Flexibile technology of protectants for grain seeds

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Abstract. The chemicalization of agriculture is an important component of an integrated plant protection system to obtain stably high crop yields and provide food products to the rapidly growing population of the Earth. Seed dressing with fungicides is a determining element in the plant protection system, and systemic drugs give the best effect. The absence of such protection of cultivated plants can lead to a decrease in wheat productivity by more than 20% due to the development of Fisararium and Helminthosporious infection. At the same time, indicators such as protein content can decrease by 10.0%, and gluten - by 8-10%. Therefore, it is very important to develop the scientific basis for the preparation of complex preparations with a low consumption rate of the active substance and the inclusion of biological products, including plant growth regulators, which enhance the growth processes and yield of the main crop. In recent years, areas for the modification of known and practiced fungicides using various methods, including methods of mechanochemistry, are promising. At the same time, high permeability of active substances is achieved both due to auxiliary substances (in particular, polysaccharides), which increase the solubility of drugs, and by adding surfactants and other formative components to the formulations. The review of the literature on the development of alternative preparative forms of fungicidal preparations based on triazole derivatives and known fungicides, as well as their biological activity, is presented.

1. Introduction

Seeds are a major and vital contribution to sustainable agricultural growth, as more than 90% of food crops are grown from seeds [1]. One of the important stages in the technology of grain production is the protection of crops from diseases and pests, and therefore research on the development of complex preparations for plant protection is very relevant, the initial stage of which is the preparation of seeds for sowing. It can be carried out by various methods - physical, chemical or biological, which are used not only for seed disinfection, but also make it possible to control diseases and pests during germination, emergence of young plants and early plant growth [2].

Seed processing has played and still plays a key role in sustainable crop production, helping to preserve the productivity of various crops. Pesticide seed treatment is one of the most environmentally friendly ways to use chemicals. When seed is treated, pesticides are applied using highly effective technology only where they are really needed.

Seed dressing with fungicides is a defining element in a plant protection system, and systemic drugs are best used [3]. Such promising drugs include triazole derivatives, which, propagating through the
intercellular space, simultaneously inhibit sterol biosynthesis in cell membranes, inhibiting the reproduction of fungi and destroying conidia and spores of parasitic fungi in the initial phase of their development, as well as when spores are found on the surface of seeds [4]. But, on the other hand, triazole fungicides, when they process grain seeds, affect the growth and development of seedlings, reducing the length of coleoptile, first leaf and internodes, and also affect the development of the root system, reducing the number of primary roots, etc. [5,6]. Therefore, it is very important to use innovative fungicidal compositions, the peculiarity of which is the growth-promoting effect on plants and high efficiency against seed infections. They combine these qualities due to the complex composition and well-selected combinatorics of active substances belonging to different chemical classes and differently acting in different directions. Work on the use of combined preparations with multifaceted fungicidal activity is known in this direction [7]. Among them, fluorinated fungicides, including those from the class of triazoles (flutriafol), as well as preparations based on them with the addition of known fungicides in various combinations, are very promising. Currently, two, three, and even four-component fungicidal compositions are used for seed treatment of grain crops [8].

The purpose of the work is a brief review of studies on the development of innovative complex dressing agents based on triazoles (tebuconazole and prothioconazole) and their combination with known fungicides (imazalil, prochloraz, metalaxyl), as well as an assessment of their growth and biological activity on spring wheat seed.

2. Materials and methods

2.1. Active substances of the studied fungicides

The active substances (AS) of some triazoles (tebuconazole, prothioconazole) and the well-known fungicides imazalil, prochloraz, and metalaxyl were selected as objects of study.

