

4 **Factors affecting the processes of penetration of protectants into grain of seeds**
5 **and increasing the yield of crops**

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14
15 **ABSTRACT**

16 In our previous studies, were prepared by mechanical treatment and tested several formulations
17 of plant protection products **based on tebuconazole (TBC)** with different delivery systems. As a
18 result of these studies, polysaccharides showed high efficiency in increasing the solubility and the
19 effectiveness of products based on these polymers. An important task in developing an effective
20 seed treatment is to increase the efficiency of adhesion and penetration. However, the question
21 arises, which factor is more important for plant protection or which factor plays the main role in
22 the activity of the protectants - the amount of dressing agent on the surface of the seed or the amount
23 penetrated into the grain? This question remained unanswered in previous experiments and the
24 purpose of this study is to find an answer to this question. For this purpose, protectants of various
25 compositions based on TBC and polysaccharides were prepared and spring wheat seeds were
26 treated with them. At the same time, these seeds were divided into two variants - seeds treated with
27 protectant (TBC on the surface and which managed to penetrate inside the seeds) and seeds whose
28 surface was washed by water and so seeds were without sorbed tebuconazole (TBC only inside the
29 seeds). So, seeds were prepared that contained only the adsorbed tebuconazole (SPrA) and seeds
30 containing the drug that penetrated into the grain (SPrP). These two types of seeds were used in
31 biological tests and the results obtained were compared. An analysis of seed germination and
32 infection with the main pathogens showed that SPrA seeds had an advantage over SPrP seeds both
33 in germination and in protection from diseases. Further research in this direction **will help to**
34 **understand** the effect of the penetration of drugs into plants on the possibility of increasing their
35 efficiency and the yield of grain crops.

36 **Keywords:** Tebuconazole, Polysaccharides, mechanical treatment, seed dressing, penetration,
37 biological efficacy.

38

39 INTRODUCTION

40 Modern agriculture cannot be imagined without pesticides to protect plants from diseases and
41 pests. At the same time, the chemical pesticides cause irreparable harm to the environment. One of
42 the prospective approaches for their using are protectants for plant seed dressing. A protective
43 coating could also contain essential nutrients for germinating plants. It allow crops to grow even
44 in unproductive soils (Sharma *et al.*, 2015). Another approach, which could improve the
45 effectiveness of protectants, is the use of nanotechnologies, in particular, nanocarriers based on
46 different delivery systems (Pereira *et al.*, 2021). This approach is actively used in the medical
47 chemistry, but the application of nanotechnology in agricultural sector is relatively new and in the
48 early stages of development (Yadav and Yadav, 2016). Currently, scientists develop a new area of
49 nanotechnology, which could revolutionize agriculture – nanopesticides: nanosized controlled
50 release systems. According to recent studies, nanopesticides have a wide range of benefits,
51 including increased stability and sustainability of yields of crops to pathogens, pests and weeds
52 (An *et al.*, 2022).

53 The seed dressing is one of the targeted and cost-effective measures to protect plants from
54 diseases and pests. In the process of treatment of pesticides are applied to the seeds to destroy not
55 only external, but also internal infections of plant origin, protect both seeds and seedlings in the
56 field from soil-dwelling phytopathogens and various pests (Vlasenko *et al.*, 2020). The
57 environmental friendliness of this method of using chemical preparations is explained by the fact
58 that fungicides are applied only where they are really needed. In all developed countries of the
59 world, dressing is considered as a legally mandatory phytosanitary measure (Afzal *et al.*, 2020).

60 In our opinion, two important factors will affect the effectiveness of the protectants for seeds
61 dressing. It is the adhesion of the drug to the surface of the seeds and the degree of its penetration
62 into the seeds through plant membranes. Unfortunately, there is no data on the differentiation of
63 these two factors on the biological activity of protectants. The important task in the development
64 of effective product for seed dressing is the increase of the adhesion and penetration efficacy
65 (Sharma *et al.*, 2015). In the present study, an attempt was made to determine the contribution of
66 each of the factors: improved adhesion of the active substance to the surface, improved penetration

67 of the active substance into the seed. Understanding the significance of each of these factors is a
68 big step towards the rational development and use of plant protection products.

