STUDY OF LABORATORY GERMINATION OF SEEDS FROM MILYANA TOMATO VARIETY AFTER ELECTROMAGNETIC TREATMENT
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ИЗСЛЕДВАНЕ НА ЛАБОРАТОРНАТА КЪЛНЯЕМОСТ НА СЕМЕНА ОТ ДОМАТИ, СОРТ МИЛЯНА, СЛЕД ПРЕДСЕИТБЕНИ ЕЛЕКТРОМАГНИТНИ ОБРАБОТКИ

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ABSTRACT
After pre-sowing electromagnetic treatments by expanded experimental plan from B_3 type and after theoretical studies of the constructed response surfaces and lines of the response – laboratory germination of the seeds from tomato variety Milyana it was theoretically confirmed that the positive results are obtained in the following values of the controlled factors: voltage of treatments U=12 kV, duration of treatment τ=35 s and length of stay to sowing T=12 days. It is proven that an effective impact could be obtained in combined increase of the controlled factor voltage of treatment and shortening of the duration of treatment τ=2 s.

РЕЗЮМЕ
След предсеитбени електромагнитни обработки по разширен план на експеримента от типа B_3 и теоретични изследвания на построените повърхнини и линии на отклика – лабораторна кълняемост на семена от домати сорт Миляна, теоретично е потвърдено, че положителни резултати се получават при стойности на управляемите фактори: напрежение на обработка U=12 kV, продължителност на въздействие τ=35 s и продължителност на престоя от обработката до засяването T=12 денонощия. Доказано е, че ефективно въздействие може да се получи и при съчетано увеличаване стойността на управляемия фактор напрежение на обработка и съкращаване продължителността на въздействие τ=2 s.

INTRODUCTION
The seeds are carriers of morphological, biological and economical characters and properties of the plants and their quality reflects in a great degree on the productivity and quality of the variety produce. (*Danailov, 2012*). High quality of the seeds is a base for development of normal plants (*Poryazov I. et al., 2013*). The growth power of the seeds influences the further development of the new grown plants and has particularly strong effect on their vegetative growth and, therefore on the productivity (*TeKrony and Egli, 1991*). The seeds with greater germination energy and germination give quick and total germination, faster development, and smaller susceptibility to the unfavourable conditions. The competence and correct application of the pre sowing treatment of the seed could be an efficient mean for increasing the sowing qualities of the cereal, technical and vegetable crops seeds (*Sirakov, 2006; Radevska M. et al., 2012*).

The results from study, the effect of pre-sowing electromagnetic treatments on the laboratory properties of seeds from tomato variety Milyana are shown in (*Ganeva D. et al., 2014*). A stimulation effect of parameters of the electromagnetic treatment, namely voltage of treatments U=12 kV, duration of treatment τ=35 s and length of seed stay from treatment to sowing T=12 days were established. It was achieved an increase of germination energy with 103.60%/c, laboratory germination with 104.60%/c, hypocotyls length with 15.73%, cotyledons length – with 21.88%, root length with 24.41% as well as an increase of the plant fresh weight – with 25.00% towards the control (untreated) seeds.

In other parameters of the pre-sowing treatment (U=6 kV, τ=5 s and stay to seed set for germination T=4 days) was established a depressive effect on the seed development – the length of the roots, hypocotyls and cotyledons were by (16…20)% smaller compared to the control and the plant fresh weight has been increased with over 22%.

According to the above considerations, the investigations were continued and the seed laboratory germination was established after conducting of pre-sowing electromagnetic treatment of the seeds by extended plan B^3 (*Mitkov, 2011*), and the response surface and lines of response were obtained.

The purpose of the study was the probable values of the controlled factors stimulating more effectively the laboratory germination of tomato seeds from Variety Milyana to be established by means of the extended plan of the experiment of pre-sowing electromagnetic treatments.

MATERIAL AND METHOD

An object of study was the laboratory germination of tomato seeds from variety Milyana – namely, determinate, large fruited variety suitable for mid-early field production. The seed germination is within (92…92.50)%.

