Development of agrotechnology of spring wheat using an environmentally safe method of disinfection and biostimulation of seeds

V N Romanov¹, N S Kozulina¹, A V Vasilenko* and A A Vasilenko²

¹ Krasnoyarsk scientific-research institute of agriculture – separate subdivision of FRC KSC SB RAS, 66, Svobodnny Avenue, Krasnoyarsk, 660041, Russian Federation
² FSBEI HE Krasnoyarsk State Agrarian University, 90, Mira Avenue, Krasnoyarsk, 660049, Russian Federation

*E-mail: WasilenkoAV@ya.ru

Abstract. The article presents the results of the development of agrotechnology of spring wheat using an environmentally safe method of disinfection and biostimulation of seeds, the impact on field germination and reduction of infection with the most harmful microorganisms. The analysis of the obtained results shows that the use of a physical method of seed treatment effectively affected the reduction of infection of wheat grain with pathogens of phytopathogenic microflora to the established thresholds of harmfulness.

1. Introduction
At the present stage in the practice of agricultural production, one of the most urgent is the problem of effective recovery of seeds and protection of plants from diseases that are transmitted with their help. In Siberia, according to V. A. Chulkina, 75% of fungal and 80% bacterial phytopathogens are transmitted through seed and planting material [1,2]. Plants grown from such seeds are characterized by weak resistance to soil and aerogenic infections. Sowing infected seeds, along with creating and maintaining foci of infection in crops, significantly increases the manifestation of diseases that are infected by the soil and infected plant residues.

In the Krasnoyarsk region, damage from root rot has significantly increased; however, in recent years, along with the traditional pathogens of this disease (Bipolaris and Fusarium species), Alternaria has an equal position. The share of fungi from Alternaria in the pathogenic complex of pathogens increased from 14-18 to 30-33%. An increase in the intensity and frequency of Fusarium outbreaks in spring wheat is also a serious threat, primarily because, along with Fusarium root rot, in the last 4-5 years, one of the most dangerous forms of the disease (ear and grain Fusarium) has been observed in the main grain-growing areas. Local epiphytotics of Fusarium-Alternaria infection may well contribute to contamination of grain and its processed products with phytotoxins that are dangerous to human and animal health and life [3].

Taking into consideration that large areas of the region occur every year epiphytoties outbreaks of leafstalks (airborne) infections, smut diseases and other harmful objects, and the volume of protective measures is far from required, it becomes apparent urgency of development of special technologies, using complex approach to the protection of crops [4,5].
In solving the current situation, on the one hand, phytosanitary, on the other – economic, the main role is not without reason assigned to the pre-sowing preparation of seeds for sowing.

Most of the territory of the region is located in conditions of weak self-cleaning ability of the soil and surface layers of the atmosphere, it becomes obvious the importance of choosing from among the existing methods that can meet the requirements of both high efficiency and bioecological safety [6,7].

Such functions can be performed by the method of seed healing in an ultra-high frequency electromagnetic field. Against the background of one hundred percent contamination of seeds in the region, the developed technology of microwave disinfection of spring wheat seeds, due to its effectiveness and environmental friendliness, is relevant [8,9].

The aim of the research is to develop agrotechnology of spring wheat using an environmentally safe method of disinfection and biostimulation of seeds for the forest-steppe economic zone of the Krasnoyarsk region.

2. Research results
The tests were carried out in the “Minderlinskoe” agricultural farm, in the experimental fields of the Krasnoyarsk State Agrarian University. The soil cover is represented by leached Chernozem, heavy loam, humus content of 7.1%. The experiment is based on dump (generally accepted for the zone) plowing, minimal processing, direct sowing on the stubble of the previous crop. Two varieties of wheat most common and widely used in the Krasnoyarsk region were selected for sowing (Novosibirskaya 15 and Memory of Vavenkov).

Experience scheme:
- Control, no special features;
- Microwave treatment (P_{relative} - 650 W / dm^3; \tau - 60 sec);
- Microwave treatment (P_{relative} - 650 W / dm^3; \tau - 60 sec; microelements).

