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Stimulation of laboratory germination of cotton seeds stored for one and two years by electromagnetic fields

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Abstract

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Stimulation of germination energy and laboratory germination of cotton seeds, stored for one and two years, of 5 Bulgarian cotton varieties Chirpan-539, Helius, Trakia, Natalia and IPK Nelina, by using electromagnetic fields, was studied. It was found that for all tested varieties, after both seed storage periods and for almost all pre-sowing electromagnetic treatments, germination energy and laboratory germination were higher than the corresponding controls for each variety and storage period. After one- and two-year storage of seeds, the highest germination energy and laboratory germination were found 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%.

Keywords: electromagnetic impact; duration of storage; cotton seeds; laboratory germination; germination energy

Introduction

Development of alternative, environmentally friendly methods and technologies to increase yields of major crops are of great importance for both modern intensive and organic agriculture (Kirchev et al., 2012; Delibaltova & Kirchev, 2010; Atanasov & Dochev, 2008). Using of physical fields for pre-sowing treatment of seeds to stimulate their sowing qualities has experimented with many cultivated plant species. A number of authors observed an increase in yield of some crops after pre-sowing electromagnetic treatments of seeds. Good results have been obtained for vegetable seeds (Palov et al., 2012) and rape seeds (Sirakov et al., 2016). The use of electromagnetic fields for energy stimulating the sowing qualities of cotton seeds and subsequent increase of yields is an alternative for ecologically cleaner production. After pre-sowing electromagnetic treatments 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). Increase in earliness and yield up to 12.0% was achieved for Chirpan-539 variety (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.

Treatment of seeds with reduced sowing qualities in an electromagnetic field could significantly improve their biological value (Ganeva et al., 2015).

The aim of this research was to study the effect of pre-sowing electromagnetic treatments on germination energy and laboratory germination of cotton seeds stored for one and two years before treatments.

Material and Methods

Seeds of five cotton varieties – Chirpan-539, Helius, Trakia, Natalia and IPK Nelina, stored for one and two years, were subjected to pre-sowing electromagnetic treatments. Seeds of each variety were treated in 5 different (applied to all varieties) electromagnetic fields with different intensity and duration of exposure. A method with periodic decrease of values of voltage U between electrodes of working camera and increase of duration of impact was used (Palov et al., 1995). Matrix used to plan the experiment is shown in Table 1. In previous studies (Bozhkova et al., 1993) variant of treatment 4 gave best results regarding electromagnetic impact on the seeds of cotton variety Beli izvor. Variant of treatment 5 with values of controllable factors indicated in the Table 1 was most effective for the seeds of Ogosta cotton variety.

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

Non-treated seeds of each variety and period of storage served as control, to compare and account the effect of electromagnetic treatments.

After treatment and stay of seeds, laboratory experiments were performed. 50 seeds of control and treated variants for each variety were planted in three replicates. 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 95%.

Seed 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). Results for each sample were averaged and 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 seed storage.

Chirpan-539 variety (national standard), untreated seeds, one year storage, was accepted as a control variant of the experiment. In addition, electromagnetic treatments were compared to the corresponding untreated controls to each variety and storage period.

Results and Discussion

Results of performed three-factor dispersion analysis of data for germination energy and laboratory germination of seeds of studied five cotton varieties after one and two years of storage and pre-sowing electromagnetic treatments are presented in Table 2. The three main factors – varieties, periods of storage and electromagnetic treatments as independent had significant impact on both studied characteristics.

Of interactions varieties × treatments and varieties × periods of storage were significant. The significant interactions show that the varieties reacted differently to the two storage periods and electromagnetic treatments about germination energy and laboratory germination. Interaction of treatments × periods of storage was insignificant, which means that the effect of electromagnetic treatments did not depend on the duration of seed storage. Interaction of the three main factors varieties × periods of storage × treatments was also insignificant.

The interaction A × C (varieties × terms of storage) had the most significant impact, as for the germination energy it was 43.35%, and for the laboratory germination it was 42.98%. Of the two factors forming it, the varieties had a slightly stronger influence than the periods of storage. Electromagnetic treatments, as an independent factor, and the interaction of varieties × treatments had a small but significant influence of 5.49% and 5.63%, respectively for the germination energy and 5.28% and 5.78% for the laboratory germination.