Controlled factors of the pre-sowing electromagnetic treatment in the AC corona discharge field are: voltage U (kV) between the electrodes (edge-plane) and the duration of treatment τ (s). After treatment the seeds were left for stay T (days) till their set for germination. The pre-sowing treatment was conducted on the 31-st of March 2014.

The tomato seeds were set in Petri dishes with wet filter paper for germination in controlled conditions in thermostat at temperature 25^{o}C and relative humidity 95%. In each variant were set 100 seeds in 4 replications after 4, 8 and 12 day stay in electromagnetic treatment (*International Seed Testing Association, 2004; Ganeva D. et al., 2014, 2015; Sirakov K. et al., 2015*).

The laboratory germination of the seeds was established for each experiment (4, 8 and 12 days) at 14th day of sowing. Data were given in percentage towards the controls (%/c).

The results were mathematically processed (*Mitkov, 2011*), and response surfaces and lines of response were obtained (*http://www.statsoft.com*).

RESULTS

The pre-sowing electromagnetic treatments were conducted by three factorial experiments according to symmetrical constructional plan from B_3 type (*Mitkov, 2011*). The values of the controlled factors and their corresponding levels of variation are shown in Table 1.

Table 1

Controlled factors

Factors		Level of controlled factors					
		high		medium		low	
Voltage, U	$\overset{\circ}{x}_1$	+1	12 kV	0	9 kV	-1	6 kV
Duration of impact, τ	$\overset{\circ}{x}_2$	+1	35 s	0	20 s	-1	5 s
Length of stay, T	$\overset{\circ}{x}_3$	+1	12 days	0	8 days	-1	4 days

The plan of the experiment with the results established for the laboratory seed germination is given in Table 2.

The reported average values of the laboratory germination (g) of the controlled seeds are the following: the germination in stay of the treated seeds for 4 days is g=92.25%, in stay of 8 days the germination is g=92.00%, and after stay of 12 days – g=92.50%. Towards them the obtained results for laboratory germination of the seeds $Y_{K.}$ for each variant of treatment and relevant stay are given in %/c.

According to the results (Y_i), given in Table 2 for the established laboratory germination of the particular variants of treatment by plan B_3, and according (*Mitkov, 2011*) the equation for regression was found. This equation expresses the relation between the laboratory germination and the combination of the individual factors (voltage U of treatment – factor $\overset{\circ}{x}_1$, duration of treatment τ – factor $\overset{\circ}{x}_2$, length T of stay to set of the seeds for germination – factor $\overset{\circ}{x}_3$) and their interactions: $\overset{\circ}{x}_1\overset{\circ}{x}_2,\ \overset{\circ}{x}_1\overset{\circ}{x}_3,\ \overset{\circ}{x}_2\overset{\circ}{x}_3,\ \overset{\circ}{x}{}_1^2,\ \overset{\circ}{x}{}_2^2\ and\ \overset{\circ}{x}{}_3^2$:

By the control (*Mitkov, 2011*) it was established that the equation (1) is adequate according to the comparison of the calculated criteria of Fisher with its critical value. On the basis of the critical value of the Student's criteria it was established that the coefficients of regression in the equation are significant.

Table 2

Experiment planning matrix

Variants	**Controlled factors**						**Laboratory germination, $Y_{к.}$, %/c**
	$\mathring{x}_1$		$\mathring{x}_2$		$\mathring{x}_3$		
	-	U, kV	-	τ, s	-	T, days	
1	+1	12	+1	35	+1	12	104.60
2	-1	6	+1	35	+1	12	100.54
3	+1	12	-1	5	+1	12	102.70
4	-1	6	-1	5	+1	12	100.81
5	+1	12	+1	35	-1	4	101.08
6	-1	6	+1	35	-1	4	102.17
7	+1	12	-1	5	-1	4	102.17
8	-1	6	-1	5	-1	4	100.54
9	+1	12	0	20	0	8	101.63
10	-1	6	0	20	0	8	99.73
11	0	9	+1	35	0	8	99.73
12	0	9	-1	5	0	8	100.00
13	0	9	0	20	+1	12	101.08
14	0	9	0	20	-1	4	100.54

$$\hat{Y}_{к.} = 99,764 + 0,839\,\mathring{x}_1 + 0,190\,\mathring{x}_2 + 0,323\,\mathring{x}_3 - 0,069\,\mathring{x}_1\,\mathring{x}_2 + 0,676\,\mathring{x}_1\,\mathring{x}_3 + 0,136\,\mathring{x}_2\,\mathring{x}_3 + 0,916\,\mathring{x}_1^2 + 0,101\,\mathring{x}_2^2 + 1,046\,\mathring{x}_3^2 \quad (1)$$