69 In the previous studies we have tested several compositions of plant protection products with
70 water soluble delivery systems, polysaccharide arabinogalactan (AG) and saponin glycyrrhizin
71 (GA) prepared by innovative “green” mechanochemical technology. As a result of these studies,
72 both AG and GA have shown high efficiency in increase of solubility and permeability of some
73 lipophilic fungicides (tebuconazole, imazalil, prochloraz) (Khalikov *et al.*, 2015; 2023).
74 Previously, when studying the processes of fungicides penetration through cell membranes, which
75 mainly consist of phospholipids forming bilayer structure, it was noted that any changes in its
76 structure and dynamics could significantly affect the properties and functions of the cell membrane
77 and associated proteins (Matsuoka *et al.*, 2015).

78 The properties of delivery systems based on glycyrrhizic acid (GA) were already studied in the
79 models significant to medicinal chemistry (Selyutina *et al.*, 2017-a). Due to its amphiphilic
80 properties, GA is capable to form micelles in water solution and “host-guest” complexes with
81 hydrophobic molecule of tebuconazole (Vlasenko *et al.*, 2019). Given the physicochemical
82 characteristics of GA and its disodium salt (Na₂GA), which forms solutions with a lower viscosity
83 in contrast to GA, a synergistic effect could be expected from the use of Na₂GA as a drug delivery
84 system (Selyutina *et al.*, 2020).

85 It was found that GA is able to interact with the cell membrane, affecting its properties, such as
86 elasticity and permeability. GA penetrates into phospholipid bilayer and forms self-associates
87 inside it, which lead also to changes in lipids mobility (Selyutina *et al.*, 2016).

88 Arabinogalactan is a natural polysaccharide consisting of arabinose and galactose fragments
89 (Chauhan *et al.*, 2018) and demonstrates strong binding with different lipophilic biologically active
90 molecules which results in a significant increase in their solubility (Selyutina *et al.*, 2020). In
91 contrast to GA, AG is located on the surface of the lipid bilayer and do not penetrate inside it.
92 However, AG is also able to affect lipid mobility and enhance membrane permeability (Selyutina
93 *et al.*, 2017). Therefore, we tried to use these promising properties of GA and AG in the
94 development of the nanopesticides (Khalikov *et al.*, 2015; 2023). An increase in the penetration of
95 pesticides into seeds in the presence of both delivery vehicles was detected, but the greatest effect
96 is observed in the presence of AG. Obtained results show that the effect of polysaccharides and
97 oligosaccharides on the penetration efficacy of nanopesticides under the presowing seed treatment

98 might be associated with the solubility enhancement and affinity of delivery systems to the surface
99 of seeds, as well as due to modification of cell membranes by poly- and oligosaccharides (Selyutina
100 *et al.*, 2017-b). However, it is still unclear, which factor is determinant in the increase of
101 nanopesticide efficiency: solubility enhancement, improved adhesion to the seed surface or a
102 better penetration of the pesticide into the seed.

103 In order to provide physicochemical and biological studies, the authors (Meteleva *et al.*, 2018)
104 obtained solid dispersions (SD) of TBC with AG, GA, Na₂GA and licorice extract (LE), as
105 substances that form supramolecular systems when the corresponding SD is dissolved in water.
106 According to the results of these studies, it was found that the obtained SDs form supramolecular
107 systems, which allow the transport of TBC through artificial and plant membranes. An attempt was
108 made to establish the correlation "biological activity of the protectants- the degree of penetration
109 of TBC". The expected result of biological activity was the sum of TBC on the surface of the seed
110 and the drug that penetrated inside.

111 A continuation of these studies is the work (Vlasenko *et al.*, 2019) on reducing the TBC norm by
112 obtaining its SDs with GA, Na₂GA, and LE. In this study, the consumption rates of TBC were
113 reduced by 1.7-4.5 times, while maintaining biological efficiency. In field experiments, during pre-
114 sowing seed treatment, wheat growth and development increased, its standing density, productive
115 bushiness and yield increased by 0.52–0.69 t / ha. In this work, the biological effect was also the
116 sum of the action of TBC on the surface of the treated seeds and TBC that penetrated into the seed
117 (Selyutina *et al.*, 2020).

118 In order to differentiate the biological activity caused by these two sources (on the seed and inside
119 the seed), in the present work we have compared the biological effect of so-called total amount of
120 the protectants (on the surface of the seed plus inside the seed) and the activity of only part
121 penetrated into the seed of wheat. To perform this work, protectants based on TBC and plant
122 metabolites (AG, GA, Na₂GA, and LE) were obtained by mechanochemistry at their mass ratio of
123 1:9.

