Pre-sowing stimulation of cereal seeds in high voltage electric field

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Abstract. The main challenge of modern land management is the need to increase the yield of cultivated crops, while maintaining quality, minimising total energy inputs into cultivation and minimising the negative impact on the environment. This is quite possible if we have healthy seeds characterised, first of all, by improved sowing qualities. In order to realise the mentioned approaches, it is possible to use seed preparation for sowing, using for this purpose various electrophysical effects, including treatment of seed material in the electric field of high voltage. The purpose of the presented article is to analyse the results obtained to study the process of treatment of cereal seeds before sowing in the electric field of constant and alternating high voltage, as well as the electric field of pulsed high-voltage discharges. A universal experimental laboratory setup was assembled for the research. According to the results of the experiments, there was a clear dependence of the speed and friendliness of germination of winter triticale and barley seeds on the effects of electrical nature on them. Efficiency of such influences is also shown in plant protection against various pests, so against bread fleas and meromysa it is treatment in the electric field of alternating high voltage with duration of 120 s, as well as against Swedish fly, but with duration of treatment of 60 s; against wheat thrips – in the electric field of constant high voltage with duration of 60 s. Besides optimisation of phytosanitary condition of crops, the stimulating effect of high voltage electric field on yield structure of cereal crops (winter barley and triticale) was revealed, as productivity increases, bushiness and more dense productive stalks are formed. Electrostimulation has a positive effect on such hard-to-regulate parameter as ear fineness – the total number of grains in the ear increases by 13.8...31.0%; the weight of 1000 grains slightly increases – by 3.0...6.2%; grain yield to total weight increases by 40.3...57.8%; positive effect on all elements of yield structure is traced.

Key words: pre-sowing electrostimulation, electric field, seeds, treatment mode, exposure parameters, electric field strength, treatment time, germination, growth energy, structure.

1 Introduction

At present, close attention is drawn to the search for technologies and technical solutions that minimise the negative impact on the environment, preserve the food safety of the produced product, and agricultural production itself as close as possible to nature-like technologies, organic farming technologies. As solutions to these problems we can offer the application of various electro-technologies and electro-technological operations, the introduction of which in the agricultural sector and processing industry is technologically effective and environmentally safe, and at the same time allows the land user to implement the modern principles of using high-tech means, while receiving a higher income from the grown, safe in all senses, products [1]. Pre-sowing stimulation of seeds of various agricultural crops can be considered as a specific approach to the implementation of the indicated technologies. Now it is proved by numerous researches and practical implementation the possibility to treat seeds before their introduction into the soil in the electric field of direct and alternating current [2]; in the magnetic field [3]; in the field of corona discharge [4]; under the influence of electric pulses [5] and with the passage of electric current [6]; irradiation with ultraviolet, infrared, monochromatic and coherent radiation [7].

2 Purpose and Statement of Objectives

The purpose of the presented article is to analyse the obtained results on the study of pre-sowing preparation of cereal seeds in the electric field of constant and alternating high voltage, as well as in the electric field of pulsed high-voltage discharges. The task of these studies was to identify the modes and parameters, as well as the type of electrical influences that have a positive effect on increasing crop yields, improving growing conditions

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due to their higher resistance to diseases and pests, as well as endurance to unfavourable factors of influences at all periods of plant development.

3 Materials and Methods

The research programme to study the effect of treatment in high voltage electric fields of cereal seeds before sowing determined the necessity to design and manufacture an experimental unit that allows to effectively carry out the treatment, monitor and control its parameters and modes. The assembled installation contains in its structure the main element – a source of regulated high AC and DC voltage, as which the device for high-voltage testing SKAT-70 was used. Applying the industrially manufactured device, which passed the factory calibration and has the ability to carry out visual control of the processing parameters and their changes in the process of research, made it possible to transform the laboratory installation with minimal cost for the tasks that were set in the experiment [8].

4 Results and discussion

Experimental studies and analysis of the obtained results made it possible to reveal that the influence of electric influences on seed material is manifested already at the initial stages of plant development – the dependence of speed and rapidity of germination of winter triticale seeds of the variety TI 17 on the influence on them of the electric field of constant and alternating high voltage, as well as the electric field of pulsed high-voltage discharges was clearly observed [9–12].

