic fields with different intensity and different duration of exposure. A special device developed and patented by a team of scientists from the University of Ruse "Angel Kanchev" was used (Terziev et al., 1995). They found experimentally that the use of this device, that was applied successfully for pre-sowing treatment of corn and seeds of other cereals, did not contribute to the effective impact on cotton seeds. This could be explained by the higher fat content in cotton seeds, which acted as a "kind of shield" for external influences.

For the purposes of pre-sowing electromagnetic treatments, a method with periodic decrease of the values of the voltage U between the electrodes of the working camera and increase of the duration of impact was used. I, II and III were sequences of electromagnetic treatment with different values of controllable factors (Palov et al., 1995).

Based on previous research (Palov et al., 1994) a matrix was used to plan the experiment, which is shown in Table. 1. In previous studies (Bozhkova et al., 1993) variant of treatment 4 gave the best results regarding the electromagnetic impact on the seeds of cotton variety "Beli izvor". Variant of treatment 5 with the values of the controllable factors indicated in the Table 1 was also set. Such pre-sowing electromagnetic treatment was most effective for the seeds of Ogosta cotton variety.

After electromagnetic treatment, the cotton seeds stayed for 23 days. According to Palov et al. (1994) this stay, after treatment until sowing, was necessary so that changes should occur in the seeds, which will subsequently favor the development of the plants.

Some of the seeds of each variety were not treated and served for control, to compare and report the effect of electromagnetic treatment.

After the treatment and the stay of the seeds, laboratory experiments were performed. 50 seeds were planted in three replicates of the control and

Table 1. Experimental planning matrix for pre-sowing electromagnetic treatment of cotton seeds

Treatment option	Processing steps					
	I		II		III	
	Controllable factors		Controllable factors		Controllable factors	
	U_1 (кV)	τ_1 (s)	U_1 (кV)	τ_1 (s)	U_1 (кV)	τ_1 (s)
1	8	15	6,5	25	5	35
2	6	15	4,5	25	3	35
3	8	5	6,5	15	5	25
4	6	5	4,5	15	3	25
5	4	5	2,5	15	2	25
6	Reference specimen (untreated seeds)					

treated variants, for each variety. The seeds of each variant were arranged on filter paper moistened with distilled water on a template. They were rolled and placed in glass baths with distilled water and then set in a thermostat under controlled conditions - temperature 25ºC and humidity of the environment 95%.

The seeds germination energy was reported on the third day (percentage of germinated seeds on the third day of their placement in a thermostat) and on the seventh day the laboratory germination was determined (percentage of germinated seeds on the seventh day of their setting in a thermostat). The results for each sample were averaged.

The results were processed by three-way analysis of variance. The ANOVA123 program was used. The factors of experience were: A – Varieties; B - Electromagnetic treatments; C - Duration of storage of seeds before their processing.

Variant Chirpan-539 variety (approved for national standard), untreated seeds, stored for one year, was accepted as a control one for the experiment. In addition, electromagnetic treatments were compared to the corresponding to each variety controls.

RESULTS AND DISCUSSION

An analysis of the variance was made to determine the force of each main factor and the interactions between the factors on the formation of each indicator. The significance of the effects was based on the smallest significant differences.

Table 2 presents the results of the performed three-factor dispersion analysis of the data for the germination energy and the laboratory germination of the seeds of the studied five cotton varieties, under different duration of storage - one and two years, after their pre-sowing electromagnetic treatment. The independent influence of the three main studied factors - varieties, duration of storage and electromagnetic treatments for both studied seed properties was very well proven.

Of the interactions, the following ones have been proven: varieties × treatments and varieties × duration of storage. Significant interactions show that the varieties have reacted differently to seed storage times and electromagnetic treatments concerning germination energy and laboratory germination. The interaction of treatments × duration of storage was insignificant, which means that the effect of electromagnetic treatments did not depend on the storage time of the seeds. The interaction of the three main factors - varieties, duration of storage and treatments was also insignificant.