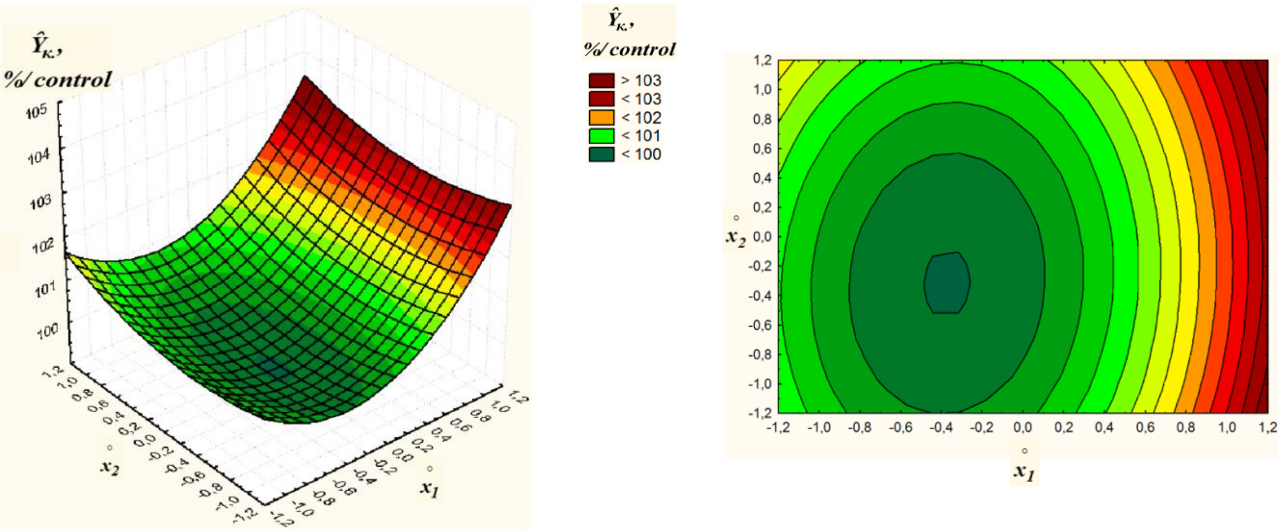
The response surfaces and lines of response are studied for evaluation of the influence and interaction between the factors on the laboratory germination. They are composed according (*Mitkov, 2011*), and the programme product Statistica 8 (*http://www.statsoft.com*). The response surfaces and lines of response are obtained as a result of consecutive elimination of each one of the factors $\mathring{x}_1$, $\mathring{x}_2$ and $\mathring{x}_3$, and the other two vary between the levels given in Table 1. Since the number of the controlled factors is 3, the obtained and analyzed response surfaces and lines of response are by 3. It is known the presence of correlation between the quadratic members itself $\mathring{x}_i^2$ of the equation (1). This forces to calculate the remaining coefficients of the model (*Mitkov, 2011*) again in elimination of some quadratic members. It should be mentioned that in this calculation, the values of the free member and non-eliminated members were only changed.

Variant 1: The factor $\mathring{x}_3$ – duration of stay T is eliminated. In that case, in interaction of the factors $\mathring{x}_1$ and $\mathring{x}_2$ the equation of the response surface is of the following kind:

$$\hat{Y}_{к.} = 100,166 + 0,839\,\mathring{x}_1 + 0,190\,\mathring{x}_2 - 0,069\,\mathring{x}_1\,\mathring{x}_2 + 1,157\,\mathring{x}_1^2 + 0,342\,\mathring{x}_2^2 \quad (2)$$

In use of the Statistica 8 *(http://www.statsoft.com*), it was built the response surface (Figure 1a) and lines of response (Figure 1b) – laboratory seed germination in function of the voltage applied between the electrodes $\mathring{x}_1$ (U) and time of electromagnetic treatment $\mathring{x}_2$ (τ), in case of elimination the influence of the factor duration $\mathring{x}_3$ (T) of stay from treatment to seeds sowing.