Tebuconazole (TBC) 

**Tebuconazole** (TBC) - [f(RS) - (p-chlorophenyl)-4,4-dimethyl-3- (IH-1,2,4-triazol-1-yl-methyl) pentan-3-yl] is an effective systemic fungicide for seed treatment. Solubility of TBC in water is 36 mg/l (http://rupest.ru/ppdb/tebuconazole.html). TBC belongs to triazoles of the third generation. It has a wide range of systemic effects. It has a protective, healing and eradicating effect. It quickly penetrates the tissues of the plant and is evenly distributed in them. Suppresses ergosterol synthesis by inhibiting demethylation at position C-14. The resulting sterols, in turn, act on metabolism, which is the difference between tebuconazole and other triazoles.

Prothioconazole (PTC) 

**Prothioconazole** (PTC) [2 -(RS) -2-hydroxy-2- (1-chlorocyclopropyl)-3-(2-chlorophenyl) propyl]-2H-1,2,4-triazole-3 (4H) -thione] - systemic fungicide, has a protective, healing and eradicating effect. Solubility of PTC in water is 300 mg/l (http://rupest.ru/ppdb/prothioconazole.html). It is used for the treatment of vegetative plants with pathogens of various diseases and for the dressing of grain. In a plant, it is metabolized to a more stable compound - prothioconazole-destio. It affects the formation of powerful seedlings with a well-developed root system, increasing bushiness and quality indicators of the harvested crop. An increase in bushiness in the first weeks of plant growth by 25-35% increases drought tolerance, improves the consumption of nutrients and moisture, which increases the tillering factor by 1.5 times. Twice the increase in shoot thickness makes the plant more resistant to mechanical damage, and the absence of mesocotyl, the most vulnerable part of the shoot for insects and pathogenic microorganisms, provides reliable protection of the crop from many types of diseases and harmful insects at the initial stages of its growth [9].

Imazalil (IMZ) - [(±)-1- (β-allyloxy-2,4-dichlorophenylethyl) imidazole] is a systemic fungicide of the imidazole class. Water solubility of IMZ is 184 mg/l (http://rupest.ru/ppdb/imazalil.html). IMZ is stable to hydrolysis in alkalis and dilute acids in the absence of light, moderately hazardous. The substance inhibits sterol biosynthesis in cell membranes of phytopathogens, inhibiting demethylation at position 14 of lanosterol or 24 met hydroxylated lanosterol.

Metalaxyl (MAL) - [N-(2,6-dimethylphenyl) - N-(2-methoxyacetyl) alanine methyl ester] - a pesticide, a systemic fungicide from the class of phenylamides, a group of oxazolidinones, is effective against pathogenic organisms belonging to the order Peronosporales. Solubility of MAL in
water is 7100 mg / L (http://rupest.ru/ppdb/metalaxyl.html). MAL is stable in acidic and neutral environments, soluble in most organic solvents.

Prochloraz (PCR) - \([N\text{-propyl-N-}[2-(2,4,6-trichlorophenoxy) ethyl] imidazole-1-carboxamide]\) is a contact and systemic fungicide of the imidazole class with a protective and eradicating effect. Solubility of PCR in water is 34.4 mg / L (http://rupest.ru/ppdb/prochloraz.html). PCR is used against a wide range of diseases. It inhibits spike fusarium by 50% when processed after the onset of signs of the disease. With 2-fold treatment, it is effective against ascites and gray rot. It penetrates into all parts of the plant and remains active for up to 4 weeks. Golden brown liquid. It hardens upon cooling and forms complexes with ions of a number of metals. At pH = 5-7 (22 °C) it does not decompose within 30 days. At a dose of 12 mg / kg, it significantly inhibits the processes of ammonification in the soil.

2.2. Solubility of fungicides’ AS and methods for increasing their solubility
The fungicides selected by us for the study, like most of the biologically active substances used in practice, belong to the class of poorly or insoluble in water and physiologically active media [10], which involves the use of overestimated doses of AS and thereby leads to higher prices the drug and increases its environmental toxicity. Various methods are known to increase the solubility of poorly soluble medicinal substances, including physical, physicochemical, etc. [11].