The lowest number of germinated seeds on the second day of observation was recorded in the variant with the use of pre-sowing stimulation in the electric field of constant high voltage, for which this indicator was equal to 4.3%. At the same time, in the control, when the seeds were not treated with anything, the germination energy averaged 3.3%. At stimulation of seeds in the electric field of alternating high voltage, as well as alternating high voltage, the indices were significantly higher in comparison with the control, and were 23.0% and 28.5%, respectively. On the third day it was revealed that the number of germinated seeds among treated seeds increased on average 2.1...2.6 times in comparison with the control. The speed and friendship of seed germination after electrical treatment on the fourth day practically levelled out. The optimal mode in this respect was the variant with treatment in the electric field of alternating high voltage, where the simultaneity of seed response was 96.0%. At treatment in electric fields of constant and pulsed high voltage the germination energy was almost the same and was 92.5 and 92.0%, respectively, but in the control variant this indicator was two times lower [13–15].

As a justification of the stimulating effect, it can be assumed that under the influence of high-voltage electric fields in the internal structure of the seed there is a redistribution of electric charges, which change the course of physicochemical processes in the cell and thus the effect is obtained, manifested in the form of more intensive growth and development of plants.

Analysing the results on germination, the following data were obtained: the most responsive seeds turned out to be under the influence of electric field of alternating high voltage, so developed (germinated) seeds turned out to be 98.7%, which was 4% higher than the control. Germination of seeds of other variants differed by 1.0% and 1.7% from the control. The result of the obtained positive stimulating effect can be explained by the intensification of biological processes in the internal structures of the seed due to the receipt of additional energy [16–19].

To identify the practical applicability of the studied method of pre-sowing stimulation, the research programme included exploratory experiments, during which it was determined that the effect of electric effects on seed development depends not only on the parameters and modes of treatment, but also on the condition of the seeds themselves, i.e. on their sensitivity to electric effects. Agrotechnological method of pre-sowing treatment in electric fields is effective for seeds with reduced germination but high viability. It was found that the greater the difference between seed germination and viability, the higher the efficiency of the studied agro-technological method.

Activation during the initial period of development of winter triticale plants of variety TI 17, grown from seeds treated in electric fields, leads to changes in their morphological characteristics (Table 1).

Table 1. Features of changes in morphometric parameters of seedlings of winter triticale variety TI 17 under the influence of high voltage electric fields

Processing mode		Germination, %	Number of roots per plant, pcs	Root length, cm	Height of seedlings, cm
Type of impact	Processing time, s				
1	2	3	4	5	6
Control – no treatment		88.7	5.1	9.4	6.3
Electric field of pulse voltage E = 3 kV/sm	60	96.8	5.6	11.3	8.2
	120	96.6	5.6	11.9	8.9
Electric field of constant high voltage E = 3 kV/sm	60	90.3	5.9	11.2	7.4
	120	91.5	6.0	12.1	7.2
High voltage alternating electric field E = 3 kV/sm	60	96.7	5.1	8.9	5.0
	120	90.0	5.1	10.4	8.5

The analysed results of experimental studies allow us to say that vegetative plants have a lengthening of the first internodes and a more powerful root system compared to the control. A very serious fact for arid zone conditions is that intensive root growth leads to faster rooting of plants, better utilisation of spring moisture and nutrients [20, 21].

The level of influence of seed stimulation in the electric field depends on the mode of treatment: the best results were found in the application of electric field of constant high voltage during treatment for 120 s. The observed increase in morphophysiological parameters of seedlings undoubtedly contributes to the increase in yield. The improvement of morpho-physiological parameters of seedlings, undoubtedly, lays down the possibility of increasing crop yield. This electrotechnological technique leads to the improvement of physiological state of the embryo, influencing up to the change in the intensity of chemical reactions [22].