The values of $\hat{Y}_{к.}$, for model (2), in %/c, are given in numerical type on the ordinate of the drawings from Figure 1.



a b

Fig. 1 – Response surface (a) and lines of response (b) – laboratory germination as a function of factors $\overset{\circ}{x}_1$ (U) and $\overset{\circ}{x}_2$ (τ), $\overset{\circ}{x}_3$ (T) switched off factor

The effect ($\hat{Y}_{\kappa.}$ in %/c) of the impact of the pre-sowing electromagnetic treatments of the seeds, obtained by the model (2), is shown in Figure 1a and Figure 1b by different colours (according to the legend of Figure 1) in the response surface and lines of response themselves. Moreover, where the dark green fields are, for example in $\overset{\circ}{x}_1$ =(+0.2…-0.9) and $\overset{\circ}{x}_2$ =(+0.8…-1.2), the pre-sowing impact should be depressing.

In case of accepting the values of the two factors in natural units it could be said that the depressing impact of the pre-sowing electromagnetic treatment on the laboratory germination should be expected in combination of the two factors in the limits U=(9.6…6.3) kV and τ=(32…2) s. Then the laboratory germination of the seeds will be smaller (i.e. <100%/к) compared to the control/untreated seeds in electromagnetic field.

Bright green, yellow and etc. to dark brown areas, for example in $\overset{\circ}{x}_1$ =(+0.5…+1.2) and $\overset{\circ}{x}_2$ =(+1.2…-1.2) demonstrate that the selected values of the two controlled factors of pre-sowing treatment influence stimulating in a different degree on the observed parameter – laboratory germination which is expected to exceed to 3% that one of the controlled seeds.

When the values of the two factors are taken in natural units it could be said that the stimulating impact of the pre-sowing electromagnetic treatment on the laboratory germination is expected in combination of two factors in the limits U=(10.5…12.6) kV and τ=(38…2) s. The laboratory germination in this case will be over 103%/c towards that of the controlled/untreated in electromagnetic field seeds.

According to Figure 1a and Figure 1b it could be concluded that in the adopted upper levels of the controlled factors $\overset{\circ}{x}_1$ =1 (i.e. U=12 kV) and $\overset{\circ}{x}_2$ =1 (i.e. τ=35 s), a stimulating pre-sowing effect is obtained – the value of the laboratory germination will be over 103%/c. In these values of the controlled factors in (*Ganeva D. et al., 2014*) is described that the laboratory germination of the pre-sowing treated seeds was g = 104.60%/c towards the control.

According to Figure 1b it could be established that in increase of the values of the two factors which are studied, for example $\overset{\circ}{x}_1$ =+1.2 (i.e. U=12.6 kV) and $\overset{\circ}{x}_2$ =+1.2 (i.e. τ=38 s) it should be expected an increase of the laboratory germination of the seeds of over 103%/c.

In this respect experiments should be conducted for pre-sowing electromagnetic treatments of the seeds by using of risen values of the two controlled factors. It should take into considerations that the excessive increase of the values of the applied voltage could not be achieved by technical reasons because probably the corona discharge between the two electrodes could develop in spark discharge and then in arc electric discharge which would results in damage – burning of the seeds.

On the basis of the Figure 1a and Figure 1b, it could be established that in decrease of the values of the two factors it should expect a stimulation of the seed laboratory germination up to 1% towards the controls. This could be obtained in voltage $\overset{\circ}{x}_1$ =-1.2 (i.e. U=5.4 kV) and duration of treatment $\overset{\circ}{x}_2$ =-1.2 (i.e. τ=2 s).