Results for the independent impact of the three main factors showed that Chirpan-539 variety had the highest germi-

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)					

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

Factors	Degrees of freedom	Germination 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^{+++}
Periods of 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 ns	63.25	0.32	12.65 ns
Interaction A×B×C	20	555.13	2.09	27.76 ns	509.50	2.60	24.47 ns
Errors	118	2187.75	8.22	18.54	1913.75	9.78	16.22

nation energy and laboratory germination of seeds, followed by Helius variety with significant slightly lower values for both characteristics (Table 3). The other three varieties had significant lower germination energy and laboratory germination, which were the lowest for the IPK Nelina variety.

All variants of electromagnetic treatment, regardless of varieties and periods of seed storage, showed better germination energy by 7.3% to 8.2% than the control (Chirpan-539 variety, one year storage, untreated seeds). The increase in laboratory germination was in the range of 5.6-6.4%. The treatment options 3 and 4 had the highest positive effects on the germination energy, 2 and 4 – on the laboratory germination.

Periods of storage as an independent factor also affected germination energy and laboratory germination of seeds. Seeds stored for two years had lower germination energy and laboratory germination than those stored for one year.

As a result of varieties × treatments interaction the highest germination energy and laboratory germination were ob-

Table 3. Independent effect of the main factors – varieties, pre-sowing electromagnetic treatments and periods of storage on the germination energy and laboratory germination of cotton seeds

Factors		Germination energy, %	In % to control	Laboratory germination, %	In % to control
Varieties	Chirpan-539	95.97	100.0	98.17	100.0
	Trakia	89.11	92.9^{000}	93.69	95.4^{000}
	Helius	93.61	97.5^{0}	96.31	98.1^{0}
	Natalia	85.17	88.7^{000}	89.72	91.4^{000}
	Nelina	81.17	84.6^{000}	85.31	86.9^{000}
	GD 5.0 %	2.01	2.1	1.88	1.9
	GD 1%	2.66	2.8	2.48	2.5
	GD 0.1 %	3.43	3.6	3.20	3.3
Treatments	1	89.93	107.6^{+++}	93.23	105.6^{+++}
	2	90.07	107.7^{+++}	93.93	106.4^{+++}
	3	90.23	109.9^{+++}	93.53	105.9^{+++}
	4	90.47	108.2^{+++}	93.77	106.2^{+++}
	5	89.73	107.3^{+++}	93.10	105.7^{+++}
	6	83.60	100.0	88.27	100.0
	GD 5.0 %	2.20	2.6	2.06	2.3
	GD 1%	2.91	3.5	2.72	3.1
	GD 0.1 %	3.75	4.5	3.51	3.9
Periods of storage	1	93.83	100.0	96.63	100.0
	2	84.18	89.7^{000}	88.64	91.7^{000}
	GD 5.0%	1.27	1.4	1.19	1.2
	GD 1.0%	1.68	1.8	1.57	1.6
	GD 0.1 %	2.17	2.3	2.03	2.1

Table 4. Interaction of factors varieties × treatments (A × B)

Varieties	Treatments	Germination energy, %	In % to control	Laboratory germination, %	In % to control
Chirpan-539	1	94.67	100.4	97.67	100.0
	2	96.00	101.8	99.00	101.4
	3	97.50	103.4	98.33	100.7
	4	97.67	103.5	98.33	100.7
	5	95.67	101.4	98.00	100.3
	6	94.33	100.0	97.67	100.0
Trakia	1	90.00	95.4	93.50	95.7
	2	90.00	95.4	94.67	96.9
	3	87.00	92.2^{00}	92.00	94.2^{0}
	4	93.00	98.6	97.00	99.3
	5	91.33	96.8	94.67	96.9
	6	83.33	88.3^{000}	90.33	92.5
Helius	1	98.33	104.2	100.00	102.4
	2	96.00	101.8	98.67	101.0
	3	94.67	100.4	97.00	99.3
	4	96.67	102.5	99.50	101.9
	5	96.67	102.5	99.00	101.4
	6	79.33	84.10^{000}	83.67	85.7^{000}
Natalia	1	88.00	93.3^{0}	91.50	93.7^{00}
	2	82.33	87.3^{000}	87.50	89.6^{000}
	3	88.67	94.0	92.33	94.5^{0}
	4	85.33	90.5^{000}	91.00	93.2^{00}
	5	85.00	90.1^{000}	89.83	92.0^{000}
	6	82.00	86.9^{000}	86.17	88.22^{000}
Nelina	1	78.67	83.4^{000}	83.50	85.5^{000}
	2	86.00	91.2^{000}	89.83	92.0^{000}
	3	83.33	88.3^{000}	88.00	90.1^{000}
	4	80.00	84.8^{000}	83.00	85.0^{000}
	5	80.00	84.8^{000}	84.00	86.0^{000}
	6	79.00	83.7^{000}	83.50	85.5^{000}
	GD 5.0 %	4.92	5.2	4.60	4.7
	GD 1.0%	6.51	6.9	6.09	6.2
	GD 0.1 %	8.39	8.9	7.85	8.0