The seed treatment mode is selected from the results of previous experiments. In the 3rd variant, microelements were added to the grain processing by the microwave method according to the materials set out in the recommendations for intensifying the thermal processes of preparing seeds for sowing with RF and microwave energy [9,10]. The experience was planned in 4-fold iterations. The sowing was done by the AGROMASTER seeder, and the yield was taken into account by the Sampo combine. Square plots 0,0038 hectares, number of plots – 72, the area of the plots to account for the harvest of 10 m^2, accommodation plots not randomized, seeding rate is 4.5 million germinating grains per hectare. Records and observations included:
- the beginning of phenological phases of wheat development;
- the plant density of wheat was determined in the phase of germination (3 sheets);
- the spread and development of diseases were taken into account in the terms established by standard techniques, evaluation in accordance with scales (in points), recommended by All-Russian Research Institute of Plant Protection of Ministry of Agriculture of Russia. Phytoexamination of seeds was taken into account using the method of wet chambers according to GOST 12044-93[11]. Sampling for analysis was according to GOST 12037-88 [12]
- the actual yield in bunker weight was taken into account for each option in 4-fold replication. First, the yield of pure grain was determined at the actual harvest moisture content, then it was brought to a standard 14% moisture content and 100% purity.

3. Research results
Surveys conducted in the phase of full shoots, showed that in the embodiment of microwave processing of seeds of wheat varieties Novosibirskaya 15 and Memory of Vavenkov stand density was at the level with the control variant, the variant with the addition of micronutrients germination below the control on all the backgrounds of soil tillage. This is due to adverse weather conditions. First, relatively low
temperatures and sufficient humidity contributed to the accumulation of infectious origin in the soil, and its further increase. Secondly, it can be assumed that for the above reason, the microelements did not work in full force (table 1).

The development and spread of root rot were influenced not only by the type of soil treatment, but also by the method of seed treatment (table 2). For example, the value of the disease spread in the control variant has the highest value at zero tillage (90-100%), and the minimum value at plowing (53-60%). In the variant with microwave treatment, the highest value is obtained with minimal tillage (54.5-56.8%), and the minimum value is also obtained with plowing (41.5-43.3%). A similar situation is observed in the variant with microwave treatment + trace elements, but the infection rate in this case is lower from 2 to 21% than in the variant with microwave treatment and from 2.3 to 66% in the control. The use of different wheat varieties did not affect the considered indicators, since the value of the development and spread index of the disease for the Novosibirskaya 15 variety is almost equal to the values of the development and spread index of the Memory of Vavenkov variety within 10%. Along with this, there is a significant difference in the analysis of tillering coefficient values. In this case, the highest value was obtained for the Memory of Vavenkov variety in comparison with the Novosibirskaya 15 variety, depending on the type of tillage, on average up to 30%.

Analyzing the data presented in table 3, we can conclude that there is no definite dependence of plant damage by intra-stem pests on the treatment option. The only thing that can be noted is that the plant's

---

**Table 1.** Field germination depending on processing options.

| Backgrounds          | Novosibirskaya 15 | Memory of Vavenkov | Microwaves + micro-elements |
|----------------------|-------------------|--------------------|-----------------------------|
|                      | Control           | Microwave          |                             |
| Plowing              | 422               | 430                | 275                         |
| Minimal plowing      | 449               | 403                | 335                         |
| No plowing           | 388               | 358                | 301                         |
|                      | 408               | 416                | 343                         |
|                      | 261               | 300                | 282                         |

**Table 2.** Registration of root rot in the tillering phase.

| №   | Variants          | Root rot (no processing) | Microwave | Microwave + micro-elements |
|-----|-------------------|--------------------------|-----------|-----------------------------|
|     |                   | D. %                     | D.D.I. %  | B.E. %                      | D. %                     | D.D.I. %  | B.E. %                      | D. %                     | D.D.I. %  | B.E. %                      |
|     |                   | B.E. %                   | B.E. %    | Tilling coefficient         | B.E. %                   | Tilling coefficient         | B.E. %                   | Tilling coefficient         | B.E. %                   | Tilling coefficient         |
| 1   | Plowing           | 53.0                     | 15.3      | 1.0                         | 31.0                     | 14.5                    | 1.2                         | 30.0                     | 13.0                    | 1.0                         |
|     |                   |                          |           |                             |                          |                        |                             |                          |                        |                             |
| 2   | Minimum plowing   | -39.8                    | -46.4     | 0.7                         | 40.0                     | 21.0                    | 0.9                         | 23.0                     | 16.1                    | 0.6                         |
|     |                   | -5.7                     | -5.7      | 0.4                         | 48.0                     | 25.0                    | 0.5                         | 34.0                     | 20.2                    | 0.6                         |
| 3   | No plowing        | -47.0                    | -57.3     | 0.4                         | 52.0                     | 30.2                    | 0.5                         | 66.0                     | 43.6                    | 0.6                         |
| 4   | Plowing           | 60.0                     | 17.5      | 1.0                         | 34.0                     | 16.5                    | 1.2                         | 32.0                     | 8.5                     | 1.3                         |
| 5   | Minimum plowing   | -35.0                    | -40.0     | 1.0                         | 35.0                     | 20.0                    | 0.7                         | 29.0                     | 6.8                     | 1.1                         |
| 6   | No plowing        | -50.0                    | -50.0     | 0.6                         | 50.0                     | 29.4                    | 0.8                         | 66.7                     | 75.7                    | 1.0                         |
appendage stems were mainly affected by the cereal fly from 8 to 27% and to a lesser extent by the stem flea 0.3-4%. There was a single minor lesion of the main stem, but only with minimal plowing.