According to Figure 1a and Figure 1b, it could be established that an increase effect of stimulation of the laboratory germination (over 3% towards the control) could be also obtained in the following values of the two factors: $\overset{\circ}{x}_1$ =+1.2 (i.e. U=12.6 kV) and $\overset{\circ}{x}_2$ =-1.2 (i.e. τ=2 s).

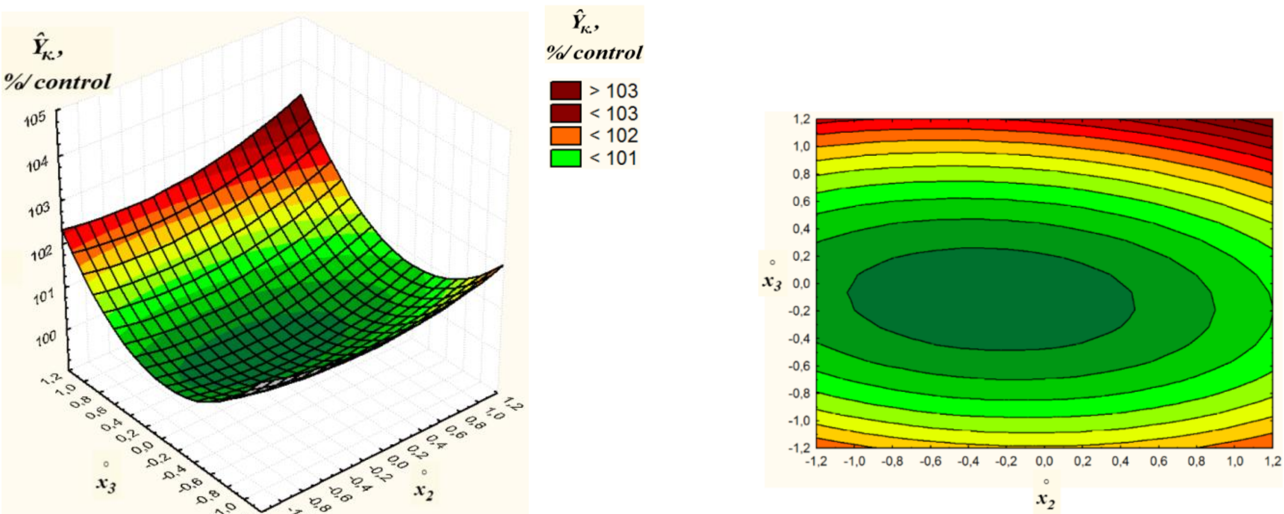
Therefore, the treatment of the seeds in the above mentioned increased voltage of the corona electrical discharge should be short as an impulse (in this case for 2 seconds). On the other hand, this would contribute for greater increase of the voltage value applied for pre sowing treatment and decrease of the probability for electrical break between the electrodes.

Variant 2: The factor $\overset{\circ}{x}_1$ – applied voltage between the electrodes U is eliminated. The equation of the response surface in the interaction of the factors $\overset{\circ}{x}_2$ and $\overset{\circ}{x}_3$ is:

$$\hat{Y}_{K.} = 100{,}116 + 0{,}190\,\overset{\circ}{x}_2 + 0{,}323\,\overset{\circ}{x}_3 + 0{,}136\,\overset{\circ}{x}_2\,\overset{\circ}{x}_3 + 0{,}312\,\overset{\circ}{x}{}_2^2 + 1{,}257\,\overset{\circ}{x}{}_3^2 \qquad (3)$$

Figure 2a and Figure 2b demonstrate the response surface and lines of response – laboratory germination of the seeds in function of the duration of electromagnetic treatment $\overset{\circ}{x}_2$ (τ) and length of stay $\overset{\circ}{x}_3$ (T) from treatment to set of seeds for germination that are built by (3).