served for treated seeds of Chirpan-539 and Helius varieties (Table 4). In both varieties, all variants of treatment showed a tendency to increase germination energy compared to the untreated control of Chirpan-539 variety. For Chirpan-539 variety, in options 3 and 4, germination energy increased by 3.4-3.5%, and for Helius variety, in option 1, this increase was by 4.2%, compared to the untreated control of Chirpan-539 variety.

For Helius variety, laboratory germination of seeds increased by 1.0% to 2.4%, in option 1, for Chirpan-539 variety it was higher by 0.3 – 1.4% in option 2. However, the differences were insignificant and the increase of laboratory germination compared to the untreated control of Chirpan-539 variety can be considered only as a positive trend.

For all studied varieties, treatment variants showed higher germination energy of seeds, compared to their respective untreated control, were observed (Figure 1). For Helius variety, in option 1, germination energy was higher by 24.0%, for Trakia variety, in option 4 – by 11.6%, for Natalia variety, in options 1 and 3 – by 7.3-8.1 %, for Nelina variety, in options 2 and 3 – by 8.4 and 5.5%, respectively, compared to the relevant untreated control.

All varieties responded positively to pre-sowing electromagnetic treatment with an increase in laboratory seed germination compared to their own controls (Figure 1). Helius variety reacted most strongly, seed laboratory germination increased in all options from 15.9% to 19.5%, regarding options 1, 4 and 5 it was the best. For other varieties this increase was weaker, for Trakia variety, in options 2 and 4, laboratory germination increased by 4.8% and 7.4%, for Natalia variety, in options 1, 3 and 4 – by 5.6-7.1%, for Nelina variety, in options 2 and 3 – by 5.4% and 7.6%.

As a result of varieties × storage periods (A × C) interaction the highest germination energy and laboratory germination were observed for the seeds Nelina variety stored for one year **(**Table 5). Varieties have reacted differently to the two periods of storage in terms of both characteristics, which could be explained by the varietals' peculiarities determining the course of physiological processes of seed aging. Variety Natalia, after one-year storage of seeds, was equal in both parameters with the control variant. Helius variety, when stored for one year, Chirpan-539 and Trakia varieties, when stored for two years, had lower but insignificant germination energy and laboratory germination. Helius, Natalia and Nelina varieties had significant lower germination energy and laboratory germination of seeds in case of two-year storage. As a result of longer storage, a stronger deterioration of laboratory germination of seeds was observed for Natalia and Nelina varieties.