124 **MATERIALS AND METHODS**

125 **Materials**

126 **Tebuconazole** (TBC) – (RS)-1p-chlorophenyl-4,4-dimethyl-3-(1H-1,2,4-triazol-1-yl-methyl)
127 pentane-3-il is a systemic fungicide for the treatment of grain seeds in the fight against
128 phytopathogens transmitted with seeds, such as *Helminthosporium* spp., *Fusarium* spp., *Bipolaris*
129

130 *sorokiniana*, *Penicillium* spp. It is also used for the treatment of vegetative plants of rapeseed and
131 cereals as an integral component of combined preparations. Solubility (25 °C) in water is 32.0 mg/l
132 (Paranjape *et al.*, 2014). Production of Shanshen Sunrising Industry Co., Ltd. (China), content of
133 active ingredient ≥ 97.84 %, powder.

134 **Arabinogalactan** (AG) is a polysaccharide consisting of arabinose and galactose units with
135 molecular weight 15 kDa (97 %, Ametis JSC, Russia). It is derived from Siberian larch *Larix*
136 *sibirica* and differs from AG from other suppliers (Khalikov *et al.*, 2015).

137 **Glycyrrhizic acid** (GA) – triterpene glycoside from licorice root extract. Its chemical name is 20
138 β -Carboxy-11-oxo-30-norolean-12-en-3 β -yl-2-O- β -D-glucopyranuronosyl-alpha-D-
139 glucopyranosiduronic acid (Selyutina *et al.*, 2016). Production of Shaanxi Pioneer Biotech Co.,
140 Ltd, China; content of active ingredient ≥ 98.14 %.

141 **Disodium salt** of glycyrrhizic acid (Na₂GA) (Selyutina *et al.*, 2014). Production of Shaanxi Pioneer
142 Biotech Co., Ltd, China- content of active ingredient ≥ 91.14 %.

143 **Licorice extract** (LE) is a dry fine powder of light to dark brown color with a content of 25 % GA.
144 Production of “Visterra”, Altai Territory, Russia.

145

146 **Methods**

147 **Mechanochemical method for obtaining of tebuconazole composition**

148 Dressing agents were obtained in the form of solid dispersions (SD) from TBC and
149 polysaccharides (mass ratio of 1:9) by their joint mechanical processing in a roller mill LE-101.
150 These SDs are finely dispersed powders that have increased solubility in water and form
151 supramolecular complexes in water with high biological efficiency (Khalikov, 2021).

152

153 **Analysis of solubility of tebuconazole composition**

154 The solubility of TBC in various compositions was determined by HPLC on an Agilent 1100
155 liquid chromatograph (Germany) on a Hypersil HyPURITY Elite C18 analytical column (150×4.6
156 mm, 5 microns) in isocratic mode (Khalikov *et al.*, 2023). The temperature of the column
157 thermostat is 30° C. Eluent-acetate buffer pH 3.4/acetonitrile in a ratio of 1:1. Eluent consumption
158 – 1 ml/min. UV detection at a wavelength of 220 nm. Data on the measurement of the solubility of
159 the studied solid dispersions are presented in Table 1.

160

161 **Biological tests of tebuconazole composition**

162 Seed dressing of wheat seeds Novosibirsk 31 was carried out (Vlasenko *et al.*, 2020) as follows:
163 wheat seeds (20.0 g) were placed in 150 ml round-bottomed glass flask. For seeds dressing 5.0 g
164 of 1% suspension of all compositions was used. The flask was rotated on the rotor (with speed of
165 100 rpm) for 15 minutes until the seeds completely poured out from the flask walls. After that, the
166 seeds were placed in a Petri dish in the humid atmosphere of the desiccator for 3 days (with periodic
167 spraying of the seeds with distilled water). Then the seeds will dried in air at room temperature 24-
168 25⁰C for 3 days and divided into three parts:

169 **A)** 7.5 g of seeds submit for biological testing (to study the effect of TBC adsorbed on the surface
170 of the seed and trapped inside the seed).

171 **B)** 7.5 g of seeds leave to find the amount of TBC adsorption on wheat seed.