To verify the stated hypothesis about changes occurring in the intracellular structures of seeds, a series of experiments were conducted, in which grains of different crops were treated in the electric field of constant high voltage. The analysis of the obtained results allows us to state that immediately after the treatment the moisture content of the seed mass increased in comparison with the same volume of untreated seeds, and then slightly decreased, but at the same time its final (steady-state) value remained higher than that of untreated seed samples. Such results may indicate that some intracellular changes occur under electric influences, as a result of which the bound internal moisture in seeds is mixed. The positive effect of high voltage electric field on seeds includes regulatory changes at all levels of organisation of the plant organism.

It was also revealed experimentally that the efficiency of the studied agro-approach in the field of plant protection from pests is in direct dependence on the modes and parameters of electrical treatment. The most effective indicators were obtained at treatment: against bread fleas (*Phyllotreta vittula Redt. L.; Chaetocnema hortensis Geoffr. L.*) and *Meromyza* (*Meromyza L.*) – in the electric field of alternating high voltage, treatment time 120 s; against Swedish fly (*Oscinella L.) – in the electric field of alternating high voltage,* treatment time 120 s.) – in the electric field of alternating high voltage, treatment time 60 s; against wheat thrips (*Haplothrips tritici L.*) – in the electric field of high-voltage pulse discharges, treatment time 60 s. Judging by the obtained data, pre-sowing electrostimulation of seeds belongs to the number of agro methods that can positively solve the problems of minimising the number of pests in agrobiocenoses and maximising the circulation of entomophages Electrical treatment of seeds, regardless of the modes and parameters of exposure, has a negative effect on the development of seed infection. The best results are shown by electrification of seeds by electric field of alternating high voltage for 60 s, providing suppression of pathogens by 5.5...27.2 (Table 2).

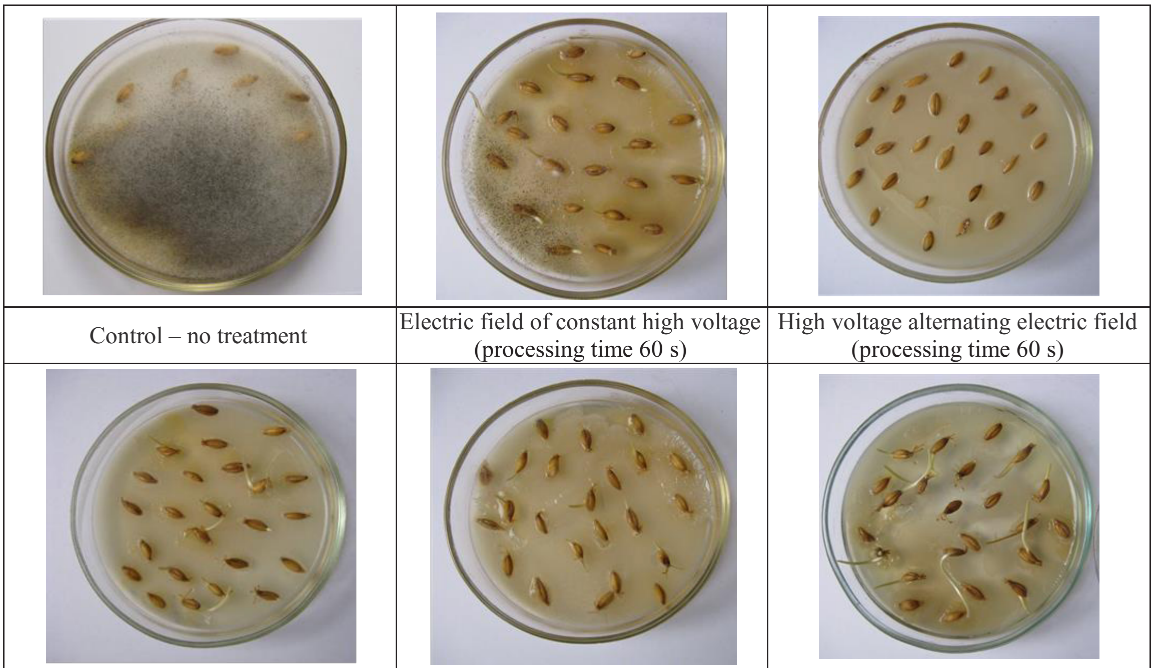
Exposure of seeds to various types of electric field, modes and parameters of exposure leads to increased immunity and resistance of grain crops to the negative impact of economically dangerous infectious diseases (Fig. 1).

