Substantiation of the ecological method application for disinfection and biostimulation of spring wheat seeds in the Krasnoyarsk territory forest-steppe zone

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Abstract. The article presents the testing results of effective modes of the electromagnetic field of super-high frequency in the field conditions, the influence on the germination of spring wheat seeds, and the reduction of infection with the most harmful microorganisms. In the conditions of high seeds infection in the Krasnoyarsk territory, the developed technology of microwave seeds disinfection is relevant due to its efficiency and environmental friendliness. The research object is the spring wheat variety – Novosibirskaya 15. Recording was performed using existing methods and State Standards. The conducted research and the obtained results allow to conclude that the electromagnetic field of super-high frequency has a positive effect on the formation of the main elements of the yield structure, the actual yield, as well as significantly reduces the infection rate and increases the spring wheat seeds germination.

1. Introduction
There has been an increase in agricultural production of the Krasnoyarsk territory agriculture in recent years but there is no rational, scientifically based approach to the choice of methods and means to improve the seed material phytosanitary condition in the tactics of protecting grain crops. Many agricultural lands that are not currently used have developed resistant complexes of harmful organisms. A number of specialized pests and pathogens annually cause biogenic emergencies that destabilize the agro-industrial complex. In many grain-producing areas, the area of crops affected Septoria spot, brown rust, powdery mildew has increased [1, 2, 3]. Root rot, ear Fusarium infection and Alternaria spot have acquired the status of epiphytotics in recent years.

Local epiphytotics of Fusarium-Alternaria infection lead to infection of grain and its processed products with phytotoxins that are dangerous to human and animal life and health.

As a result, the grain does not meet the basic and restrictive conditions for phytosanitary, technological and biological properties.

In the solution of the current situation, on the one hand, phytosanitary, on the other – economic, the main role is given to the pre-sowing preparation of seeds for sowing.

Given that most of the territory of the region is in a weak self-cleaning ability of the soil and the atmosphere surface layers, the importance of choosing from among the existing such methods that can meet the requirements of both high efficiency and bioecological safety becomes obvious. Such functions
are able to be performed by the method of seed sanitary improvement in the electromagnetic field of super-high frequency (EMFSHF).

The purpose of the research is to evaluate the application of the effective mode of super-high frequency electromagnetic field to seeds as an ecological method of disinfection and biostimulation of spring wheat seeds.

2. Materials and methods
The tests were carried out in the Experimental farm “Minderlinskoe”, on the experimental fields of the Krasnoyarsk State Agrarian University, with the support of the Regional science Foundation. The soil cover is represented by leached chernozem, heavy loam, humus content is 7.1%. The experiment scheme included a variant with a fungicide, a variant with an effective microwave field mode, and control, respectively.

Experiment scheme:
- Control, without treatment;
- Microwave treatment, a heating rate of 0.6 °C/s and exposure time – 60 seconds;
- Dividend Star, suspension concentrate – 0.75 l/ha, basic.

The experiment was conducted in 4-fold repetition. The predecessor was potato variety. The object of the research was spring wheat variety – Novosibirskaya 15. Seed treatment was carried out on the PS-10 treater, microwave processing was carried out on an experimental installation developed on the basis of the Russian Federation patent for invention No. 2311022 “Device for heat treatment of bulk dielectric materials”, authors: Bastron A.V., Meshcheryakov A.V., Tsuglenok N. V. [4]. Sowing was performed by a selection seeder SSFC-7, harvesting was carried out by a “Sampo” combine. The experimental area was 1500 m². Recording was performed using existing methods and State Standards.

Records and observations included:
- onset of phenological phases of spring wheat development;
- the density of standing wheat plants was determined during the germination phase (3 leaves). On the diagonal of the site, experimental plots with the size of 1/3m were allocated. For row seeding, 2 rows with a length of 1.11 m were taken and the plants were counted;
- the spread and development of diseases were taken into account within the time limits set by standard methods, the assessment was conducted in accordance with the scales (in points) recommended by the All-Russian Research Institute of Grain and its Processing Products of the Ministry of Agriculture of the Russian Federation [5];
- phytopathological and microbiological methods were used during the research [6, 7, 8];
- phyto-expertise of seeds was carried out using the method of wet chambers according to State Standard 12044-93 [9]. Selection of samples for analysis was done according to State Standard 12037-88;
- biometric indicators were taken into account at the same time with wheat plant diseases [10, 11];
- to analyze the structure of the yield, plants were selected using the method of trial sites, which were allocated along the diagonal of the site, at regular intervals, on all variants and in non-contiguous repetitions of the experiment;
- the actual yield in the hopper weight was taken into account for each variant in 4-fold repetition. First, the yield of pure grain was determined at the actual harvest humidity, and then the grain yield was brought to the standard 14% humidity and 100% purity.