172 **C)** 5.0 g of seeds leave to learn the degree of penetration of TBC into wheat seed.
173

174 **Analysis of penetration process of tebuconazole composition**

175 *The amount of the TBC adsorption on the seed* was determined as follows:

176 **7.5 g** of treated seeds was immersed in a conical flask for 50 ml and, after adding 10 ml of acetone,
177 stirred on a magnetic stirrer for 10 minutes. Acetone filtrates were analyzed for the content of TBC
178 and it is an indicator of the drug's adsorption on the seed (see Table 2).The remainder of wheat
179 seeds were transferred to biological tests (to study the effect of TBC that penetrated into the seed).

180 *The amount of TBC penetrated from various SDs was determined as follows:*

181 **5.0 g** of treated seeds was placed in a conical flask for 25 ml and, after adding 10 ml of acetone,
182 the system was stirred for 10 minutes. The seeds were separated by decanting the solvent and were
183 dried in the air for 2 days at a temperature of 24-25⁰ C. The dried seeds were crushed in a mortar
184 and, after being loaded into a 50 ml conical flask, 10 ml of acetone was poured and the system was
185 stirred on a magnetic stirrer for 1 h. The acetone filtrate was analyzed for the content of TBC and
186 it is an indicator of the penetration of TBC into the seed (see Table 2).

187 *The biological effect* was studied based on the development of spring wheat seedlings of the
188 Novosibirsk 31 variety and their infection with diseases after treating their seeds with preparations
189 in the form of SD based on TBC and polysaccharides (AG, GA, Na₂GA and LE). In the laboratory
190 experiment, the effect of drugs on the development of seed diseases (Vlasenko *et al.*, 2020) and on
191 the length of the seedling, the length and number of roots was evaluated by the "roll" method. As
192 a control, untreated wheat seeds were used in comparison with treated seeds, and in the experiment

193 with seeds washed from protectants, the control seed material was also washed with acetone. The
 194 results of biological investigations are presented in Tables 3 – 6.

195 Statistical analysis. All experiments were repeated thrice and resulted values were calculated as
 196 an arithmetic mean, and resulted error was calculated as mean value of least squares errors, the
 197 differences were considered statistically significant at $p < 0.01$ using a t-test (Dospekhov, 2012).

198

199 RESULTS AND DISCUSSION

200 Tebuconazole is the active substance of the most widely used fungicidal drugs used both for seed
 201 treatment and for plant treatment during the growing season (Vlasenko *et al.*, 2020). Due to the
 202 poor solubility in water, various formulations of TBC have been developed, which to some extent
 203 improve its solubility and bioavailability. Despite this, the consumption rates of TBC in these
 204 preparations are quite high, namely, in the preparations Raxil SC 60 or Raxil Ultra the TBC content
 205 is 60 and 120 g/l, respectively. Solid dispersions obtained by machinery of TBC and
 206 polysaccharides had 100% efficiency with a reduction in the flow rate to 10 – 15 g / l. These results
 207 were explained by a significant increase in the solubility of the obtained SDs (see Table 1).

208 **Table 1.** Solubility* of tebuconazole compositions obtains after 3 h machinery.

Preparation	Solubility	
	Absolute, mg/l	Increase, times
TBC, initial	32.0	-
SD of composition TBC : AG (1:9)	185.6	5.8
SD of composition TBC : GA (1:9)	601.6	18.8
SD of composition TBC : Na ₂ GA (1:9)	144.0	4.5
SD of composition TBC : EL (1:9)	403.2	12.6

209 *- Value of standard error $\pm 3\%$.

210

211 To understand the difference in biological activity caused by two sources (on the seed and inside
 212 the seed), the amount of TBC on the surface and inside the treated seeds have been measured. The
 213 results are shown in Table 2.

214 **Table 2.** Adsorption of TBC-based compositions on the seed and its penetration into the seed (All
 215 experiments were repeated thrice and resulted values were calculated as an arithmetic mean).

N	composition	TBC* content, %	
		On the grain (adsorption)	Inside the grain (penetration)
1	TBC : AG	61	39
2	TBC : GA	57	43
3	TBC : Na ₂ GA	71	29
4	TBC : EL	68	32

216 *- Value of standard error $\pm 3\%$.

217

218 Data analysis of Table 2 indicates that the sorption of TBC on the seed surface slightly depends
 219 on the adhesive properties of polysaccharides, and the amount of TBC on the surface is almost two
 220 times higher than inside the seed. Also, all compositions show effective penetration of TBC into
 221 the seed. This effect might be explained by the similar mechanism of influence of these carriers on
 222 the plant membranes and the earlier studied lipid membranes (Selyutina *et al.*, 2017-a).

