Study of the post-effect from the electromagnetic treatment on fresh seeds of Bulgarian pepper varieties (*Capsicum annuum* L.)

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Abstract

A study to establish the post-effect of the electromagnetic treatment on the sowing qualities and morphological characters of fresh seeds from Bulgarian pepper variety "Kurtovska Kapia 1" was performed during the period 2016-2017 in the "Maritsa" Vegetable Crops Research Institute – Plovdiv. The research was conducted under controlled laboratory conditions. It was performed a pre-sowing treatment of the seeds in 12 variants with controllable factors: voltage *U* (kV), duration of impact τ (s) and time of stay of the seeds from the treatment to sowing - days *T*. The sowing qualities are studied: germination energy - *GE* (%) and germination - *G* (%), and morphological characters: root length ℓr (mm), hypocotyl length ℓh (mm) and cotyledon length ℓc (mm).

The best positive effect was found in fresh seeds after treatment with a voltage of 6 kV, lenght of exposure of 35 s and time of stay - 8 days.

Key words: *Capsicum annuum* L.; electromagnetic treatment; sowing qualities; morphological characters

INTRODUCTION

It is known that the application of magnetic fields with extremely low frequencies has a positive effect on some characteristics of plants and seed sowing qualities, such as seed germination, development of germs, plant length, fresh weight; fruit production and average fruit weight (Danilov et al., 1994; Namba et al., 1995; Aladjadjiyan, 2002; Esitken, 2003; Rochalska & Orzeszko-Rywka, 2005; De Souza et al., 2006; Nimmi & Madhu, 2009; Cakmak et al., 2010). The applying of fertilizers and pesticides in the cultivation of crops by conventional methods results in pollution of the environment and therefore an innovative methods for increase of the agricultural production are searched (Carbonell et al., 2000; Hernández et al., 2006; Domínguez et al., 2010; Aladjadjiyan, 2012). This type of methods is considered environmentally friendly, alters the processes taking place in the seeds, increases seed vitality and provides better plant development at later stages (Fernández, et al., 2002). It was established that in optimal doses for a particular plant species the seed sowing qualities can be improved after pre-treatment with electromagnetic fields (Samy, 1998; Podlesny et al., 2005; Soltani et al., 2006). Studies with pre-sowing electromagnetic seed treatments have been performed in wheat (Martinez et al., 2002; Penuelas et al., 2004; Palov et al., 2008), peas (Podlesny et al., 2005; Jamil & Ahmad, 2012), corn (Flórez et al., 2007; Palov et al, 2008) technical crops (Stoilova et al., 2011; Spendier et al, 2018), vegetable crops such as pepper (Nimmi & Madhu, 2009; Ahamed et al., 2013; Antonova et al., 2013; Martínez et al., 2014; Antonova et al., 2018; Antonova-Karacheva, 2020), head cabbage (Sirakov et al., 2016), tomato (Ganeva et al., 2013) etc.

The aim of this study was to investigate the post-effect after harvesting of the crops which seeds have been pre-sowing treated electromagnetically at different length of the stay until sowing the seeds obtained from the fruits on the sowing qualities and morphological characters of the studied Bulgarian pepper variety, Kapia type.

MATERIAL AND METHODS

The experimental work was carried out in the period 2016-2017 at the Maritsa Vegetable Crops Research Institute, Plovdiv, Bulgaria. The object of the study was to investigate the post effect of the treated fresh seeds on the sowing qualities and morphological characters of Bulgarian pepper variety, Kapia type – "Kurtovska kapia 1", intended for medium early field production. The research was conducted in collaboration with the Electrical Power Engineering Department at the University of Ruse, Ruse. An electromagnetic field of alternating current corona discharge between blade-plane electrodes was used for pre-sowing treatment of the seeds of the variety. Controllable impact factors are: the voltage U (kV) between the treatment electrodes, the duration of exposure τ (s), and time of stay of the seeds after treatment until sowing T (days). The experiment includes 12 variants in which the control factors vary at 3 levels (Table 1), i.e. a complete factor experiment of B^3 type was conducted (Mitkov & Kardashevski, 1977). The study is a continuation of experiments conducted in laboratory conditions and the impact of treatments on produced seedlings (Antonova et al., 2018; Antonova-Karacheva, 2020).