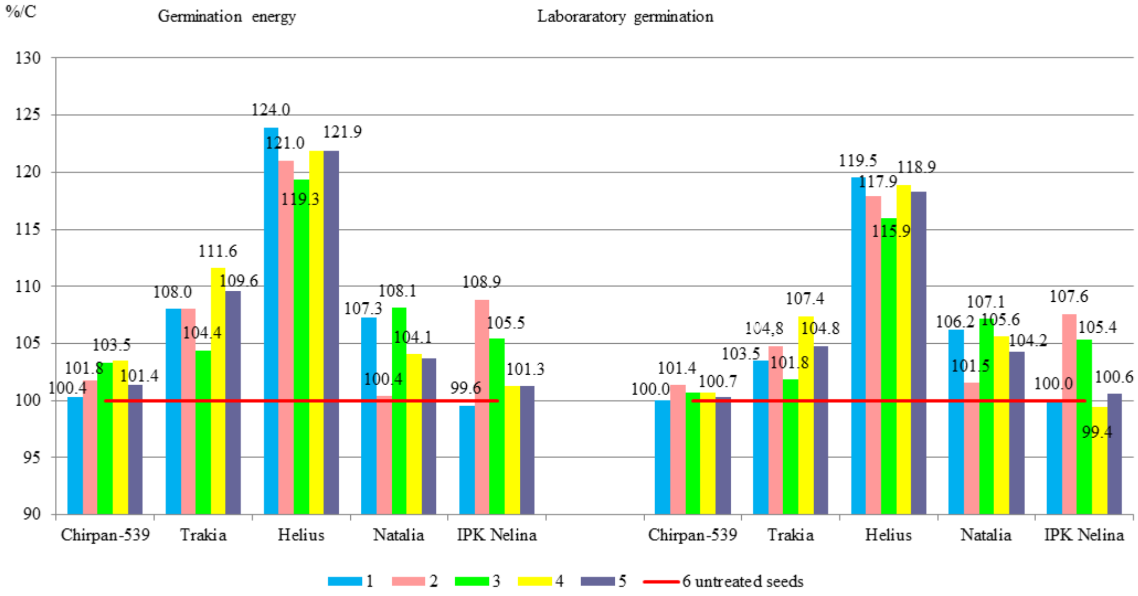

Figure 1.

Table 5. Interaction of factors varieties × storage terms (A × C)

Varieties	Storage terms	Germination energy, %	In % to control	Laboratory germination, %	In % to control
Chirpan-539	1 year	96.50	100.0	98.55	100.0
	2 years	95.44	98.9	97.78	99.2
Trakia	1 year	84.44	87.5^{000}	89.83	91.1^{000}
	2 years	93.78	97.2	97.55	99.0
Helius	1 year	94.33	97.7	96.61	98.0
	2 years	92.89	96.3^{0}	96.00	97.4^{0}
Natalia	1 year	96.11	99.6	98.55	100.0
	2 years	74.22	76.9^{000}	80.89	82.1^{000}
Nelina	1 year	97.78	101.3	99.61	101.1
	2 years	64.56	66.9^{000}	71.00	72.0^{000}
	GD 5.0%	2.84	2.9	2.66	2.7
	GD 1.0%	3.76	3.9	3.51	3.6
	GD 0.1%	4.84	5.0	4.53	4.6

On the basis of smallest significant differences, сигнификант differences in germination energy and laboratory germination of seeds stored for one and two years, subjected to pre-sowing electromagnetic treatment, have been established.

All treatment options had a significant positive effect on germination energy and laboratory germination of seeds stored for one year (Table 6). After pre-sowing electromagnetic treatment germination energy of seeds increased by 6.8% in option 2 to 9.1% in option 4, laboratory germination increased by 5.3-6.4%

Seeds stored for two years, after pre-sowing electromagnetic treatment had lower germination energy and laboratory germination than the control variant (1 year seed storage, no treatment). After two-year seed storage and pre-sowing electromagnetic germination energy increased by 6.7-8.8%, laboratory germination – by 5.2-7.6%, compared to the corresponding control (two- year storage, no treatment) (Figure 2).

Calculated smallest significant differences showed presence of significant differences for the interaction of varieties × treatments × storage periods (Table 7). Higher germination energy and laboratory germination after pre-sowing electromagnetic treatment of seeds, compared to control variant (variety Chirpan-539, one-year storage of seeds, without treatment) was observed for the varieties: Chirpan-539 and Helius, for the two storage periods; Natalia and Nelina – af-

Table 6. Interaction of factors treatments × storage periods (B × C)

Storage periods	Treatments	Germination energy, %	In % to control	Laboratory germination, %	In % to control
1 year	1	94.93	107.7^{+++}	97.40	105.5^{+++}
	2	94.13	106.8^{+++}	97.20	105.3^{++}
	3	94.60	107.3^{+++}	97.20	105.3^{++}
	4	96.13	109.1^{+++}	98.20	106.4^{+++}
	5	95.07	107.9^{+++}	97.53	105.7^{+++}
	6 – Control	88.13	100.0	92.27	100.0
2 years	1	84.93	96.4	89.07	96.5^{0}
	2	86.00	97.6	90.67	98.3
	3	85.87	97.4	89.87	97.4
	4	84.80	96.2^{0}	89.33	96.8^{0}
	5	84.40	95.8^{0}	88.67	96.1^{0}
	6	79.07	89.7^{000}	84.27	91.3^{000}
	GD 5.0 %	3.11	3.5	2.91	3.1
	GD 1.0%	4.12	4.7	3.85	4.1
	GD 0.1 %	5.31	6.0	4.96	5.4