The impact of the pre sowing electromagnetic treatments of the seeds is shown in different coloured zones in Figure 2 as well as in Figure 1.



a

b

Fig. 2 – Response surface (a) and lines of response (b) – laboratory germination as a function of factors $\overset{\circ}{x}_2$ (τ) and $\overset{\circ}{x}_3$ (T), $\overset{\circ}{x}_1$ (U) switched off factor

The analysis of Figure 2a and Figure 2b demonstrates that in eliminated factor $\overset{\circ}{x}_1$ and in values of the controlled factors τ ($\overset{\circ}{x}_2$) and T ($\overset{\circ}{x}_3$) as follows: $\overset{\circ}{x}_2$ within (+1.2…-1.2) and $\overset{\circ}{x}_3$ – within (+0.6…-0.6), the pre sowing electromagnetic treatment will be with inhibiting effect.

When the values of the factors are in natural units the inhibiting effect of the pre sowing electromagnetic treatment on the laboratory germination is expected in combination of the two factors in the limits τ=(38…2) s and T=(10…6) days. The laboratory germination of the seeds in this case will be smaller (i.e. <100%/c) than that of the control/untreated seeds.

According to Figure 2a and Figure 2b could be concluded that an increase of the effect from pre sowing electromagnetic impact i.e. an increase of laboratory germination from 102%/c to over 103%/c could be obtained in combination of the values of the two controlled factors in the limits $\mathring{x}_2$ =(+1.2…-1.2) and $\mathring{x}_3$ =(+0.8…+1.2), respectively.

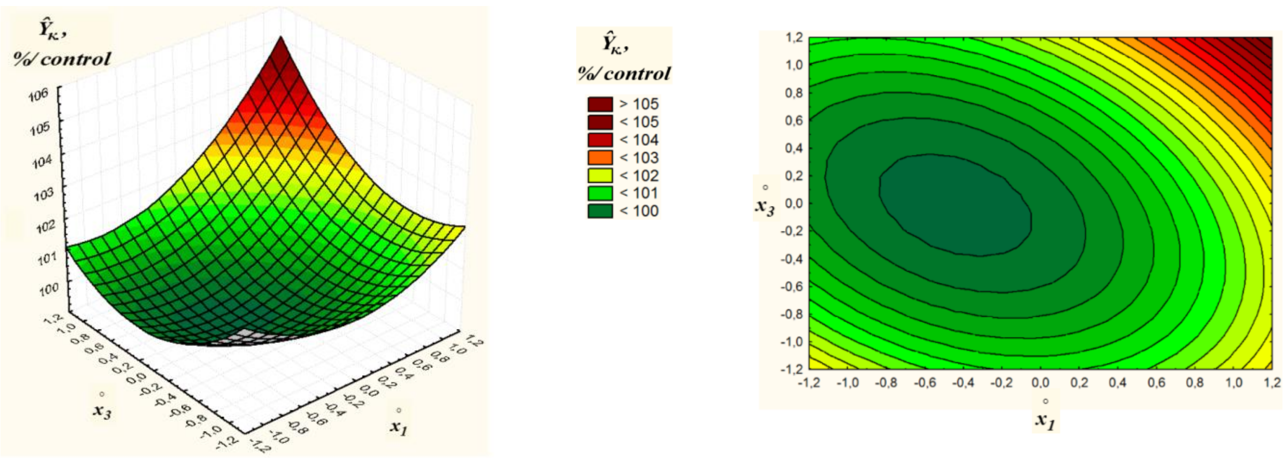
When the values are in natural units, the stimulation effect of the pre sowing electromagnetic treatment on the laboratory germination could be expected in combination of the two factors in the limits τ=(38…2) s and T=(11…13) days. Then the laboratory seed germination will be greater (over 103%/c) than that of the control/untreated seeds.

Variant 3: In this variant the factor $\mathring{x}_2$ – duration of the electromagnetic impact τ was eliminated. In this case in the interaction of the factors $\mathring{x}_1$ and $\mathring{x}_3$ the equation of the response surface is:

$$\hat{Y}_{K.} = 99,803 + 0,839\,\mathring{x}_1 + 0,323\,\mathring{x}_3 + 0,676\,\mathring{x}_1\,\mathring{x}_3 + 0,939\,\mathring{x}_1^2 + 1,069\,\mathring{x}_3^2 \qquad (4)$$

Figure 3a and Figure 3b show, respectively the response surface and lines of response – laboratory germination of the seeds in function of voltage $\mathring{x}_1$ (U) of the electromagnetic treatment and length $\mathring{x}_3$ (T) of stay from treatment to set the seeds for germination, built by the Model (4).