Twelve variants of processing in 3 replications are set in laboratory conditions, in petri dishes (100 seeds/replication). The seeds are placed in a thermostat at a temperature of 25°C and a humidity of 95%. Raw seeds were used for control. Ten germinated seeds were randomized taken from each replication of a variant.

The sowing qualities of the seeds were studied: germination energy - *GE* (%) and germination – *K* (%) and the morphological characters: root length ℓr (mm), hypocotyl length ℓh (mm) and cotyledon length ℓc (mm).

The indicators are reported on the 6th and 14th day, according to the methodology of ISTA (2004), and the measurement was performed with a caliper (accuracy up to 0.01 mm). The results were statistically processed by analysis of variance (Duncan, 1955; Lidanski, 1988) and were given as a percentage towards the control (% / K).

RESULTS AND DISCUSSION

On the basis of the analysis of the data on the sowing qualities of fresh seeds from the pepper variety "Kurtovska Kapia 1" it is established that the pre-sowing electromagnetic treatments have a positive effect on the germination energy in some of the studied variants , and on the seed germination - in all studied variants (Table 2). In variant 5 with a processing time $T = 4$ days, $U = 14$ kV and time $\tau = 35$ s, the highest values of the germination energy - 54.41% were reported. During stay-time $T = 8$ days the germination energy is improved by 25.00 % in

Table 1. Matrix of planning experiment

Treatments	Controllable factors				
	Voltage		Duration of impact		Length of stay
	U		τ		T
	level	kV	level	s	day
K	0		0		0
1	+	14	+	35	12
2	-	6	+	35	
3	+	14	-	5	
4	-	6	-	5	
5	+	14	+	35	4
6	-	6	+	35	
7	+	14	-	5	
8	-	6	-	5	
9	+	14	+	35	8
10	-	6	+	35	
11	+	14	-	5	
12	-	6	-	5	

Table 2. Sowing qualities of the germinated of Kurtovska kapia 1 variety

Length of stay, day	Treatments	Germination energy, %			Germination, %		
		$\bar{x}$	%/K	VC%	$\bar{x}$	%/K	VC%
K		22,67±2,08 bcd	100,00	9,18	66,33±9,29 d	100,00	14,01
4	5	35,00±2,65 a	154,41	7,56	77,33±2,25 a-d	116,58	2,92
	6	22,50±3,50 bcd	99,26	15,56	81,83±11,77 abc	123,37	14,39
	7	20,33±7,85 cd	89,71	38,59	82,17±10,68 abc	123,87	13,00
	8	20,67±0,29 bcd	91,18	1,40	78,50±6,06 a-d	118,34	7,72
8	9	28,33±4,25 ab	125,00	15,01	84,83±4,25 ab	127,89	5,01
	10	27,00±4,50 bc	119,12	16,67	87,33±2,31 a	131,66	2,64
	11	12,17±1,61 e	53,68	13,21	72,67±7,82 a-d	109,55	10,76
	12	15,67±2,02 de	69,12	12,90	68,17±11,07 a-d	102,76	16,24
12	1	19,67±0,58 cd	86,76	2,94	70,50±9,26 ab	106,28	13,13
	2	19,67±7,59 cd	86,76	38,58	83,00±3,12 ab	125,13	3,76
	3	19,83±3,69 cd	87,50	18,58	81,83±6,05 abc	123,37	7,39
	4	25,50±4,36 bc	112,50	17,09	86,83±3,75 a	130,90	4,32

a,b,c ….P<0.05; ns - non significant – Duncan's Multiply Range Test

the 9th and 10th variant - 19.12% (U = 14, 6 kV, time τ = 35 s). Variant 4 with U = 6 kV, time τ = 5 s shows the highest results (12.50%) from the group of seeds with a stay before sowing T = 12 days. It was reported that the pre-sowing electromagnetic

treatments have a positive effect on the germination in all variants. The highest values were reported in variant 10 with U = 6 kV, time τ = 35 s, stay of T = 8 days (31.66 %/K), followed by variant 4 with U = 6 kV, time τ = 5 s, stay of T = 12 days (30.90% / K) as they are proven to be different from the control.