**Table 3. Damage to spring wheat by intra-stem pests.**

| №  | Variants         | Control (no processing) | Microwave | Microwave + micro-elements |
|----|------------------|-------------------------|-----------|----------------------------|
|    |                  | Main stem               | Lateral   | Main stem                  | Lateral   |
|    |                  | cereal fly, pcs         | stem flea, pcs | cereal fly, pcs       | stem flea, pcs |
| 1  | Plowing          | 0                       | 0         | 20                       | 0         |
| 2  | Minimum plowing  | 0                       | 0         | 18                       | 0         |
| 3  | No plowing       | 0                       | 0         | 18                       | 0         |

|    |                  | Main stem               | Lateral   | Main stem                  | Lateral   |
|    |                  | cereal fly, pcs         | stem flea, pcs | cereal fly, pcs       | stem flea, pcs |
|    | Novosibirskaya 15| 0                       | 0         | 18                       | 0         |
|    |                  | 0                       | 0         | 22                       | 0         |
|    |                  | 0                       | 0         | 10                       | 0         |
|    |                  | 0                       | 0         | 26                       | 0         |

|    |                  | Main stem               | Lateral   | Main stem                  | Lateral   |
|    |                  | cereal fly, pcs         | stem flea, pcs | cereal fly, pcs       | stem flea, pcs |
|    | Memory of Vavenkov| 0,3                     | 20        | 0                        | 0         |
|    |                  | 0                       | 0         | 12                       | 0,3       |
|    |                  | 0                       | 0         | 13                       | 0         |
|    |                  | 0                       | 0         | 11                       | 0         |

The effect of seed treatment options on the infestation of spring wheat with leaf-stem diseases is shown (table 4) that the control variant is affected, although to varying degrees, but all types of leaf-stem diseases, regardless of the wheat variety and type of tillage. In the remaining variants, the infection of plants with rust and brown spots was not observed. The lowest infection rate was observed in the variant with the treatment of seeds with microwave energy and microelements both in the case of the Novosibirskaya 15 variety and in the Memory of Vavenkov variety.

Under the current conditions, pathogens of Septoria were also detected among the pathogenic microflora of wheat. Spica Septoria is transmitted with seeds and can persist on the remains of diseased plants. The fungus does not live in the soil, where its development is suppressed by antagonists. The disease is caused by imperfect fungi of the genus Septoria, which is part of the order Pycnidiales.

A feature of representatives of this order is that conidia are formed in pycnidia and come out only when they swell. A common symptom of the disease, in this regard, is the formation of the pathogen pycnidia on the affected parts of the plant, in the form of tubercles or black dots, especially on sparse crops, where ultraviolet rays freely penetrate. Septoria tritici (leaf form of the pathogen) is observed among other types of fungi that cause wheat septoria. The frequency of occurrence of the pathogen is about the same as that of Septoria nodorum, and in most years they are observed in crops in a complex, are ubiquitous and quite often - strong development, especially against the background of the use of intensive technologies for growing spring wheat. Wheat Septoria is manifested on all aboveground plant organs, starting from seedlings (Septoria nodorum), and Septoria tritici joins it mainly at the heading phase.

In the Krasnoyarsk region the disease is observed everywhere and, with an early manifestation, causes a significant decrease in yield (table 4).

A general tendency is observed in the studied wheat varieties with regard to the infection of the spica with Septoria. The highest biological efficiency is observed in the “Microwave + microelements” option. It is not significant, but it is higher than the biological efficiency in the variant with microwave treatment by an average of 8%, except for zero tillage. In this case, the situation is the opposite, and the biological efficiency of microwave treatment is 2% higher than the biological efficiency of the “Microwave + microelements” option. The values of the development and the index of the spread of the disease in the
control variants have greater values than in the studied variants, regardless of the wheat variety and reach 100%.