It is known a method for mechanochemical modification of poorly soluble drugs by the joint mechanical treatment of their substances with water-soluble polymers [12]. The resulting solid dispersions (SD) had not only increased solubility in water but, increasing anthelmintic activity for several benzimidazole drugs (such as carbendazim, albendazole, fenbendazole, triclabendazole etc.). By spreading this method to increase the solubility of poorly soluble fungicides’ AS, we developed a way to obtain SD from AS of fungicides and water-soluble polymers. By joint mechanical treatment of TBC with some polysaccharides were prepared SD which had increased solubility in water and were of interest as innovative fungicidal preparations [13]. Based on such positive results this method was used to create innovative protectants based on selected fungicides.

2.3. Method of solid-phase synthesis of innovative preparations
Mechanochemical modification of the selected fungicides was carried out based on joint mechanical treatment of fungicide’ AS and polymers inside of metal drum of ball mill LE-101 (made of Hungary) [12]. To determine the solubility taken SD was used the method of HPLC analysis, which confirmed the increasing of solubility of the etchants by 10 or more times [14].

2.4. Formalations and their role in increasing the efficacy of preparations
It is known that the formulation procedure of pesticides plays an important role in the manifestation of its biologic activity and therefore different preparations (or rather, preparative forms) with the same AS can differ in efficacy [15]. Innovative formulations include, for example, microemulsions (ME) and concentrates of colloidal solutions (CCS), which, compared to traditional forms (WP, CE, SC), have higher biological activity, since the dispersion of organic matter reaches 0.005-0.1 μm, because 50-1000 times less than in traditional forms (2-5 microns).

Seed dressers are produced in the form of suspension concentrates (SC), which contain adhesives in their composition, which allow to keep AS on the surface of the seed (grains). But in recent years, forms in the form of oil emulsions (EOC) have been more attractive as dressing agents, which provide the maximum penetration of AS into the seed due to the solubilization of AS within the microemulsion droplet [16].

Preparative forms (or formulations) are constantly being improved [17], which affects the biochemical and physiological functions of plants, causing both retardant and stimulating effects [18]. The high permeability of active substances is provided by the addition of surfactants to the preparative forms of fungicides, and combinations with broad-spectrum adaptogens help to relieve the pesticidal load on plants, soil, and manifest an immunoprotective effect. The use of such innovative fungicide
compositions reduces the infectious load of both root rot pathogens (*Bipolaris sorokiniana* Sacc. Shoemaker, *Fusarium* spp., and *Alternaria* spp. and *Penicillium* spp.) by 67-76%, increase in energy and germination by 3-6%, productivity - by 10.4-33.7% [19].

Increasing the efficiency of seed dressing in order to prevent the formation of fungicide resistance in pathogens is realized through the use of combined preparations with multifaceted fungicidal activity. The study and comparative evaluation of the effectiveness of their use in various preparative forms allows us to identify forms with the highest biological activity, increased solubility, adherence, contact-systemic action, and the least toxic load, which is an urgent task in increasing the productivity of grain agrocenoses.

3. Results and discussion
Modern agricultural production aimed at providing humanity with safe and high-quality products cannot be imagined without the use of innovative drugs (chemical and biological plant protection products) for high yields, their conservation and rational use [20]. In this regard, an important task is the creation and improvement of preparations for plant protection, in particular seed dressers, as well as methods for their use, since they play an important role in the formation of crop yields.

3.1. Features of mechanochemical modification of fungicides
There are two ways to create new chemical plant protection products. The first is the search for new AS, the second is the development of preparative forms of known active substances that allow the most complete use of their target properties [21]. At the same time, many underestimate the importance of the preparative form of the pesticide, while modern studies have shown that innovative formulations, compared with traditional ones, can provide higher biological efficacy of drugs with the same active substance. In addition, they allow you to reduce the rate of application for AS and reduce the pesticidal load on agrocenosis.