The interaction A × C (varieties × duration of storage) had the most significant impact, as for the germination energy it was 43.35%, and regarding laboratory germination it was 42.98%. Of the forming it two factors, the varieties had a slight-

Table 2. Results of three-way ANOVA for germinating energy and laboratory germination after electromagnetic treatment of seeds of 5 cotton varieties after 1 and 2 years storage of seeds

Factors	Degrees of freedom	Germinating energy			Laboratory germination		
		Sum of squares	Sum of squares, %	Dispersion	Sum of squares	Sum of squares, %	Dispersion
Varieties – A	4	5272.37	19.81	1318.09^{+++}	3820.25	19.5	955.06^{+++}
Treatments – B	5	1461.00	5.49	292.2^{+++}	1032.50	5.28	206.5^{+++}
Storage – C	1	1875.50	14.56	3873.5^{+++}	2606.75	13.3	2606.75^{+++}
Interaction A×B	20	1498.13	5.63	74.91^{+++}	1131.00	5.78	56.55^{+++}
Interaction A×C	4	11534.5	43.35	2883.6^{+++}	8410.00	42.9	2102.5^{+++}
Interaction B×C	5	108.37	0.41	21.67	63.25^{ns}	0.32	12.65
Interaction A×B×C	20	555.13	2.09	27.76	509.50^{ns}	2.60	24.47
Errors	118	2187.75	8.22	18.54	1913.75	9.78	16.22

ly stronger influence than the duration of storage. Electromagnetic treatments, as an independent factor, and the interaction of varieties × treatments had a small but significant strength of influence - 5.49% and 5.63%, respectively for the germination energy and 5.28% and 5.78% for the laboratory germination.

The results for the independent action of the three main factors on the studied seed characteristics are presented in Figure 1. Of the varieties showed the highest germination energy was Chirpan-539, followed by Helius. The other three varieties had lower very well-proven germination energy, which was the lowest for the Nelina variety (a). All variants of electromagnetic treatment, regardless of the varieties and duration of seeds storage, showed better germination energy by 7.3% to 8.2% of the control (Chirpan-539 variety, storage time one year, without treatment) (b). The strongest improvement of germination energy was observed for the treatment options 3 and 4.

Duration of storage as an independent factor also affected the seeds germination energy. It has been shown to be lower for the two-year term of storage (Fig. 1 c).

In terms of laboratory germination the results were similar to germination energy. The highest laboratory germination of seeds was observed for the Chirpan-539 variety, and the lowest was reported for the Nelina variety. The increase in laboratory germination was in the range of 5.6-6.4%. The treatment options 2 and 4 had the strongest positive effects on the laboratory germination. After the two-year storage duration of the seeds, their laboratory germination has been shown to be lower than those stored for one year.

The results about the electromagnetic treatment force of influence on the germination energy are presented in Table 3. The highest germination energy, as a result of the interaction of varieties × treatments (A × B), was observed for the seeds of the Chirpan-539 and Helius varieties. For the Chirpan-539 variety, at the treatment variants 3 and 4, the seeds germination energy increased by 3.4-3.5%, and for the Helius variety, at variant of treatment 1, this increase was by 4.2%, compared to the untreated control of Chirpan-539 variety. For all studied varieties, treatment variants showed higher germination energy of the seeds, compared to their respective untreated control, were observed. The largest increase in the germination energy, compared to the corresponding control, was found for the Helius variety, at the variant of treatment 1.

As a result of the interaction varieties × duration of storage (A × C) the highest germination energy was observed for the seeds of Nelina variety, after the shorter storage period of one year. On the basis of the smallest significant differences, significant ones for the germination energy of the seeds stored for one and two years, subjected to pre-sowing electromagnetic treatment, have been established. Significant higher germination energy than of the control variant Chirpan-539 variety, one year storage, without treatment, was observed for the seeds stored one year at all variants of electromagnetic treatment. The seeds stored for two years, after