**Table 4. Infection of a spica of spring wheat with Septoria.**

| №  | Variants       | Spica Septoria Plowing | Minimum plowing | No plowing |
|----|----------------|------------------------|-----------------|------------|
|    |                |                        | D. B.E. %        | D. B.E. %  | D. B.E. %  | D. B.E. %  |
|    |                |                        |                |            |            |            |
|    |                |                        | D.D.I. %        | D.D.I. %   | D.D.I. %   | D.D.I. %   |
|    |                |                        |                |            |            |            |
|    | Novosibirskaya 15 |                        |                |            |            |            |
| 1  | Control        | 98.0                   | 42.5            | 100.0      | 44.5       | 100.0      |
|    |                |                        | -2.0            | 1.0        | -2.0       | -15.0      |
| 2  | Microwave      | 44.0                   | 12.0            | 46.0       | 11.5       | 54.0       |
|    |                |                        | 54.0            | 74.2       | 46.0       | 73.0       |
| 3  | Microwave + micro-elements | 42.0                  | 10.5            | 28.0       | 7.5        | 56.0       |
|    |                |                        | 72.0            | 83.1       | 44.0       | 72.0       |

|    | Memory of Vavenkov |                        |                |            |            |            |
|    |                |                        |                |            |            |            |
|    | Novosibirskaya 15 |                        |                |            |            |            |
| 1  | Control        | 100.0                  | 50.0            | 100.0      | 59.5       | 100.0      |
|    |                |                        | 0               | -16.0      | 0          | -27.0      |
| 2  | Microwave      | 40.0                   | 10.0            | 46.0       | 11.5       | 50.0       |
|    |                |                        | 60.0            | 54.0       | 80.7       | 50.0       |
| 3  | Microwave + micro-elements | 34.0                  | 8.5             | 36.0       | 9.0        | 46.0       |
|    |                |                        | 66.0            | 83.0       | 54.0       | 83.2       |

The influence of seed treatment variants on the infection of spring wheat with root rot in the wax ripeness phase is presented in table 6, the spread of root rot in the control variant is 100%, and the index of disease development on the plant is in the range of 40 - 52%, and the data are comparable as in the Novosibirskaya 15 variety and in the Memory of Vavenkov variety. Seed treatment with microwave energy and microelements can significantly reduce plant contamination. So, for example, the maximum biological efficiency according to the disease development index was 53% in the variant "Microwave + microelements" with the Memory of Vavenkov variety on plowing, the minimum - 33.3% in the same variant, but with minimal tillage. The biological effectiveness of the spread of the disease for all variants is within 7 - 31%.

**Table 5. Registration of root rot in the phase of wax ripeness.**

| №  | Variants  | Root rot | Root rot B.E., % | Root rot B.E., % |
|----|-----------|----------|------------------|------------------|
|    |           | D. %     | D.D.I. %         | D. %             | D.D.I. %         |
|    |           |          |                  |                  |                  |
|    | Novosibirskaya 15 |          |                  |                  |                  |
| 1  | Plowing   | 100      | 49.2             | 75.0             | 25.0             |
|    |           |          |                  |                  | 77.0             | 25.7             |
| 2  | Minimum plowing | 100     | 43.3             | 79.0             | 26.7             |
|    |           |          |                  |                  | 80.0             | 26.7             |
| 3  | No plowing | 100      | 51.0             | 89.0             | 30.0             |
|    |           |          |                  |                  | 93.0             | 31.0             |

|    | Memory of Vavenkov |          |                  |                  |                  |
| 4  | Plowing   | 100      | 48.8             | 70.0             | 23.3             |
|    |           |          |                  |                  | 69.0             | 23.0             |
| 5  | Minimum plowing | 100     | 40.5             | 74.0             | 24.7             |
|    |           |          |                  |                  | 81.0             | 27.0             |
| 6  | No plowing | 100      | 52.0             | 86.0             | 30.2             |
|    |           |          |                  |                  | 89.0             | 29.7             |

The effect of seed treatment options on the yield of spring wheat plants is shown in table 6.
Table 6. Spring wheat yield.