An analysis of the modern studies described above in the field of creating highly effective agricultural preparations indicates the promise of obtaining finely dispersed systems, in particular, systems with nanosized particles, for which solutions are offered in the form of a wide range of formulations, including based on TBC. The attempts to obtain nanodispersed powder of TBC during its individual grinding in the AGO-2 planetary centrifugal mill did not give the expected result, because when grinding the powdered substance TBC, an equilibrium occurs between the processes of grinding and adhesion of finely dispersed particles [22]. With the joint grinding of the TBC substance with polymers, it was possible to obtain nanostructured powders by incorporating tebuconazole nanoparticles into the polymer matrix (e.g., arabinogalactan, kelp, and other polysaccharides).

3.1.1. Obtaining compositions of TBC with arabinogalactan by method of mechanochemical modification. With the joint mechanical treatment of TBC with polymers, including polysaccharides such as AG and HES, it was possible to increase the water solubility of the preparations by a factor of ten. Such a significant increase in the solubility index was explained by the formation of supramolecular complexes with high fungicidal activity [13]. This technology to improve the solubility of poorly soluble substances was also used for other fungicides by their solid-phase mechanochemical modification with water-soluble polymers [14]. Thus, in the joint mechanical treatment of TBC with AG and powder saponin (*Sapindus trifoliates*), a free-flowing powder was obtained, which is a composition of the TBC: AG: surfactant (was named TAS) composition.

Biological studies have shown that the TAS preparation:

- had a positive effect on the germination of seeds of soft spring wheat cultivar Novosibirskaya 29;
- effectively inhibited the growth of phytopathogenic microorganisms and therefore grains treated with this composition gave 100% normally developed seedlings, while in the control (without treatment with the preparations) and the standard (Raxil SC,60), only 73.4% and 91.2% were observed healthy grains, respectively;
had a positive effect on growth processes, namely, when treating seeds with the proposed composition, the number of roots (+ 4.7%), their length (+ 32%) and air-dry biomass (+ 23.9%) increased;
• showed a high level of healing effect on the root system of spring soft wheat grown on soil with a high density of spores of the phytopathogen Bipolaris sorokiniana;
• was also effective in a field experiment to limit the damage to wheat plants by the pathogens of ordinary root rot.

3.1.2. Obtaining compositions of TBC with kelp. The efficacy of fungicidal preparations is composed of the nature of AS and the correct choice of a formulation that preserves the useful properties of AS. The appearance of new drugs does not fundamentally change the general situation in protecting plants from diseases. An innovative approach is considered to be promising in the creation of integrated plant protection systems against diseases, which involves the use of biologically active substances (BAS) that ensure the restoration and activation of natural regulatory mechanisms that increase biological diversity in agrobiocenoses and their stability, as well as crop productivity.

It is appropriate to note here such an important factor as the ability of AS of preparations to penetrate into processed objects (grains, plants, etc.) associated with the ability of transmembrane transport of auxiliary components, which are polysaccharides [23]. The use of biomass from kelp algae, which has a high content of polysaccharides (alginic acid up to 50% in solids) during joint mechanical treatment with TBC, allowed us to obtain intermolecular complexes with increased solubility and transmembrane permeability of TBC compared with the initial substance of TBC. A study of the biological activity of the complex “TBC-kelp” confirmed its high efficiency, namely, the preparation completely heals the seed from the phytopathogens B. sorokiniana and Fusarium spp., the spread of ordinary root rot decreases by 3.5 times, the intensity of plant damage by 5.5 times. At the same time, the harvest of wheat and barley grains in the experimental variants (2.73 and 2.81 t / ha) exceeded the control (2.45 and 2.51 t / ha). Wheat yields increased by 11.4% or 0.28 t / ha, barley - by 11.9% or 0.3 t / ha. Similar increases in the variant with seed treatment with Raxil, SC were lower - 1.7 (wheat) and 3.9 times (barley) [24].