223 As a next step, we have compared the biological effectiveness of total TBC adsorbed on the seed
 224 surface and entered into the seed ("treated seeds" = *TS*) with the biological effectiveness of the part
 225 of TBC penetrated into the grain ("seeds treated and washed" = *STW*).

226 As a result of the conducted studies, it was found that *TS* increased germination by 4 – 17%, and
 227 *STW* - by 13 – 21% relative to the control variants (62 and 55%) (Table 3). The maximum increase
 228 in the percentage of germination in both cases was observed from the treatment of seeds with TBC
 229 with GA and TBC with EL: 14 and 17% - in the first case, 19 and 21% - in the second. It should
 230 be noted that the percentage of germination of seeds when germinating in rolls is low, due to high
 231 humidity conditions.

232
 233 **Table 3.** Effect of treatment of spring wheat seeds with compositions of TBC on the percentage of
 234 germination and infection with the main pathogens (All experiments were repeated thrice and
 235 resulted values were calculated as an arithmetic mean).

Composion	Seed germination rate, %	Infection with diseases, %			
		<i>Fusarium</i> spp.	<i>Bipolaris sorokiniana</i>	<i>Penicillium</i> spp.	<i>Alternaria</i> spp
<u>Treated seeds (TS)</u>					
Control (non-treated)	62	6	4	1	78
TBC : AG	66	3	0	1	30
TBC : GA	76	2	2	0	32
TBC : Na ₂ GA	73	1	0	0	33
TBC : EL	79	3	3	0	40
<u>Seeds treated and washed (STW)</u>					
Control (only washed)	55	2	6	1	56
TBC : AG	68	1	0	1	8
TBC : GA	74	3	2	0	16
TBC : Na ₂ GA	68	0	2	0	15
TBC : EL	76	0	1	0	18

236
 237 Phytoanalysis of seeds sprouted in rolls showed the best results in reducing the infection rate of
 238 their main root rot pathogens (*Fusarium spp* and *Bipolaris sorokiniana*) from the protectants TBC
 239 : AG, TBC: GA and TBC : Na₂GA in 3.3, 2.5 and 10 times. When analyzing the washed seeds, the
 240 best results were shown by the compositions TBC : AG, TBC : Na₂GA and TBC : EL, where the
 241 percentage of infection of seeds with these pathogens in relation to the control variant decreased

242 by 8, 4, and 8 times, respectively. It should be also noted that the germination of washed seeds
 243 significantly reduces the level of damage to seedlings of *Alternaria spp.*

244 All the studied preparations showed their growth-stimulating abilities to a greater or lesser extent
 245 already on the 7th day of plant growth, increasing the root length by 0.8 – 4.1 cm (8.8 – 45.3%)
 246 relative to the control (9.05 cm) when germinating seeds treated with protectants and by 0.25 – 3.4
 247 cm (2.2 – 29.3%) when washing off the protectants from the seed surface (in the control – 11.6
 248 cm). Due to the retardant effect of chemicals (in this case, tebuconazole) on plant height, the length
 249 of sprouts in most variants was lower than the control ones (Table 4). The number of roots in the
 250 variants increased relative to the control (2.85 pcs.) by 10.5 – 28.1% from the surface treatment of
 251 seeds and by 5.5 – 6.8% from the treatment with the flushing of the drug (in the control, 3.65 pcs.).

252 **Table 4.** Effect of treatment of spring wheat seeds with compositions of TBC on the biometrics of
 253 spring wheat seedlings, day 7.

Composition	Biometrics		
	Sprout length, cm	Number of roots, pcs	Root length, cm
<u>Treated seeds (TS)</u>			
Control	8,9±5,05	2,85±1,0	9,05±4,25
TBC : AG	7,2±2,4	3,65±1,0	11,35±2,3
TBC : GA	9,3±3,45	3,5±0,8	13,15±3,45
TBC : Na ₂ GA	8,15±3,45	3,55±1,0	10,85±4,0
TBC : EL	7,65±3,35	3,15±1,15	9,85±4,15
<u>Seeds treated and washed (STW)</u>			
Control	9,95±2,6	3,65±0,9	11,6±2,85
TBC : AG	10,2±2,0	3,9±0,85	15,0±2,0
TBC : GA	8,8±2,2	3,9±0,8	11,35±2,7
TBC : Na ₂ GA	9,3±2,25	3,85±0,85	11,85±2,85
TBC : EL	8,95±2,2	3,6±0,75	12,5±2,6