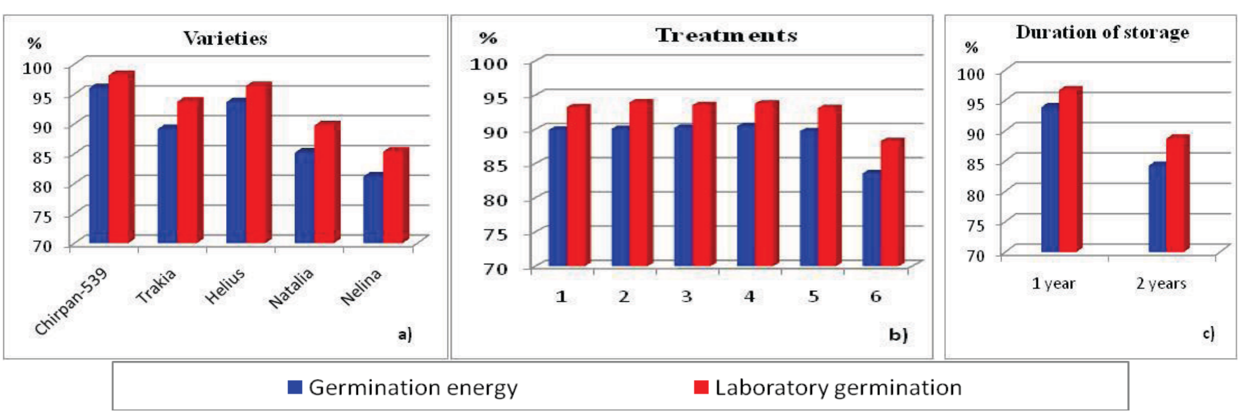

Figure 1. Independent action of the main factors - varieties, pre-sowing electromagnetic treatments and duration of storage on the germination energy and laboratory germination of cotton seeds, in %

electromagnetic treatment had lower germination energy than the control variant.

Of the analysis of the germination energy variance, the interaction of the three factors varieties × duration of storage × treatments was insignificant (Table 2). The smallest significant differences, however, indicated the presence of significant differences. Higher germination energy after pre-sowing electromagnetic treatment of the seeds, compared to the control variant, was observed for the varieties: Chirpan-539 and Helius after both storage periods; Natalia and Nelina after shorter storage period of one year and Trakia after storage period of two years. This increase was strongest for the Nelina variety, at the treatment option 4, by 6.4%. The differences were statistically insignificant for all variants. However, there were significant lower values of germination energy after pre-sowing electromagnetic treatment of seeds for the varieties: Trakia, after the shorter storage period of one year; Natalia and Nelina, stored for 2 years.

Compared to the corresponding controls, improvement of germination energy after pre-sowing electromagnetic treatment was observed for all varieties, in both seed storage periods, and at most treatment variants. The germination energy after electromagnetic treatment of Helius variety seeds was very strongly increased, from 23.1% to 26.5% with one year of storage and from 19.0% to 21.5% with two years of storage, compared to the respective untreated controls. In the case of Nelina variety, with the two-year storage of seeds, after electromagnetic treatment, at treatment options 2 and 3, the germination energy increased by 19.6% and 13.0%, respectively and in the case of Trakia variety, with one-year storage, at treatment options 4 the increase was by 14.4%. As for the other varieties, the effect of electromagnetic treatment was smaller and the germination energy improving was in the range of 1.4-9.3% after one-year storage of seeds and 2.1-10.5% after two-years of storage.

The effect of electromagnetic treatment on the laboratory germination of seeds of studied varieties is presented in Table 4. As a result of the interaction of factors varieties × treatments, the highest laboratory germination of seeds was reported for the Helius and Chirpan-539 varieties, but it was insignificant compared to untreated control of Chirpan-539 – standard variety. For all varieties however, the treatment variants prevailed, causing higher laboratory germination of the seeds than their respective untreated control. The Helius variety reacted most strongly, the seed laboratory germination increased at all treatment options from 15.9% to 19.5%, regarding the variants 1, 4 and 5 it was the best.

As a result of the interaction of the factors varieties × duration of storage, the Nelina variety, with storage term of one year, had the highest laboratory germination of seeds of 101.1% compared to the control. Different varieties reacted differently to the two duration of storage as regards the laboratory germination. The Helius, Natalia and Nelina varieties had significant lower laboratory germination of seeds in case of two-year storage. The seeds of the Natalia and Nelina varieties have lost the germination the most during their two-year storage.

As a result of the interaction of the factors treatment × duration of storage, the laboratory germination of the seeds stored for one year was increased in all variants of treating by 5.3-6.4%, while after two year seed storage it was insignificant and significant less than the control variant of Chirpan -539 variety - after one year of storage.

As a result of the interaction of the three main factors varieties × duration of storage × treatment, in case of some varieties and variants of treatment, after the two storage periods, higher but insignificant laboratory germination was observed. Compared to the respective controls, for all varieties, after both storage periods and for almost all variants of electromagnetic treatment, the laboratory germination was higher. In the case of the Helius variety, the laboratory germination was most strongly increased after the two storage periods, by 18.5% to 20.0% after one year of storage and by 12.3% to 19.5% after two years of storage.

Electromagnetic treatment had a stimulating effect on the germination energy and laboratory germination of seeds more pronounced for the varieties showed lower values regarding both studied characteristics after the longer storage period, where both properties had lower values. Seeds having low laboratory germination should be subjected to pre-sowing electromagnetic treatment.