For the first time, glycyrrhizic acid (GA) and its derivatives (sodium salt of GA / Na₂GK / and licorice root extract / LE /) were used to modify TBC, and compositions were obtained with an increase in solubility of 34; 3 and 15 times in the series "GA - Na₂GA - LE". It was expected that an increase in the biological activity of the obtained compositions was noted, which makes it possible to recommend, for use in agricultural practice, a fairly cheap and widely distributed plant material from licorice roots in the Russian Federation [25].

3.1.3. The effect of mechanochemical compositions of TBC on the state and dynamics of the spread of seed and soil infection. It is known, when cultivating the host plant on the same field on the straw, pustulecilia with bags and ascospores of the fungus are preserved [26]. And in contrast to the alternaria black embryo, which does not affect the sowing quality of seeds, their infection with the fungus Bipolaris sorokiniana can dramatically reduce germination and cause the death of seedlings [27]. After germination of such kernels, the fungus mycelium after 5 days captures half the length of the basal part of the primary roots. Often, instead of three primary germinial roots, one or two grows. Wheat seedlings grown from affected seeds unproductively consume endosperm nutrients and are significantly stunted [28]. The defeat of the phytopathogen leads to both decay of the root and root parts of plants, resulting in inhibition of growth, yellowing and drying of leaves, delayed earing, grain frailty, and the death of productive stems. When isolating wheat from the affected parts of wheat plants, the proportion of Bipolaris sorokiniana from the total phytopathogenic complex can be 75-80% [29]. If the infection already exists, then the seeds should be treated with fungicide. At present, the development and introduction into practice of less dangerous multicomponent seed dressers with a high degree of degradation in the soil, with a gentle effect on the microbiota, is a priority.
Along with seed infection, soil also plays an important role. The high survival of conidia of *B. sorokiniana* in soil allows them to be used as a test object in the study of its phytotoxicity [30]. The magnitude of the occurrence of infectious structures in the rhizosphere of the host plant is the main factor in the defeat of spring wheat by the pathogen *B. sorokiniana*. The accumulation of spores of this main causative agent of ordinary root rot in the forest-steppe zone of Western Siberia determines both abiotic and biotic and agrarian-anthropogenic factors. Preparations containing tebuconazole are able to suppress the growth of *Bipolaris sorokiniana* mycelium, significantly limit the spread of the disease in wheat agroecosystem, and increase the resistance of plants to low-temperature stress [31].

In order to determine the level of spore accumulation of the main causative agent of ordinary root rot *Bipolaris sorokiniana* in the rhizosphere of crops grown from seeds treated with tebuconazole compositions with the polysaccharides described above (AG, kelp, etc.), studies were carried out during 2014-2016 on the experimental field in the Central Forest-Steppe of the Novosibirsk Region. Soil - leached chernozem, medium loamy, medium thick [32]. The tests showed that TBC compositions with various polysaccharides (NaCMC, GA, Na$_2$GA and AG) affect the reproductive process of *Bipolaris sorokiniana*, the main causative agent of ordinary root rot in the forest-steppe zone of Western Siberia. They are also able to successfully control the conidia abundance in the rhizosphere of crops grown in the conditions of the Central Forest-Steppe Priobsky agrolandscape area of the Novosibirsk Region on leached chernozem. The efficacy of TBC compositions depends on their composition, consumption rate and sown crop.

### 3.2 Development of formulations based on TBC and other fungicides

Seed dressers are quite effective in the initial period of plant development - from the emergence of seedlings to the phase of tillering or bobbing, and subsequently their effect is significantly weakened. The effect of treating agents can be enhanced by the selection of certain fillers, surfactants, adhesive additives, which improve the penetration of the active substance into the tissue. And since seed treatment with fungicides can enhance dormancy or affect the growth and intensity of germ cell division, the problem of removing both biotic and abiotic stresses during germination of seeds treated with fungicides is considered to be very relevant and should be addressed in a comprehensive manner. In this regard, we selected a spectrum of fungicides widely used in the compositions of promising drugs used in practice, as well as a number of well-known plant growth regulators (PGR) [33]. In order to develop a complex fungicide protectant, we used technical products of well-known fungicides (tebuconazole, imazalil, metalaxyl), as well as bioregulators (Floroxane and Crezacin) [34].