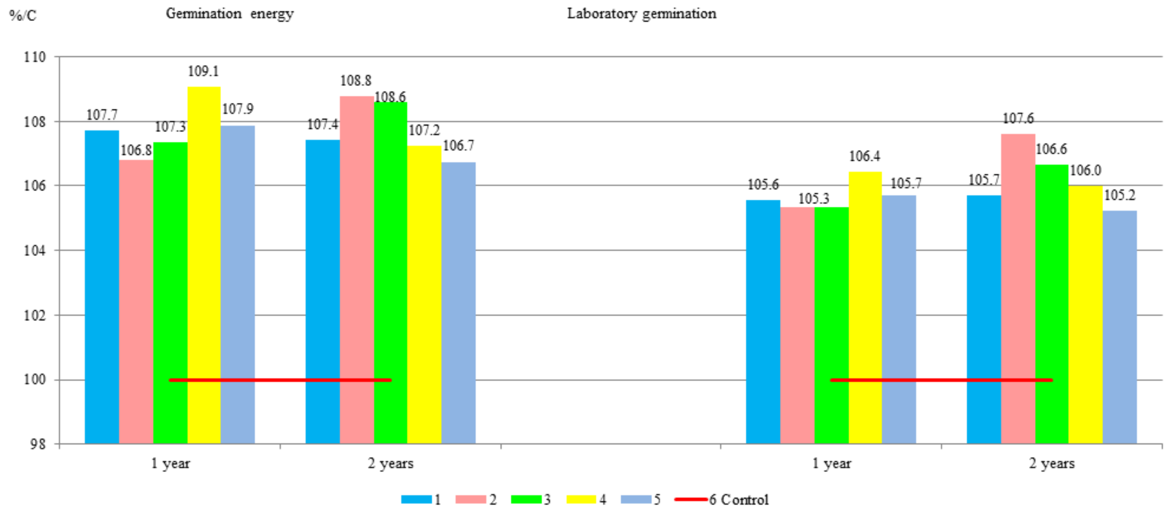

Figure 2.

Table 7. Interaction of factors varieties × treatments × storage terms (A × B × C)

Varieties	Years	Treatments	Germination energy, %	In % to control	Laboratory germination, %	In % to the control
Chirpan-539	1 year	1	97.33	104.3	98.87	102.3
		2	96.67	103.6	99.33	102.7
		3	97.67	104.7	99.33	102.7
		4	97.32	104.3	98.0	101.4
		5	96.67	103.6	99.33	102.7
		6	93.33	100.0	96.67	100.0
	2 years	1	92.00	98.6	96.67	100.0
		2	95.33	102.1	98.67	102.1
		3	97.33	104.3	97.33	100.7
		4	98.00	105.0	98.67	102.1
		5	94.67	101.4	96.67	100.0
		6	95.33	106.4	98.67	102.1
Trakia	1 year	1	83.33	89.3^{00}	88.67	91.7^{0}
		2	85.33	91.4^{0}	90.33	93.4^{0}
		3	83.33	89.3^{00}	89.00	92.1^{0}
		4	90.00	96.4	94.33	97.6
		5	86.00	92.1^{0}	90.33	93.4^{0}
		6	78.67	84.3^{000}	86.33	89.3^{00}
	2 years	1	96.67	103.6	98.33	101.7
		2	94.67	101.4	99.00	102.4
		3	90.67	97.1	95.00	98.3
		4	96.00	102.9	99.67	103.1
		5	96.67	103.6	99.00	102.4
		6	88.00	94.3	94.33	97.6
Helius	1 year	1	98.67	105.7	100.0	103.4
		2	96.00	102.9	98.67	102.1
		3	98.67	105.7	99.67	103.1
		4	97.33	104.3	99.33	102.7
		5	97.33	104.3	98.67	102.1
		6	78.00	83.6^{000}	83.33	86.2^{000}
	2 years	1	98.00	105	100.0	103.4
		2	96.00	102.9	98.67	102.1
		3	90.67	97.1	94.33	97.6
		4	96.00	102.9	99.67	103.1
		5	96.00	102.9	99.33	102.7
		6	80.67	86.4^{000}	84.00	86.9^{000}
Natalia	1 year	1	98.67	105.7	100.00	103.4
		2	94.00	100.7	97.67	101.0
		3	96.00	102.9	98.00	101.4
		4	96.67	103,6	99.33	102.7
		5	97.33	104.3	99.33	102.7
		6	94.00	100.7	97.00	100.3
	2 years	1	77.33	82.9^{000}	83.00	85.6^{000}
		2	70.67	75.7^{000}	77.33	80.0^{000}
		3	81.33	87.1^{000}	86.67	89.7^{00}
		4	74.00	79.3^{000}	82.67	85.5^{000}
		5	72.67	77.9^{000}	80.33	83.1^{000}
		6	70.00	75.0^{000}	75.33	77.9^{000}

Table 7. Continued...