CONCLUSIONS

The pre-sowing electromagnetic treatment, with the selected values of the controllable factors, had

Table 3. Effect of pre-sowing electromagnetic treatment on the seed germination energy of 5 cotton varieties after 1 and 2 years duration of storage. (In brackets – in % to the variety corresponding control)

Varieties	Treatments	Duration of storage		Interaction A×B	In % to the control
		1 year	2 years		
Chirpan-539	1	97.33	92.00	94.67 (100.4)	100.4
	2	96.67	95.33	96.00 (101.8)	101.8
	3	97.67	97.33	97.50 (103.4)	103.4
	4	97.32	98.00	97.67 (103.5)	103.5
	5	96.67	94.67	95.67 (101.4)	101.4
	6	**93.33**	95.33	94.33 (**100**)	**100.0**
Interaction A × C		96.50	95.44	***Factor A*** **-** 95.97	
Trakia	1	83.33	96.67	90.00 (108.0)	95.4
	2	85.33	94.67	90.00 (108.0)	95.4
	3	83.33	90.67	87.00 (104.4)	92.2^{00}
	4	90.00	96.00	93.00 (111.6)	98.6
	5	86.00	96.67	91.33 (109.6)	96.8
	6	78.67	88.00	83.33 (**100.0**)	88.3^{000}
Interaction A × C		84.44	93.78	***Factor A*** **-** 89.11	
Helius	1	98.67	98.00	98.33 (124.0)	104.2
	2	96.00	96.00	96.00 (121.0)	101.8
	3	98.67	90.67	94.67 (119.3)	100.4
	4	97.33	96.00	96.67 (121.9)	102.5
	5	97.33	96.00	96.67 (121.9)	102.5
	6	78.00	80.67	79.33 (**100.0**)	84.10^{000}
Interaction A × C		94.33	92.89	***Factor A*** **-** 93.61	
Natalia	1	98.67	77.33	88.00 (107.3)	93.3^{0}
	2	94.00	70.67	82.33 (100.4)	87.3^{000}
	3	96.00	81.33	88.67 (108.1)	94.0
	4	96.67	74.00	85.33 (104.1)	90.5^{000}
	5	97.33	72.67	85.00 (103.7)	90.1^{000}
	6	94.00	70.00	82.00 (**100.0**)	86.9^{000}
Interaction A × C		96.11	74.22	***Factor A*** **-** 85.17	
Nelina	1	96.67	60.67	78.67 (99.6)	83.4^{000}
	2	98.67	73.33	86.00 (108.9)	91.2^{000}
	3	97.33	69.33	83.33 (105.5)	88.3^{000}
	4	99.33	60.67	80.00 (101.3)	84.8^{000}
	5	98.00	62.00	80.00 (101.3)	84.8^{000}
	6	96.67	61.33	79.00 (**100.0**)	83.7^{000}
Interaction A × C		97.78	64.56	***Factor A*** **-** 81.17	
				Factor B	
Interaction B × C	1	94.93	84.93	89.93	107.6***
	2	94.13	86.00	90.07	107.7***
	3	94.60	85.87	90.24	107.9***
	4	96.13	84.80	90.47	108.2***
	5	95.07	84.40	89.74	107.3***
	6	**88.13**	79.07	83.60	**100.0**
Mean factor **C**		93.83	84.18		

Errors at:	Factors						
	A	B	C	A×B	A×C	B×C	A×B×C
P=5.0%	2.1	2.6	1.4	5.2	2.9	3.5	7.5
P=1.0%	2.8	3.5	1.8	6.9	3.9	4.7	9.9
P=0.1%	3.6	4.5	2.3	8.9	5.0	6.0	12.7

Table 4. Effect of pre-sowing electromagnetic treatment on the laboratory germination of seeds of 5 cotton varieties after 1 and 2 years of storage. (In brackets – in % to the variety corresponding control)