The analysis of Figure 3a and Figure 3b demonstrates that in eliminated factor $\mathring{x}_2$ and in values of the two controlled factors U ($\mathring{x}_1$) and T ($\mathring{x}_3$) as follows: $\mathring{x}_1$ within (+0.5…-1.2) and $\mathring{x}_3$ – within (+0.9…-1.1), the pre sowing electromagnetic impact will be inhibiting.



a b

Fig. 3 – Response surface (a) and lines of response (b) – laboratory germination as a function of factors $\mathring{x}_1$ (U) and $\mathring{x}_3$ (T), $\mathring{x}_2$ (τ) switched off factor

When the values of the controlled factors are in natural units the inhibiting effect of the pre sowing electromagnetic treatment on the laboratory germination could be expected in combination of the factors duration of treatment τ=20 s with the remaining two factors in the limits U=(10.5…5.4) kV and T=approximately (11…3) days. In this case the laboratory germination of the seeds will be smaller (<100%/к) then that of the controls/untreated seeds.

The analysis of the Figure 3a and Figure 3b demonstrates that it is necessary the two controlled factors $\overset{\circ}{x}_1$ (U) and $\overset{\circ}{x}_3$ (T) to be with equal values or with greater values over the levels accepted as upper ones, i.e. $\overset{\circ}{x}_1 \geq 1$ and $\overset{\circ}{x}_3 \geq 1$ for stimulation of the laboratory germination with over 103%/c. Therefore if the factor $\overset{\circ}{x}_2$ is accepted at the mean level, i.e. $\overset{\circ}{x}_2 = 0$ (τ=20 s), the voltage of treatment $\overset{\circ}{x}_1$ should be accepted U≥12 kV and the length of stay $\overset{\circ}{x}_3$ – T 12 days.

The obtained theoretical results are confirmed by the presented in (*Ganeva D. et al., 2014*, 2015; *Sirakov K. et al., 2015*). Data demonstrates that as a result of the performed laboratory investigations after pre sowing electromagnetic treatments of the seeds from tomato variety Milyana by variant 1 – Table 2 (U=12 kV and τ=35 s) and length of the stay of the seeds to their set for germination T=12 days and T=365 days, the obtained results are the following:

- in T=12 days stay, the laboratory germination is stimulated to 4.6% over that of the control seeds, the root length of the germinated seeds – to 24.41%, of the hypo cotyledons – to 15.73%, of the cotyledons – 21.88% and the fresh plant weight – to 25.00%;
- in 365 days stay, the laboratory germination is increased over 9%, the root length – over 47%, the length of the hypo cotyledons – over 11.87% and that of the cotyledons over 16%.

According to that described above, it could be mentioned that by experimental (*Ganeva D. et al., 2014*, *2015*; *Sirakov K. et al., 2015*), and theoretical way is shown that in order to be obtained a stimulating effect of the pre sowing electromagnetic treatment of the seeds from tomato variety Milyana it is necessary that the controlled factor values to be higher – for voltage U≥12 kV, for duration of treatment τ≥35 s and length of stay to set of the seeds for germination T=(12 to 365) days, respectively. Similar stimulation effect could be expected when the pre sowing electromagnetic treatment is short/impulse with duration τ=2 s and voltage U≥12 kV, and T=(12 to 365) days from treatment to sowing.

CONCLUSIONS

1. On the basis of the performed laboratory investigations (*Ganeva D. et al., 2014*, *2015*; *Sirakov K. et al., 2015*), was established that the effective impact on the sowing properties of tomato seeds from variety Milyana could be obtained after pre sowing electromagnetic treatments in use of controlled factors with the following values: voltage of treatment U=12 kV, duration of treatment τ=35 s, length of stay from treatment to seed set for germination T=12 days. It was established that the positive effect as a result of pre sowing treatment is kept after 365 days from the treatment in U=12 kV and τ=35 s.