Nelina	1 year	1	96.67	103.6	99.67	103.1
		2	98.67	105.7	100.00	103.4
		3	97.33	104.3	100.00	103.4
		4	99.33	106.4	100.00	103.4
		5	98.00	105.0	100.00	103.4
		6	96.67	103.6	98.00	101.4
	2 years	1	60.67	65.0^{000}	67.33	69.6^{000}
		2	73.33	78.6^{000}	79.67	82.4^{000}
		3	69.33	74.3^{000}	76.00	78.6^{000}
		4	60.67	65.0^{000}	66.00	68.3^{000}
		5	62.00	66.4^{000}	68.00	70.3^{000}
		6	61.33	65.7^{000}	69.00	71.4^{000}
GD 5.0%	6.96	7.5	6.51	6.7		
GD 1.0%	9.20	9.9	8.61	8.9		
GD 0.1%	11.87	12.7	11.10	11.5		

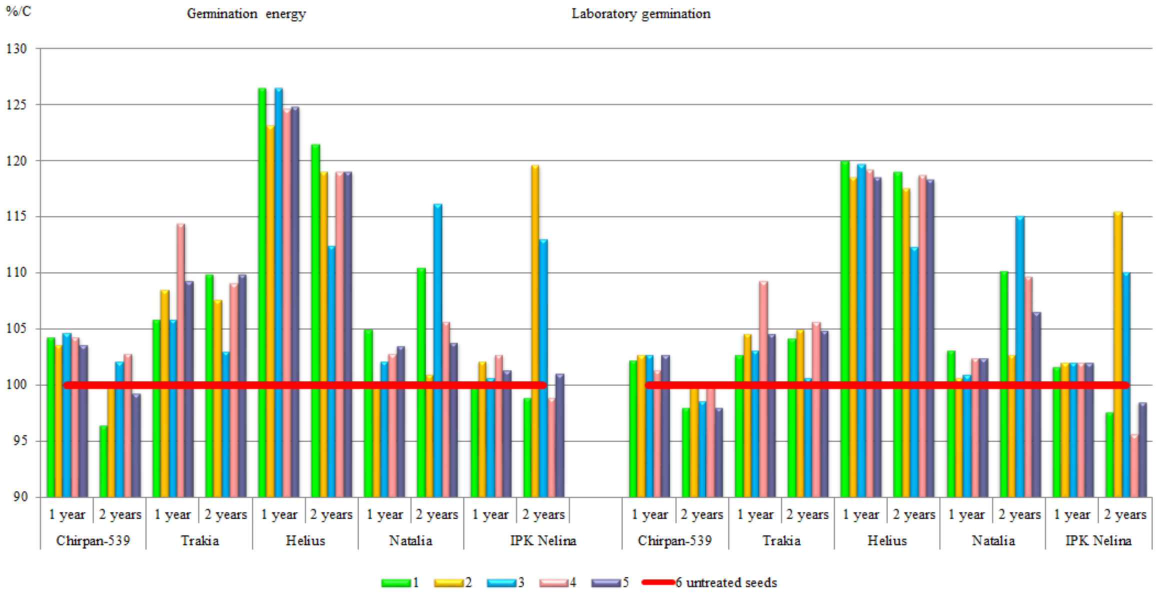

Figure 3.

ter one-year storage; Trakia – after two- year storage. However, the differences were statistically insignificant and higher values could be considered only as a positive trend.

Laboratory germination was lower after the pre-sowing electromagnetic treatment for the varieties: Trakia, for seeds stored for one year; Natalia and Nelina, for seeds stored for two years, in all variants of treatment.