Seed treatment in high-voltage electric fields increases plant defence against leaf-stalk pathogens to the greatest extent. Thus, in the case of helminthosporiosis and septoriosis, a small number of necrotic spots were formed on the leaves of plants grown from treated seeds and further development of these diseases was not observed. The effect of electric field of alternating high voltage with treatment time of 60 s was more effective – the intensity of leaf-stalk infections development decreased: in spring barley by 5%, in winter triticale – by 5.4...10.8%. Treatment in the electric field of constant high voltage had less effect on plant immunity [23].

However, it should be noted that increasing the treatment time up to 120 s reduced the intensity of leaf blight development by 4.2...11.5%. Root rot pathogens were less responsive to electric treatment. Exposure of seeds to high voltage electric fields provides reduction of disease development of vegetative plants by 3.1...4.2%. Together with the optimisation of phytosanitary condition of crops of seeds treated in the electric field of high voltage, the stimulating effect of the latter on the structure of cereal crops yield was revealed (Table 3).

Table 2. Efficiency of pre-sowing treatment of seeds of winter triticale variety TI 17 in high voltage electric fields

Processing mode		Plants damaged,%			Number of records, pcs./unit.	
Type of impact	Processing time, s	*Phyllotreta vittula Redt. L.; Chaetocnema hortensis Geoffr. L.*	*Oscinella L.*	*Meromyza L.*	*Haplothrips tritici L.*, pcs./ear	Entomophages, pcs./unit accounting
1	2	3	4	5	6	7
High voltage alternating electric field *E* = 3 kV/sm	60	25.0±1.1	9.4±0.22	1.5±0.090	103.1±2.0	6,1±0,12
	120	21.1±1.7	13.3±0.41	0.3±0.003	78.3±2.3	6,4±0,06
Electric field of constant high voltage *E* = 3 kV/sm	60	28.6±0.4	15.5±0.55	1.2±0.100	88.0±3.1	6,0±0,02
	120	34.8±2.2	17.2±0.30	0.7±0.010	118.7±4.7	6,1±0,08
Electric field of pulse voltage *E* = 3 kV/sm	60	52.6±2.3	12.4±0.26	1.0±0.020	61.0±0.6	6,8±0,03
Control – no treatment		78,3±3,1	19.8±0.21	2.6±0.300	192.4±4.5	6.0±0.05



Control – no treatment | Electric field of constant high voltage (processing time 60 s) | High voltage alternating electric field (processing time 60 s)

Electric field of constant high voltage (processing time 120 s) | High voltage alternating electric field (processing time 120 s) | Electric field of pulse voltage (processing time 60 s)

Fig. 1. Effect of stimulation of seed material with an electric field (tension of 3 kV/cm) of alternating, direct and pulsed high voltage on the development of seed infection

Table 3. Effect of pre-sowing treatment of spring barley seeds of the Donetsk-8 variety with high-voltage electric fields on the development of diseases, %

Type of impact	Processing time, s	Powdery mildew	Septoria	Dark brown spotting	Bacteriosis	Helminth-sporium-fusarium rot
1	2	3	4	5	6	7
High voltage alternating electric field E = 3 kV/sm	60	18.2	10.0	16.2	20.6	5,8
	120	20.9	12.1	18.6	23.1	7,5
Electric field of constant high voltage E = 3 kV/sm	60	20.6	13.5	20.7	23.9	7,5
	120	19.4	10.8	21.1	27.2	7,3
Electric field of pulse voltage E = 3 kV/sm	60	–	–	17.5	23.6	6,2
	120	–	–	18.3	23.5	6,3
Control – no treatment		30.0	15.0	24.5	35.4	9.0