The highest suppressive effect registered after the treatments on the germinating energy, with proven statistical differences were reported in variant 11 with U = 14 kV, time τ = 5 s (46.42 %/K) and variant 12 with U = 6 kV, time τ = 5 s (30.88 %/K) with a stay before sowing of T = 8 days.

Positive results were found in the character "embryonic root length" ℓr at the studied variants, compared to the control after electromagnetic treatment of seeds, as a stimulating effect was found in almost all variants (Table 3). The highest results after the analysis were registered in variant 10 with U = 6 kV, time τ = 35 s and stay before sowing T = 8 days (20.75% / K). In the group with a stay before sowing of 4 days the highest values were registered in variant 7 with U = 14 kV, time τ = 5 s (14.28%), and in the group with a stay of 12 days - in variant 4 with U = 6 kV, time τ = 5 s (18.74%).

Similar results were registered for the length of the hypocotyl ℓh, as confirmation in the variant with 10 U = 6 kV, time τ = 35 s and stay before sowing T = 8 days, the highest values were reported. In the group with stays of 4 days the highest results were reported in variant 5 with U = 14 kV, time τ = 35 s. At stays of 12 days before sowing, the analysis shows that variant 2 with U = 6 kV, time τ = 35 s has the highest values compared to the control variant - 17.90%. The greatest impact on the morphological characters of the germinated seeds was registered in variant 10 with voltage U = 6 kV, time τ = 35 s and T = 8 days, where the growth of the root and hypocotyls is by 20.75% and 31.78%, respectively greater than the control.

The highest positive effect on the length of the cotyledons ℓc was found in variant 7 with U = 14 kV, time τ = 5 s and T = 4 days (4.88%) and with minimal positive proven differences compared to the control were found in all other variants from 0.68 to 3.48%, only in variant 1 with U = 14 kV, time τ = 35 s and stay before sowing T = 12 days a suppressive effect was established - 1.28% / K.

Suppressive effect of treatments on root length ℓr and hypocotyl length ℓh from the influence of controllable factors on morphological characters in variety "Kurtovska Kapia 1" of the data shows that they had a negative impact on the observed parameters, as it is the most strongly expressed in variants 6, 8 and 9 during the stay of the seeds until

their sowing $T = 4$ and 8 days. Negative values for the root length ℓr, were reported in variants 6 and 8 with $U = 6$ kV, time $\tau = 35$, 5 s and $T = 4$ days - 19.60 and 10.61 %/K, respectiely followed by variant 9 $U = 14$ kV, time $\tau = 35$ s and $T = 8$ days - 3.37 %/K. Negative effect for the length of the hypocotyl ℓh was expressed in variants 6 and 8 with stays of 4 days - 17.47 and 11.06 %/K, respectively, and for variant 9 with $T = 8$ days the variation of the values reaches 14.60 %/K.

The data from the studied sowing qualities for the three varieties were analyzed by three-factor analysis of variance (Table 4).This analysis gives an assessment of the interaction of the factors - variety (A), stress (B) and stay before sowing (C).

Based on the conducted three-factor analysis of variance for the germinated energy, significant statistical differences have been found to influence the variety, stresses and stay until sowing, as well as of the interaction between the factors A x B, B x C and

Table 3. Morphological characteristics of the germinated of Kurtovska kapia 1 variety

Length of stay, day	Treatments	Length of root ℓ_r, mm		Length of hypocotyl, ℓ_h mm		Length of cotyledons ℓ_c, mm	
		$\bar{x}$	%/K	$\bar{x}$	%/K	$\bar{x}$	%/K
K		29,2 b-e	100,00	21,04 b-e	100,00	10,71 bc	100,00
4	5	30,23 a-e	103,53	24,13 abc	114,68	11,07 ab	103,30
	6	23,48 f	80,40	17,37 e	82,53	10,79 abc	100,68
	7	33,37 a-d	114,28	22,83 a-e	108,47	11,24 a	104,88
	8	26,10 ef	89,39	18,72 cde	88,94	10,73 bc	100,16
8	9	28,22 def	96,63	17,97 de	85,40	11,1 ab	103,61
	10	35,26 a	120,75	27,73 a	131,78	11,01 abc	102,80
	11	28,63 cde	98,06	21,81 b-e	103,66	11,08 ab	103,39
	12	34,06 ab	116,64	21,5 b-e	102,17	11,09 ab	103,48
12	1	34,11 ab	116,80	23,67 abc	112,50	10,58 c	98,72
	2	33,65 abc	115,24	24,81 ab	117,90	11,01 abc	102,80
	3	31,65 a-d	108,40	23,91 abc	113,64	10,94 abc	102,12
	4	34,67 a	118,74	23,28 a-d	110,63	10,90 abc	101,74

a,b,c ….P<0.05; ns - non significant – Duncan's Multiply Range Test

Table 4. Three-way analysis of variance and degree of influence of sources of variation