254 On the 15th day of wheat plant growth in rolls, the indicators of biometrics of sprouts and roots
 255 and the number of roots retained the trends of the previous accounting (Table 5): the main decrease
 256 in the length of sprouts compared to the control, an increase in the length of roots in the variants
 257 by 3.1 – 4.6 cm (41.4-60.5%) and an increase in the number of roots by 18.2 – 34.8% in the first
 258 method of using drugs and an increase in their number by 8.2 – 14.2% in the second.

260 **Table 5.** Effect of treatment of spring wheat seeds compositions of TBC on the biometrics of spring
 261 wheat seedlings, 15 days.
 262

Composition	Biometrics		
	Sprout length, cm	Number of roots, pcs	Sprout length, cm
<u>Treated seeds (TS)</u>			
Control	14,65±7,2	3,3±1,05	7,6±4,05
TBC : AG	11,15±3,5	4,4±0,9	11,4±2,3

TBC : GA	14,65±4,4	4,35±0,85	12,2±3,7
TBC : Na ₂ GA	11,75±5,0	4,45±1,0	11,0±3,6
TBC : EL	11,6±4,9	3,9±1,05	10,75±3,2
<u>Seeds treated and washed (STW)</u>			
Control	18,5±5,55	3,65±1,05	11,9±2,9
TBC : AG	15,4±3,75	4,05±0,8	13,9±2,35
TBC : GA	15,3±3,35	4,15±0,85	11,3±2,45
TBC : Na ₂ GA	15,9±3,9	4,17±0,8	11,9±2,6
TBC : EL	15,6±3,35	3,95±0,75	11,9±2,55

263
264 When studying the new protectants, a significant growth-stimulating effect was also observed on
265 the air-dry biomass of sprouts and roots (Table 6). The level of growth of aboveground biomass in
266 the first case varied in the variants from 1.0 to 21.5% (the weight of sprouts in the control was
267 0.404 g) and root – from 62.9 to 90.3% (the weight of roots – 0.197 g). When the preparations were
268 washed off, the accumulation of biomass by sprouts was slightly more intense than the control
269 indicator (0.459 g) only in the variants of compositions TBC: GA (by 2.4%) and TBC: Na₂GA (by
270 1.1%), and the root mass – when using TBC: AG, by 14.3% (in the control – 0.384 g).

271
272 **Table 6.** Effect of treatment of spring wheat seeds with compositions of TBC on the air-dry
273 biomass of sprouts and roots, g/50 plants (All experiments were repeated thrice and resulted values
274 were calculated as an arithmetic mean).

Composition	Aboveground (sprouts)	Underground (roots)
<u>Treated seeds (TS)</u>		
Control	0,404	0,197
TBC : AG	0,481	0,375
TBC : GA	0,491	0,361
TBC : Na ₂ GA	0,455	0,329
TBC : EL	0,408	0,321
<u>Seeds treated and washed (STW)</u>		
Control	0,459	0,384
TBC : AG	0,436	0,439
TBC : GA	0,470	0,370
TBC : Na ₂ GA	0,464	0,372
TBC : EL	0,459	0,368

275
276 **CONCLUSIONS**
277 For effective treatment of wheat seeds, solid dispersions of tebuconazole with plant metabolites
278 were prepared, forming supramolecular complexes when dissolved in water. These compositions
279 have increased solubility and effectiveness while reducing the dose of TBC by 10 times or more.
280 These preparations in water formed stable working solutions, convenient for the process of treating
281 soft spring wheat seeds Novosibirsk 31. Studies conducted using spring wheat seeds treated with

282 TBC compositions showed its high (from 29 to 43%) penetrating ability into the seeds. This value
283 was maximum in the case of the composition with GA. Comparison of the biological effectiveness
284 of treated seeds with treated and washed seeds did not reveal differences in their effect on
285 pathogens of common root rot. Approximately the same results were observed when comparing
286 the growth processes of spring wheat seedlings. Such results can be explained by the fact that
287 during the initial treatment of seeds, the foci of diseases on the seeds are already suppressed and
288 further washing of the surface of the seeds from drug residues no longer affects the biological
289 results.

290

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294

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