| N  | Variants          | Control (no processing) | Microwave | Microwave + micro-elements |
|----|-------------------|-------------------------|-----------|---------------------------|
| 1  | Plowing           | 19.0                    | 16.7      | 15.4                      |
| 2  | Minimum plowing   | 17.7                    | 16.6      | 16.8                      |
| 3  | No plowing        | 9.4                     | 13.2      | 10.9                      |

Novosibirskaya 15

Memory of Vavenkov

| N  | Variants          | Code                  | Yield     |
|----|-------------------|-----------------------|-----------|
| 4  | Plowing           | 13.5                  | 15.0      | 12.3                      |
| 5  | Minimum plowing   | 17.3                  | 19.9      | 20.4                      |
| 6  | No plowing        | 15.0                  | 15.0      | 18.8                      |

Analyzing the data presented in table 7, we can conclude that there is no certain dependence of the yield value on the type of tillage and wheat variety. All values are approximately at the same level within the error range. If you compare the yield values in the treatment options with the control, the biological efficiency has both negative and positive values. The maximum yield increase relative to the control was 3.8 C / ha on wheat of the Memory of Vavenkov variety when processed in microwave electromagnetic field with microelements and direct sowing.

4. Conclusion

Analyzing the above material, we can conclude that the treatment of wheat seeds with the microwave and electromagnetic field with the addition of Vita Mix NPK fertilizer with microelements has not only a stimulating, but also a decontaminating effect, which is higher compared to the control version. In some cases, the data were obtained at the level of the control variant, due to the prevailing weather conditions and the rate of development of plants (passing through their development phases), which was observed earlier. Thus, this method of seed treatment in the current growing season has not shown sufficient effectiveness. In the following years, a more in-depth study of the task is planned.

References

[1] Chulkina V A, Toropova E Yu and Stetsov G Ya 2007 *Ecological Foundations of Integrated Plant Protection* Sokolov M S and Chulkina V A ed. (Moscow: Kolos) p 568

[2] Tsuglenok N V, Tsuglenok G I and Khalanskaya A P 2003 *System of Protection of Grain and Leguminous Crops from Seed Infections* (Krasnoyarsk: Krasnoyarsk State Agrarian University) p 243

[3] Kozulina N S, Vasilenko A A, Vasilenko A V and Shmeleva Zh N 2020 Toxin-forming properties of Siberian isolates of the genus Fusarium fungi *IOP Conf. Series: Earth and Environmental Science* **548** 042020 https://doi.org/10.1088/1755-1315/548/4/042020

[4] Khalanskaya A P and Nikolaeva O A 1989 Leaf-stem Diseases of Spring Wheat and Measures to Protect them with Intensive Technology in the Forest-steppe Zone of the Krasnoyarsk Region Territory *Intensive technologies* 32-6

[5] Kozulina N S, Vasilenko A A and Shmeleva Zh N 2019 The development of the environmentally safe method for disinfection and biostimulation of spring wheat seeds using electromagnetic field of super-high frequency *IOP Conf. Ser.: Earth Environ. Sci.* **315** 022047 https://doi.org/10.1088/1755-1315/315/2/022051

[6] Kozulina N S and Vasilenko A A 2019 Influence of pre-sowing treatment of barley seeds in an electromagnetic field of ultra-high frequency on its productivity in the field *Resource-saving technologies of agriculture* **11** 70-3

[7] Kozulina N S and Vasilenko A A 2020 The effectiveness of the modes of the super-high frequency electromagnetic field on the viability and infection of the second-generation barley seeds *IOP Conf. Ser.: Earth Environ. Sci.* **421** 042009 https://doi.org/10.1088/1755-
1315/421/4/042009

[8] Bastron A V, Vasilenko A A , Zapletina A V, Zubova R A and Gorelov M V 2017 Treatment of seeds with microwave energy *Rural Mechanic* **264** 33-5

[9] Kozulina N S, Vasilenko A A, Vasilenko A V and Shmeleva Zh N 2020 Substantiation of the ecological method application for disinfection and biostimulation of spring wheat seeds in the Krasnoyarsk territory forest-steppe zone *IOP Conf. Series: Earth and Environmental Science* **548** 052034 https://doi:10.1088/1755-1315/548/5/052034

[10] Vasilenko A A, Emelyanov A A and Bastron A V 2007 Device for heat treatment of bulk dielectric materials *Agrarian Science at the Turn of the Century: Proceedings of regional Scientific-practical Conf.* **2** 1656

[11] GOST-12044-93 Agricultural seeds Methods for determining the incidence of diseases

[12] GOST 10968-88 CORN Methods for determining energy and germination ability