Optimization of a Pre-Sowing Treatment of Corn Seeds with Low-Frequency Pulse Electric Field to Improve the Germination and Development of Seedlings

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Abstract. Corn is one of the key forage crops in agriculture. However, corn production in Russia still remains behind of its demand, so the search and development of technologies allowing to improve its yield are very relevant. Pre-sowing treatment of seeds of corn and other crops with physical fields provides stimulation of the growth and development of plants, but its efficiency depends on some parameters including duration of such treatment. The laboratory evaluation of the effect of a pre-planting treatment of corn seeds with low-frequency pulse electric field for 1–9 h on their germination, average lengths of the coleoptile and radicle root, and the number of seminal roots made it possible to determine the optimum exposure time (4 h) providing a significant improvement of germination (+26.7% of the control) and increase in the coleoptile length (+21.2% of the control). The maximum negative effect was revealed for a 5-h exposure; it resulted in a significant reduction of the coleoptile and radicle root lengths (421.7 and 16.3% of the control, respectively), as well as the reduction of the average number of seminal roots (4.8% of the control).

1. Introduction
Corn is characterized by a wide range of use as the forage, food, and technical crop and represents one of the most important cereal crops in a global scale including Russia. The volume of a corn production in a global scale continuously grows. The forecast for the global corn production in 2020–2021 is increased to 1.134 billion tons comparing to 1.116 billion tons produced in the preceding season [1]. Due to a high nutritional value (12.8–13.7 MJ/kg of dry matter), corn grain is an important component of forages used in animal husbandry and poultry farming [2]. In addition, this crop is also used for silage production. In general, corn is the main forage crop for the animal husbandry.

In Russia, the volume of corn production in 2020 was 14 mln. tons [3] that was inferior only to the wheat and barley production. At the same time, the volume of the corn import to Russia in 2020 reached 51.3 thousand tons [1] that confirms still existing pent-up demand for this crop. Therefore, increase in the corn production in Russia is very relevant, first of all, to provide the food safety of the country.

Corn is very sensitive to the growing conditions: water shortage, mineral deficiency, weed infestation, overcrowding, and infection with pathogenic microorganisms and pests may significantly reduce the yield [4]. Therefore, the complex of activities intended to increase corn production should
include environmentally safe approaches providing increase in the crop capacity and quality of the obtained production, i.e., the maximum possible realization of the biological potential of this crop.

One of the ways to improve the crop capacity of agricultural crops is the stimulation of their growth and development by various electrophysical methods [5]. There are numerous publications reporting the stimulating effect of the pre-sowing treatment of corn grain with various physical waves including red light, magnetic field, cold plasma, etc. [6–8]. A similar technology based on the use of low-frequency pulse electric field (LF-PEF) was developed by Russian scientists and successfully used on potato and some other crops [9, 10].

The efficiency of any pre-sowing treatment with physical waves depends on some factors including the treatment duration (see, for example, [11, 12]). Generally, for each crop there is an optimum treatment duration providing the best effect. The purpose of this study was determination of the optimum duration for the treatment of corn seeds with LF-PEF providing the best germination and development of seedlings.

2. Materials and methods

Seeds of a diploid hybrid sweet corn Nika 353 were used as the object of study. The LF-PEF treatment of seeds was carried out two days prior their germination using an experimental model of the modulated pulse electric field generator providing electric field with the required characteristics [10]. Untreated seeds were used as the control. The tested treatment duration varied from 1 to 9 h. Each variant included 20 seeds in three replications.

The effect of treatment was assessed using the following parameters: germination rate (%), length of the radicle root, coleoptile length, and the number of seminal roots. To assess germination rate, seeds were put in Petri plates on several layers of moist filter paper and germinated for 72 h in the dark at 24ºС. To assess other parameters, seeds were germinated in paper rolls for 4 days at 24ºС.

The obtained data were treated using the MS Excel program package. The significance of differences between variants was evaluated by ANOVA using a Statistica 6.0 package.

3. Results

The results of the study on the effect of a pre-sowing LF-PEF treatment of different duration on the germination rate of corn seeds are shown in Fig. 1. The maximum germination rate (71.7 ± 4.9%) was observed for the 4-h treatment; this value exceeded that in the untreated control (45.0 ± 4.7%) by 26.7%. The revealed difference was statistically significant (LSD_{0.95} = 23.1). Other variants of treatment did not show any significant difference from the control.

![Figure 1](image_url)

**Figure 1.** Effect of a pre-sowing treatment with LF-PEF of different duration on the germination rate of corn seeds (Nika 353 hybrid). Here and in Figs. 2, 3: dark bar (0 h) corresponds to the untreated control. LSD_{0.95} = 23.1.
The effect of a pre-sowing LF-PEF treatment of different duration on the average lengths of the coleoptile and radicle root is shown in Fig. 2. In the first case, a significant increase in the average coleoptile length was observed for the 4-h variant (50.8 ± 2.2 mm vs 41.9 ± 3.6 mm in the control). Note that some variants showed a significant reduction of this index comparing to the control (1, 5, 6, and 8 h). In the case of the average radicle root length, the value of this index in the 4-h variant (110.3 ± 1.8 mm) exceeded that in the control (104.3 ± 3.3 mm), but was not statistically significant. At the same time, for the 1-h and 5-h variants, the value of this index was significantly lower than in the control, and this difference was statistically significant.

![Graph showing the average coleoptile and radicle root lengths](image)

**Figure 2.** Dependence of the average coleoptile length (top, LSD$_{0.95}$ = 6.6) and the average radicle root length (bottom, LSD$_{0.95}$ = 13.1) in corn seeds (Nika 353 hybrid) on the duration of the pre-sowing LF-PEF treatment.

The average number of seminal roots in variants with the different treatment duration are shown in Table 1. The performed data analysis showed no statistically significant differences between the variants, excepting the 5-h variant, where the value of this index was significantly lower than in the control.

| Treatment duration, h | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  |
|-----------------------|----|----|----|----|----|----|----|----|----|----|
| Average number of seminal roots | 3.33 | 3.26 | 3.26 | 3.28 | 3.33 | 3.17 | 3.43 | 3.31 | 3.51 | 3.55 |
| Standard error        | 0.05 | 0.11 | 0.03 | 0.04 | 0.11 | 0.05 | 0.15 | 0.14 | 0.06 | 0.00 |

**Table 1.** Effect of the pre-sowing treatment of corn seeds (Nika 353 hybrid) with LF-PEF of different duration on the average number of seminal roots on seedlings (LSD$_{0.95}$ = 0.12)
4. Conclusions
The performed study showed the efficiency of a pre-sowing treatment of corn seeds with low frequency pulse electric field in relation to the chosen indices depends on the duration of the treatment. The less significant effect of such treatment was observed in relation to the average number of seminal roots and the average length of a radicle root. The obtained data allow us to conclude that the optimum treatment duration for the diploid hybrid sweet corn Nika 353 is 4 h providing a significant increase in the germination rate (26.7%) and average coleoptile length of seedlings (21.2%). The most negative effect of the LF-PEF treatment was observed for the 5-h variant (reduced germination rate comparing to the control, a significant reduction of the average length of the coleoptile and radicle root by 41.7 and 16.3% of the control, respectively, as well as the reduction of the average number of seminal roots by 4.8% of the control.

5. References
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