Varieties	Treatments	Duration of storage		Interaction A × B	In % to the control
		1 year	2 years		
Chirpan-539	1	98.7	96.7	97.7 (100.0)	100.0
	2	99.3	98.7	99.0 (101.3)	101.4
	3	99.3	97.3	98.3 (100.6)	100.7
	4	98.0	98.7	98.3 (100.6)	100.7
	5	99.3	96.7	98.0 (100.3)	100.3
	6	96.7	98.7	97.7 (**100.0**)	**100.0**
Interaction A × C		98.5	97.8	***Factor A** – 98.2*	
Trakia	1	88.7	98.3	93.5 (110.4)	95.7
	2	90.3	99.0	94.7 (111.8)	96.9
	3	89.0	95.0	92.0 (108.6)	94.2^{0}
	4	94.3	99.7	97.0 (114.5)	99.3
	5	90.3	99.0	94.7 (111.8)	96.9
	6	75.0	94.3	84.7 (**100.0**)	92.5
Interaction A × C		87.9	97.5	***Factor A** – 92.7*	
Helius	1	100.0	100.0	100.0 (119.5)	102.4
	2	98.7	98.7	98.7 (117.9)	101.0
	3	99.7	94.3	97.0 (115.0)	99.3
	4	99.3	99.7	99.5 (118.9)	101.9
	5	98.7	99.3	99.0 (118.3)	101.4
	6	83.3	84.0	83.7 (**100.0**)	85.7^{000}
Interaction A × C		96.6	96.0	***Factor A** – 96.3*	
Natalia	1	100.0	83.0	91.5 (106.1)	93.7^{00}
	2	97.7	77.3	87.5 (101.5)	89.6^{000}
	3	98.0	86.7	92.3 (107.1)	94.5^{0}
	4	99.3	82.7	91.0 (105.6)	93.2^{00}
	5	99.3	80.3	89.8 (104.2)	92.0^{000}
	6	97.0	75.3	86.2 (**100.0**)	88.22^{000}
Interaction A × C		98.5	80.9	***Factor A** – 89.7*	
Nelina	1	99.7	67.3	83.5 (100.0)	85.5^{000}
	2	100.0	79.7	89.8 (107.5)	92.0^{000}
	3	100.0	76.0	88.0 (105.4)	90.1^{000}
	4	100.0	66.0	83.0 (99.4)	85.0^{000}
	5	100.0	68.0	84.0 (100.6)	86.0^{000}
	6	98.0	69.0	83.5 (**100.0**)	85.5^{000}
Interaction A × C		99.6	71.0	***Factor A** – 85.3*	
				Factor B	
Interaction B × C	1	97.4	89.1	93.2	107.0
	2	97.2	90.7	93.9	107.8
	3	97.2	89.9	93.5	107.3
	4	98.2	89.3	93.8	107.7
	5	97.5	88.7	93.1	106.9
	6	90.0	84.3	87.1	**100.0**
Mean Factor C		96.2	88.6		

Errors at:	Factors						
	A	B	C	A × B	A × C	B × C	A × B ×C
P=5.0%	1.9	2.0	1.1	4.6	2.6	2.9	6.5
P=1.0%	2.5	2.7	1.6	6.1	3.5	3.8	8.6
P=0.1%	3.2	3.5	2.0	7.8	4.5	5.0	11.1

stimulating effect on the germination energy and laboratory germination of the seeds stored for one and two years, more pronounced strongly expressed after their one-year storage. Compared to the control - variety Chirpan-539, untreated seeds, one year of storage - the increase of the germination energy was by 7.3 - 9.9% at treatment variant 3 [U = (8… 5) kV and τ = (5… 25) s], of the laboratory germination – was by 5.6 - 6.4%, as the best were found treatment variants 2 [U = (6… 3) kV, τ = (15… 35) s] and 4 [U = (6… 3) kV, τ = (5 … 25) s].

Compared to the corresponding untreated control for each storage period, the electromagnetic effect had a stimulating effect for both storage periods: 6.8 - 9.1% at option 4 [U=(6…3)kV, τ=(5…25)s] and 6.7 - 8.8% on option 2 [U=(6…3)kV, τ=(15…35) s] for germination energy and 5.3 - 6.4% on option 4 and 5.2 - 7.6% on option 2 for laboratory germination, respectively after one- and two-year storage of seeds.

As a result of the interaction of varieties × treatments (A × B), the Helius and Chirpan-539 varieties had the highest values of germination energy and laboratory germination of seeds of all variants of electromagnetic treatment.

As a result of the interaction of the three main factors varieties × duration of storage × treatments (A × B × C), for some of the varieties and the treatment variants, after the two storage periods, were observed higher values of germination energy and laboratory germination, compared to the accepted control Chirpan-539 variety, untreated seeds, one year storage.

The variety Helius was the most responsive to the electromagnetic impact, after treatment the germination energy increased by 23.1 - 26.5% and 19.0 - 21.5%, respectively, during one and two years of storage. Similary, laboratory germination increased by 18.5 - 20.0% and 12.3 - 19.5%.

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