3. Research results
Laboratory and field small-scale experiments were conducted in order to determine the effective mode of pre-sowing microwave treatment of barley seeds in the Krasnoyarsk State Agrarian University. The obtained results were compared with the data that were determined earlier in the research on the studied method effect on wheat. The calculations carried out during the full germination phase of spring wheat showed that in the tested version, the stem density was 220 pcs/m² (table 1), which is higher than in the control by 7.7% and higher than in the “basic” version by 6.8%.

Table 1. Biometric indicators of wheat plants in the full germination phase.

| Variants                        | Stem density per 1 m² | Plant height, cm |
|--------------------------------|-----------------------|------------------|
| Control                        | 203                   | 15.4             |
| Microwave treatment            | 220                   | 16.2             |
| Dividend Star, suspension conc. | 205                   | 16.1             |

In the phases of stem elongation, milk ripeness and full ripeness, the influence of protectants on the development of the aboveground part (plant height) and plant bushiness was determined (table 2).

Table 2. Biometric indicators of wheat sowing.

| Indicators                              | Variants                  |
|-----------------------------------------|---------------------------|
|                                        | Control | Microwave treatment | Dividend Star |
| Development phase – stem elongation     |         |                     |               |
| 1. Plant height, cm                     | 49.8    | 56.9                | 55.6          |
| 2. Number of stems per 1 plant, pcs    | 1.1     | 1.0                 | 0.8           |
| Development phase – earing, beginning of flowering |         |                     |               |
| 1. Plant height, cm                     | 81.5    | 90.5                | 83.1          |
| 2. Number of stems per 1 plant, pcs    | 1.1     | 1.6                 | 1.1           |
| 3. Ear length, cm                       | 4.7     | 5.9                 | 4.9           |

The height of wheat plants treated with the microwave field significantly differed from the other variants of the experiment in all phases of development. Relative to the control variant, the increase was from 9.6 to 12.5%, relative to the base variant – from 2.3 to 8.9% (table 2).

Wheat seeds treated with the Dividend Star protectant and the control variant, later in the growing season of plants show almost the same value of the ear length. In the version with microwave treatment, the biometric indicators are significantly higher. The excess of the ear length was: relative to the control by 20.3% in the earing phase and by 21.0% in the full ripeness phase; relative to the Dividend Star protectant by 17.0% in the earing phase and 16.1% in the full ripeness phase.

The main factors of plant life (modes of moisture and heat supply) in certain periods of vegetation did not meet the biological requirements of the crop and did not contribute, in this regard, to increase in their resistance to pathogens. The adverse weather conditions increased the harmful activity of pathogenic and saprophytic microflora, reducing to a considerable extent the level of wheat compensatory ability.
Figure 1. Wheat plants of Novosibirskaya – 15 variety (phase of waxy ripeness).

This combination of limiting factors was favorable for increasing the harmful activity of root rot. Moreover, pathogens of R. *Alternaria* were added to the previously dominant genera of *Bipolaris* and *Fusarium* pathogens. Air-aerogenic-dust infections, in particular, brown rust, were less common.

The favorable combination of natural factors for the development and spread of diseases was supplemented by the initial stock of inoculum, concentrated in the seed material and soil, which was sufficient for a mass outbreak of diseases.

The stock of conidia of ordinary root rot in the soil of the experimental site was 60 in 1g of air-dry soil.

Thus, with a favorable combination of factors contributing to the emergence of the disease, its further spread and development, various forms of manifestation and harmfulness of diseases were noted.

In the given conditions, wheat pathogenic microflora was also marked by pathogens of Septoria (S. *nodorum*). They were isolated in the germination phase – the beginning of bushiness, with the first accounting of root rot – on the coleoptile in the form of brown stripes; there were isolated cases of seedlings bending.
The first recording of plant diseases by root rot was carried out in the germination phase, the second – in the milky-waxy ripeness of wheat (table 3).

**Table 3. Influence of treatment options on plant infection with root rot.**

| Variants            | 1 record: bushiness phase | 2 record: milky-waxy ripeness phase |
|---------------------|---------------------------|------------------------------------|
|                     | distribution, % | development index, % | biological efficiency, % | distribution, % | development index, % | biological efficiency, % |
| Control             | 36          | 11.2                  | -                      | 100         | 41                      | -                      |
| Microwave treatment | 26          | 7.0                   | 27.7                   | 86          | 24.5                    | 40.2                   |
| Dividend Star       | 26          | 6.8                   | 27.7                   | 96          | 27.5                    | 32.9                   |

The disease development index varied from 6.8% after the Dividend Star protectant to 11.2% in control. Microwave treatment provided 7.0% of the disease development. Biological efficiency was in the range of 27.7% in both cases.

By the second recording, the disease was still observed on each plant studied in the control version. The disease development index increased by more than 3 times and was in the range from 24.5% after microwave treatment to 41.0% in control, in the variant with a Dividend Star was 27.5%. Despite this, the biological efficiency increased in both variants, it was 40.2% with microwave treatment, and 32.9% with the Dividend Star protectant.