2. It is proved that after pre sowing electromagnetic treatment by extend plan of the experiment from B3 type and theoretical studies of the built response surfaces and lines of response – laboratory germination:

a) Positive results are obtained in the following values of the controlled factors: voltage of treatment U=12 kV, duration of treatment τ=35 s and length of stay from treatment to sowing T=12 days;

b) Efficient impact could be obtained in increase of the controlled factor values: voltage of treatment U over 12 kV, duration of treatment τ over 35 s and length of stay T of the seeds from treatment to sowing over 12 days;

c) Efficient impact should expect in combined increase of the values for controlled factor voltage of treatment and shortening of the duration of treatment to 2 s.

3. Theoretically established possibilities for efficient stimulation of the sowing properties and morphological characters of tomato seeds after pre sowing electromagnetic treatments should be examined in laboratory and field studies.

REFERENCES

[1] Danailov Zh., (2012), *Breeding and seed production of tomato (Solanum lycopersicum* L.*). History, methods, achievements, trends (Селекция и семепроизводство на домати* (*Solanum lycopersicum* L.). *История, методи, постижения, тенденции),* "Prof. M. Drinov" Academic Publishing House, Sofia/Bulgaria;

[2] Ganeva D., Sirakov K., Mihov M., Martev K., Zahariev S., Palov I., (2014), Influence of pre-sowing electromagnetic treatments on propagating seed qualities of tomato variety Milyana (*Влияние на предсеитбените електромагнитни обработки и срока на съхранение върху кълняемата енергия и лабораторната кълняемост на семена от български сортове домати), Proceedings of the International Symposium ISB-INMA TEH`2014*, pp. 646-653, Bucharest/Romania;

[3] Ganeva D., Sirakov K., Mihov M., Zahariev S., Palov I., (2015), Influence of pre-sowing electromagnetic treatments and duration of storage on germination energy and laboratory germination of seeds from Bulgarian tomato varieties (*Влияние на предсеитбените електромагнитни обработки и срока на съхранение върху кълняемата енергия и лабораторната кълняемост на семена от български сортове домати), INMATEH – Agricultural Engineering*, vol.45, Issue 1, pp.43-50, Bucharest/Romania,;

[4] International Seed Testing Association, (ISTA), (2004), *International rules for seed testing*. Bassersdorf, Switzerland;

[5] Mitkov A., (2011), *Theory of experiment (Теория на експеримента), "*Dunavpress" Publishing House, Rouse/Bulgaria;

[6] Poryazov I., Petkova V., Tomlekova N., (2013), *Vegetable growing (Зеленчукопроизводство)*, "Dimi-99" Publishing Hause, Sofia/Bulgaria;

[7] Radevska M., Stoilova A., Palov I., Sirakov K., (2012), Impact of electromagnetic treatment and storage term on the pre-sowing properties of cotton seeds. I. Laboratory germination (Влияние на електромагнитната обработка и срока на съхранение върху посевните качества на семена от памук. I. Лабораторна кълняемост). *Plant Science*, vol.49, Issue 1, pp. 19-27, Sofia/Bulgaria;

[8] Sirakov K., (2006), Results of study after pre-sowing electromagnetic treatment of maize seed of Bulgarian and American hybrids (*Резултати от изследване след предсеитбени електромагнитни обработки на царевични семена от български и американски хибриди)*. Scientific works of "A. Kanchev" University of Ruse/Bulgaria, vol. 46, Issue 3.1, pp.87-91;

[9] Sirakov K., Ganeva D., Zahariev S., Palov I., Mihov M., (2015), Results of the investigation regarding the influence of pre-sowing electromagnetic treatment and storage period on sprouting of seeds of Bulgarian tomato varieties (Резултати от изследване влиянието на предсеитбените електромагнитни обработки и срока на съхранение върху прорастването на семена от български сортове домати)*, Ecology and Future*, vol. 14, Issue 1-2, pp. 65-71, Sofia/Bulgaria;

[10] TeKrony D.M., Egli D.B., (1991), Relationship of seed vigor to crop yield: A Review*, Crop Science,* Madison/WI, vol. 31, Issue 3, pp. 816-822;

[11] *** http://www.statsoft.com;