Data analysis shows that seed treatment in the electric field provides an increase in productivity, bushiness and formation of a thicker productive stalk up to 500 ears/m^2 . It is also the cheapest and most effective way to suppress in-stem pests, infectious diseases and weeds. Electrostimulation has a positive effect on such a hard-to-regulate parameter as ear ear fineness. Thus, the total number of grains in the ear increases by 13.8...31.0%, the weight of 1000 grains slightly increases by 3.0...6.2%, and the grain yield to total weight increases by 40.3...57.8%. Presowing stimulation of seeds in the electric field of high voltage has a positive effect on all elements of the yield structure. Thus, the yield of winter triticale variety TI 17 increases on average by 33.1%. But still the greatest effect, and on all indicators of exposure, is achieved with the use of electric field of constant high voltage. Taking into account unfavourable weather conditions during the period of grain filling, higher indicators of 1000 grain weight on variants with application of electric field of constant high voltage indicate an increase in the general level of drought resistance of plants (Table 4). As intermediate results, it can be noted that the increase in the yields obtained consists of: an increase in productive bushiness, which is accompanied by the accumulation of biomass and, as a consequence, the formation of a thicker stalk; obtaining larger grains and, accordingly, a higher yield of grain per ear and plant. All of the above, in general, provided an increase in grain yield on the experimental field plots from 4.9 to 8.4 kg/ha.

It can be noted that the increase in yields is the result of: an increase in productive bushiness, which is accompanied by the accumulation of biomass and, as a consequence, the formation of a thicker stalk; obtaining larger grain and, accordingly, higher grain yield per ear and plant. All of the above in general provided an increase in grain yield on experimental field plots from 4.9 to 8.4 kg/ha.

Table 4. Effect of seed treatment in high voltage electric fields on the structure of the crop

Type of impact	Processing time, s	Number of productive stems, pcs./m^2	Straw weight, g/m^2	Spike length, cm	Number of grains in an ear, pcs.	Weight of 1000 grains, g	Yield increase, %
1	2	3	4	5	6	7	8
Spring barley variety Donetsk 8							
High voltage alternating electric field E = 3 kV/sm	60	438.0	230.8	7.5	19.0	38.2	+57,80
	120	500.0	218.4	7.2	17.3	39.4	+40,30
Electric field of constant high voltage E = 3 kV/sm	60	424.0	178.0	6.5	16.5	36.3	+7,00
	120	376.0	192.4	6.5	16.5	32.3	–1,90
Control – no treatment		392.0	161.6	6.5	14.5	37.1	–
Winter triticale variety TI-17							
High voltage alternating electric field E = 3 kV/sm	60	96.0	102.6	8.5	42.2	36.7	+43,60
	120	73.0	80.9	8.4	41.8	37.7	+24,00
Electric field of constant high voltage E = 3 kV/sm	60	91.3	83.4	7.8	38.2	39.5	+21,60
	120	111.3	101.8	7.8	35.4	41.1	+29,80
Electric field of pulse voltage E = 3 kV/sm	60	104.3	91.0	8.1	41.1	37.9	+21,98
Control – no treatment		64.0	61.1	7.4	46.5	37.0	–

5 Conclusion

Seed treatment before sowing in electric fields of high voltage (constant, alternating and pulse) at different modes of action is effective for plant protection against various pests, for example, against bread fleas and meromysis (*Phyllotreta vittula Redt. L.; Chaetocnema hortensis Geoffr. L.*) – it is treatment in electric field of alternating high voltage with duration of 120 s., as well as against Swedish fly (*Oscinella L.*), but with a treatment duration of 60 s.; against wheat thrips (*Haplothrips tritici L.*) – treatment in an electric field of constant high voltage with a duration of 60 s.

In addition to optimising the phytosanitary condition of crops, the stimulating effect of high voltage electric field on the yield structure of cereal crops (winter barley and triticale) has been revealed, which increases productivity, bushiness and forms a thicker productive stem. Electrostimulation has a positive effect on such a hard-to-regulate parameter as ear fineness – the total number of grains in the ear increases by 13.8...31.0%; the weight of 1000 grains slightly increases by 3.0...6.2%; grain yield to total weight increases by 40.3...57.8%; a positive effect on all elements of yield structure is traced. Thus, the yield of winter triticale variety TI 17 increases on average by 33.1%. The greatest effect, and on all indicators of processing time, is achieved when using the electric field of constant high voltage. Taking into account unfavourable weather conditions in the period of grain filling, higher indicators of 1000 grain weight in the variants with the use of electric field of constant high voltage indicate an increase in the overall level of drought resistance of plants

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