Factors of variation	Degree of freedom	Germination energy, %		Germination, %	
		Mean square	Influence	Mean square	Influence
	df	MS	%	MS	%
Variety A	2	85,74*	0,51	27,23ns	
Voltage B	4	251,71***	3,00	756,48***	23,40
Stay of seeds C	1	27737,78***	82,78	23,51ns	
Interaction A x B	8	155,44***	3,71	257,65*	15,94
Interaction A x C	2	70,88ns		85,21ns	
Interaction B x C	4	190,14***	2,27	111,71ns	
Interaction A x B x C	8	96,07**	2,29	71,82ns	
Residual	60	27,93		109,61	

* p<0.05, ** p<0.01, *** p<0.001, ns – non significant

A x B x C. Among these factors the greatest influence on the germinating energy has the stay before sowing (82.78%), followed by the voltage (3.00%) and the effect of the variety (0.51%), about the interaction between the factors it is established that their combination of A x B x C (variety, voltage and stays before sowing) complement each other (2.29%), as an essential role is played by electromagnetic treatments at the set values for the controlled factors B x C (2.27%).

According to the results of the analysis of variance for the "germination" character it is established that only the stress factor C and the interaction between variety and stress A x B have been proven to be significant. The strongest source of variation is the voltage (23.40%), followed by the interaction between the factors variety x voltage (15.94%). There are no statistical differences between the other factors and interactions between them.

The general analysis of the data from Table 4 shows that the performed pre-sowing electromagnetic treatments of the seeds, with controllable impact factors have a positive effect on the studied characters. The conducted three-factor analysis of variance in the characters germination energy and germination proves the influence of the applied pre-sowing electromagnetic treatments in the field of corona discharge as a determining factor in the seeds of the studied pepper variety.

Based on the conducted researches, it can be assumed that the pre-sowing electromagnetic treatments with the selected values of the controllable factors on the seeds of the studied variety of pepper can be applied as follows:

For variety "Kurtovska kapia 1", voltage $U = 6$ kV, duration of treatment $\tau = 35$ s and stay before sowing $T = 8$ days (variant 10).

The results after the study confirm those ones obtained in the study of seedlings from the "Kurtovska Kapia 1" variety under the same controllable factors (Antonova et al., 2018). These results demonstrate that there is a presence of residual effects of pre-sowing electromagnetic treatments, but they are versatile for different crops. This can be explained by the difference in the values used of the voltage between the electrodes and the duration of seed treatment (Palov et al. 2012; Stoilova et al, 2012; Sirakov et al. 2014). Spendier et al, (2018), found that under the influence of magnetic fields with a specific intensity, the percentage values for germination and morphological characters in hemp reach their maximum, which determines the potential of the crop for the respective method of physical impact.

As a result of the experiments performed Kuzmanov et al., (2010) and Palov et al, (2010) have not established a regularity in the results obtained after electromagnetic treatment of seeds of cucumbers variety "Gergana" and barley variety "Obzor", which correlates with the data obtained from the studied pepper variety.

CONCLUSIONS

It was established a positive effect on pepper seeds after pre-sowing electromagnetic treatments in the ac corona discharge field on the sowing qualities and morphological characters of pepper seeds from "Kurtovska Kapia 1" variety, with a stay of treatments before sowing of 4, 8 and 12 days.

The best effect on the sowing qualities - germination energy and germination of seeds is established in variant 10 with voltage $U = 6$ kV, duration of processing $\tau = 35$ s and stay before sowing $T = 8$ days. The most suitable values of the controllable factors on the morphological characters of the seeds are voltage $U = 6$ kV, duration of processing $\tau = 35$ s in the variants 10, 2 with stay before sowing of 8 and 12 days.

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