#### 3.2.1 Suspension forms of fungicides with plant growth regulators (PGR)

Given the physicochemical properties of the selected fungicides (in particular, low solubility in water) and the advantages of modern suspension forms over a number of known formulations, e.g. emulsion concentrates (fire hazard, the use of toxic solvents, etc.) [35], it was conducted a series of studies on the development of multifunctional fungicide disinfectants in the form of suspension concentrates with the addition of PGR. For biological tests, naturally infected seeds of soft spring wheat cultivar Novosibirsk 31 were used, fungicidal compositions were tested (the composition of the components is given below) for seed dressing:

- **composition No. 1** composition: metalaxyl (7.8%); imazalil (9.8%); TBC (5.9%); crezacin (5.9%) with a consumption rate of 0.36 l / t seed;
- **composition No. 2** composition: metalaxyl (4.3%); imazalil (5.4%); TBC (3.3%); floroxane (0.3%) with a consumption rate of 0.64 l / t seed;
- **composition No. 3** composition: metalaxyl (10.5%); imazalil (13.2%); TBC (7.9%) with a consumption rate of 0.27 l / t of seeds.

A comprehensive assessment of the morphometric parameters of wheat germ (leaf, stem, root system length), indicators of sowing seed availability, as well as fungicidal activity against seed pathological microflora showed that *composition No. 2* showed a longer protective and growth-promoting activity.
This form of protectant stimulated the formation of a powerful root system of seedlings. *Composition No. 1* led to growth stimulation of the leaf apparatus and stem at the initial stage of ontogenesis. The effect obtained in the first case is a positive moment when growing spring wheat in the arid conditions of the natural zone for the formation of a powerful root system at the initial stages of crop growth [34]. The maximum activation of the morphophysiological processes of wheat seedlings due to the mutual enhancement of the effect of phytoregulators on plants in composition with phenylamide and azole class fungicides can be the basis for the development of innovative fungicides to protect crops from soil-seed infections and to increase wheat productivity.

### 3.2.2 Suspension emulsions with PGR

Given the low melting point of some fungicides’ AS, the technology of mechanochemical suspension in a liquid medium was used, which makes it possible to record local temperature changes [36]. The preparation of suspension emulsion and suspension forms of compositions based on tebuconazole and low melting fungicides (for example, prochloraz) was carried out in a 2% aqueous polymer solution with the addition of a nonionic surfactant, emulsifier, antifreeze during mechanical treatment for 1-5 hours. Finished products in the form of suspoemulsions were investigated for various types of biological activity on crops. To conduct the laboratory experiment, naturally infected seeds of soft spring wheat of the Omskaya 36 variety were used, fungicidal compositions were tested by seed treatment:

- **composition No. 4** - suspoemulsion composition: prochloraz (1.0%); imazalil (14.6%); TBC (14.6%); floroxyne (0.3%).
- **composition No. 5** - suspoemulsion composition: prochloraz (0.3%); imazalil (4.3%); TBC (4.3%); crezacin (2.2%).
- **composition No. 6** - suspension concentrate composition: prochloraz (1.2%); imazalil (18.1%); TBC (18.1%).

In the experiment, the effect of the preparations on the germination energy, the germination of wheat seeds, on the development of seed diseases and on the indicators of growth force - the length of the stem, cotyledon leaf and length was evaluated [37]. Assessment of the biological effectiveness of disinfection of spring wheat seeds of a multicomponent fungicide protectant with the addition of growth substances (*compositions No. 4 and No. 5*) showed that they are somewhat inferior to *composition No. 6*, probably due to a decrease in the number of active substances that make up their composition. At the same time, protectant suspensions with biologically active substances stimulated growth processes. It should be noted that due to the stimulation of the growth of the root system in the field, the plants are affected by root rot. A more balanced development of plants in combination with fungicidal protection of the crop increases its resistance to stress, which is a positive thing when growing spring wheat in modern cultivation technologies in order to obtain high yields and produce high-quality grain.