Described differences could be explained by the variety peculiarities and the presence of some more significant differences in the germination energy and laboratory germination of untreated control corresponding to each variety and storage period. Control variant (variant 6 of Chirpan-539 variety) had high laboratory germination for both storage periods – 96.67% and 98.67%, respectively one and two years of storage. Control variants of the varieties with significant lower laboratory germination after pre-sowing electromagnetic treatment had low laboratory germination – 86.33% for Trakia variety after one year of storage and 75.33% and 69.0% for Natalia and Nelina varieties after two years of storage. For these varieties and the indicated periods of seed storage, electromagnetic treatments had a stimulating effect, but the initial laboratory germination of untreated seeds was low, which was the main reason for the lower values of treated seeds, compared to the control Chirpan-539 variety, untreated seeds and one year storage.

Compared to the corresponding untreated controlc of each variety and storage period, increase in germination energy and laboratory germination after pre-sowing electromagnetic treatment was observed for all varieties, in both seed storage periods, for most treatment variants (Figure 3). For Helius variety germination energy and laboratory germination of seeds after electromagnetic treatments were most strongly increased compared to the corresponding untreated controls: germination energy from 23.1% to 26.5% after one year of storage and from 19.0% to 21.5% after two years of storage; laboratory germination from 18.5% to 20.0% after one year of storage and from 12.3% to 19.5% after two years of storage. In the studies of Starodubtseva & Fedorishchenko (2001) after pre-sowing electromagnetic treatment of sorghum seeds, laboratory germination was increased by 6-8%.

Results obtained from the study for germination energy and laboratory germination were higher or comparable, depending on the treatment variant, variety and duration of seed storage, with those reported in literature for other crops. After pre-sowing electromagnetic treatment of pea seeds, laboratory germination was increased by 2.6% (Kuzmanov et al., 2012; Palov et al., 2013), of triticale seeds, Boomerang variety, germination energy was increased to 3.0% and laboratory germination – up to 6.0% (Sirakov et al., 2021). Compared to magnetic treatments, the exposure time was much shorter, which confirms the reports of Bilalis et al. (2013), Kostov et al. (2014), Alvarez et al. (2019), Alvarez et al. (2021).

Laboratory germination increased much more strongly in case of lower control values. Absolute laboratory germination cannot be more than 100% and therefore the effect of electromagnetic treatments in case of high laboratory germination of the control was lower. This explains the fact that for some varieties, after electromagnetic treatment, germinating energy and laboratory germination of seeds increased more strongly after two-year storage, compared to one year storage. This shows that the electromagnetic impact added energy to seeds, stimulating the two studied characteristics.

Increased indicators for germination energy and laboratory germination prove benefit of pre-sowing electromagnetic treatment to improve seed viability. Results of study also show that electromagnetic treatments improve the biological value of sufficiently long-stored seeds.

Achieved results show that the proposed method could be used in conventional and organic cotton production to improve the sowing qualities of stored (reserve) cotton seeds for sowing, as well as to improve the viability of seeds from plant genetic resources that have lost part of their laboratory germination.

Conclusion

Pre-sowing electromagnetic treatment, with the selected values of controllable factors, had stimulating effect on germination energy and laboratory germination of seeds stored for one and two years.

All treatment options as an independent factor had a positive impact. Compared to the untreated control, germination energy increased by 7.3 – 9.9% in treatment option 3 [$U = (8…5)$ kV, $\tau = (5…25)$ s], laboratory germination – by 5.6 – 6.4%, the best treatment options were 2 [$U = (6…3)$ kV, $\tau = (15…35)$ s] and 4 [$U = (6…3)$ kV, $\tau = (5…25)$ s].

Seeds stored for one year, in all variants of electromagnetic treatment, had higher germination energy and laboratory germination than control variant for the experiment – seed stored for 1 year, no treatment.

Compared to the untreated control corresponding to each storage period, the electromagnetic impact had a stimulating effect for the two storage periods: for germination energy – from 6.8% to 9.1% in option 4 and 6.7% to 8.8% in option 2; for laboratory germination – from 5.3 – 6.4% in option 4 and 5.2 – 7.6% in option 2, respectively for one- and two-year storage of seeds.

Variants of electromagnetic treatment with insignificant higher values than the control variant for the experiment – variety Chirpan-539, one-year storage, untreated seeds, were accounted only after one-year storage of seeds.

Compared to the untreated control corresponding to each variety and storage period, for all studied varieties, after both seed storage periods, and in almost all variants of pre-sowing electromagnetic treatment, germination energy and laboratory germination were higher.

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

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