**Table 4. Influence of treatment options on disease infection of basal leaves.**

| Variants            | Septoria spot | Brown patch |
|---------------------|---------------|-------------|
|                     | distribution, % | development index, % | biological efficiency, % | distribution, % | development index, % | biological efficiency, % |
| Control             | 99            | 78          | -                      | 93          | 71                      | -                      |
| Microwave treatment | 90            | 64          | 17.9                   | 85          | 63                      | 11.3                   |
Analyzing table 4, we can conclude that Dividend Star had a higher efficiency in protecting against Septoria spot and Brown patch compared to microwave treatment. The biological efficiency was higher by 1.3 and 8.4%, respectively.

**Table 5.** Influence of treatment options on the spread and development of diseases (milk ripeness phase) (DI – development index, BE – biological efficiency).

| Experimental variants | Flag leaf | Ear |
|------------------------|-----------|-----|
| Control | Microwave treatment | Dividend Star | Control | Microwave treatment | Dividend Star |
| DI | DI | BE | DI | BE | DI | DI | BE | DI | BE |
| Fusarium disease | - | - | - | - | 20.0 | 0 | 100.0 | 10.0 | 50.0 |
| Helminthosporiosis | - | - | - | - | 5.0 | 0 | 100.0 | 2.5 | 50.0 |
| Alternaria disease | - | - | - | - | 10.0 | 0 | 100.0 | 0 | 100.0 |
| Septoria spot | 59.0 | 39.0 | 33.9 | 44.0 | 25.4 | 52.0 | 47.5 | 13.5 | 42.5 | 13.5 |
| Brown patch | 38.0 | 36.0 | 5.3 | 39.0 | - | - | - | - | - | - |

**Figure 2.** Ear of Novosibirskaya 15 wheat variety (a – control, b – microwave treatment, c – Dividend Star).
Options for processing wheat seeds had an ambiguous effect on the elements of the yield structure. Both positive and negative effects were observed on the following elements of the structure: the number of plants per square meter, plant height, ear length, productive bushiness, water content of the ear and plant, the mass of 1000 grains compared to the control, which allowed to form a yield of 38.1 C/ha for microwave processing, against 35.2 C/ha for the control, and 36.3 C/ha in the variant with the Dividend Star protectant. A lower yield of 4.7 C/ha, compared to microwave processing, was formed by wheat processed by Dividend Star, due to the lower productive stem stand (by 10.4%), the less productive bushiness (by 31.2%), the grain content of the plant (by 31.5%) and the mass of 1000 grains (by 3.8%) (table 6).

| Indicator                  | Variant                  |
|----------------------------|--------------------------|
| Number of plants, pcs/m²   | Article II.              |
| Article V. Plant height, cm | Article VI.              |
| Article IX. Productive bushiness, pcs | Article X. |
| Article XIII. Ear length, cm | Article XIV.             |
| The number of grains per ear, pcs | Article XVII.            |
| Article XXI. Plant grain content, pcs | Article XXII.            |
| Article XXV. Weight of 1000 grains, g | Article XXVII.           |
| Article XXIX. Biological yield, C/ha | Article XXIII.          |
| Article XXXIII. Actual yield, C/ha | Article XXXIV.           |
| Article XXXVII. HCP 05     | Article XXXVIII. 0.5r    |

| Variant                  | Yield, C/ha | Preserved yield, C/ha | Economic efficiency, % |
|--------------------------|-------------|-----------------------|------------------------|
| Control                  | 35.2        | -                     | -                      |
| Microwave treatment      | 38.1        | 2.9                   | 108.2                  |
| Dividend Star            | 36.3        | 1.1                   | 103.1                  |
| HCP 05                   |             | 1.5                   |                        |

The use of microwave treatment allowed to obtain an increase in the wheat yield of 2.9 C/ha and in the variant with the fungicide Dividend Star of 1.1 C/ha compared to the control. Economic efficiency was 8.2 and 3.1%, respectively (table 7).

| Variant                  | Yield, C/ha | Preserved yield, C/ha | Economic efficiency, % |
|--------------------------|-------------|-----------------------|------------------------|
| Control                  | 35.2        | -                     | -                      |
| Microwave treatment      | 38.1        | 2.9                   | 108.2                  |
| Dividend Star            | 36.3        | 1.1                   | 103.1                  |
| HCP 05                   |             | 1.5                   |                        |

4. Conclusions
The electromagnetic field of super-high frequency in the research allowed to reduce the infection with root rot pathogens to the threshold of harmfulness, while preserving wheat sowing qualities. The most
effective option for microwave treatment was the variant with a heating speed of 0.6 °C/s and an exposure of 60 seconds.

In the field conditions, EMFSHF has a positive effect on the formation of the main elements of the yield structure, the actual yield, and also showed a significant reduction in infection and increased germination of spring wheat seeds.

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