### 3.2.3. Oil emulsions of fungicides

Continuing studies on the development of alternative preparative forms of triazoles, we conducted studies on the development of emulsion formulations (oil emulsions / OE/) and suspension forms (SC) for the previously described fungicides (tebuconazole, imazalil) [37] and not previously described prothioconazole. The preparation of dressing agents in the form of oil emulsions was carried out in reactors by mixing an organic phase based on cyclohexanone, isopropanol, an emulsifier and an aqueous phase based on propylene glycol; in this case were received:

- **Composition No. 7** - oil emulsion composition: prothioconazole (25%). Consumption rate of 0.25 l / t of seeds.
- **Composition No. 8** - oil emulsion composition: prothioconazole (25%) & tebuconazole (15%). Consumption rate of 0.17 l / t of seeds. The preparation of the dressing agent in the form of a suspension concentrate (*composition No. 3*) was carried out by liquid-phase suspension in the LE-101 ball mill [34].
• **Composition No. 9** - suspension concentrate composition: prothioconazole (4.1%) & tebuconazole (2.4%). The consumption rate is 1.04 l/t of seeds.

As a result of the phyto-examination of spring wheat seeds of the Omskaya 36 variety, the development of mycoses — *Penicillium spp.*, *Alternaria spp.* (13.2 and 5.6%, respectively), *Fusarium spp.* - 0.1%. The biological efficacy of Composition No. 7 and No. 8 was 23 and 12% lower, respectively, in comparison with Composition No. 9, which suppressed the infection by 72%. An analysis of the properties of the fungicides studied revealed the peculiarities of the effect of suspension and emulsion forms of fungicides on the growth and development of spring wheat seedlings. With a 19% development of mycosis infection on seeds of spring wheat of Omskaya 36 variety, a suspension and dressing emulsion containing prothioconazole and TBC suppressed it up to 10 and 8%, respectively, an emulsion of prothioconazole up to 5%, and the biological efficacy of the studied forms was 49, 60 and 72% respectively. When using the emulsion form (prothioconazole and TBC), a more proportional growth of the aboveground and underground parts of wheat seedlings occurs. This form of fungicide has a low retardant effect on plants in the initial phases of their development, which allows us to conclude the prospects of its use for the treatment of spring wheat seeds.

4. **Conclusions**
The efficacy of pesticides is composed of the nature of AS and the correct choice of a formulation that preserves the beneficial properties of AS. The emergence of new fungicides does not fundamentally change the general situation in the protection of plants from diseases. Dangerous diseases are often epiphytic in nature, there is not only an increase in the harmfulness of the known, but also the emergence of new dangerous types of phytopathogens. Therefore, a new approach to creating systems of integrated plant protection from diseases involves the use of not only fungicides, but also various biologically active substances that ensure the restoration and activation of natural regulatory mechanisms that increase biological diversity in agrobiocenoses and their stability, as well as crop productivity.

Dressing, being one of the most environmentally friendly methods of using chemical preparations, limits the manifestation of seed infection by 60-100% and primary aerogenic, soil and contained in plant debris by 30-80%. At the same time, the productivity of spring wheat increases by 0.2-0.3 t/ha. Seed dressers are quite effective in the initial period of plant development - from the emergence of seedlings to the phase of tillering or bobbing. In the future, their effect is significantly weakened. The effect of dressing agents can be enhanced by the selection of certain fillers, surface-active substances, adhesive additives, providing improved penetration of the active substance into the tissue. A brief review of the works devoted to this issue allows us to propose new approaches both in the development of alternative formulations and innovative methods, in particular, mecanochemical modification of known fungicides using water-soluble polymers and polysaccharides.

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