PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

IDENTIFICAÇÃO DE DIVERSIDADE DE SEMENTES DE BETERRABA HÍBRIDAS E DECENDENTES

IDENTIFICATION OF SEEDS DIVERSITY IN SUGAR BEET HYBRIDS AND LINES

ОПРЕДЕЛЕНИЕ РАЗНОКАЧЕСТВЕНОСТИ СЕМЯН ГИБРИДОВ И ЛИНИЙ САХАРНОЙ СВЕКЛЫ

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RESUMO

Introdução: A diversidade das sementes manifesta-se na sua heterogeneidade de acordo com as características morfológicas e qualidades de semeadura, que dependem do genótipo e das condições de cultivo. Um dos principais indicadores das diferentes qualidades das sementes de beterraba é a energia germinativa e a capacidade de germinação, que dependem do genótipo. A influência de fatores agrotécnicos na diversidade de sementes supera a genética. **Objetivos**: o objetivo do estudo é identificar os efeitos do tratamento de pré-semeadura do composto químico inorgânico na diversidade de sementes de beterraba sacarina (*Beta vulgaris* L.) para linhagens e híbridos. **Métodos**: Como os sinais da diversidade de sementes são compreendidos, energia germinativa, comprimento da muda, massa da muda. Foi apresentado um método para identificação da diversidade genética de sementes de híbridos e linhagens de *Beta vulgaris*, incluindo o tratamento de sementes com solução aquosa da substância química inorgânica na concentração de 10% com exposição de 15 s, cálculo de critérios para a diversidade de sementes: energia germinativa, comprimento da muda, massa da muda. **Resultados e Discussão**: Foram utilizadas altas concentrações do composto químico inorgânico para revelar a diversidade genética das sementes. As reações dos genótipos da beterraba sacarina no fator provocativo (a substância química inorgânica) foram diferentes umas das outras. O composto químico inorgânico foi utilizado como fator provocativo e o método agrotécnico, e as características de comprimento da muda e massa da muda foram levadas em consideração como indicadores da heterogeneidade de híbridos e linhagens nos estágios iniciais de desenvolvimento da planta. **Conclusões**: O estudo permitiu revelar a diversidade genética de sementes de beterraba sacarina segundo os critérios energia de germinação e avaliar a heterogeneidade de híbridos e linhagens em estágios iniciais de desenvolvimento vegetal de acordo com as características de comprimento da muda e massa da muda.

Palavras-chave: *diversidade de sementes, energia germinativa, comprimento da muda, massa da muda.*

ABSTRACT

Background: Seeds diversity manifests in their heterogeneity according to morphological characteristics and sowing qualities, depending on the genotype and growing conditions. One of the main indicators of the different qualities of beet seeds is the germinative energy and germination capacity, which depend on the genotype. The influence of agrotechnical factors on the diversity of seeds exceeds genetic. **Aim:** The purpose of the study is to identify the effects of the pre-sowing treatment of the inorganic chemical compound on the diversity of sugar beet (*Beta vulgaris* L.) seeds for lines and hybrids. **Methods:** As the signs of the seeds diversity is understood, germinative energy, seedling length, seedling mass. It is presented a method for identifying the genetic diversity of seeds of hybrids and lines of *Beta vulgaris*, including the treatment of seeds with an aqueous solution of the inorganic chemical substance at a concentration of 10 % with an exposure of 15 s, calculation of criteria for the diversity of seeds: germinative energy, seedling length, seedling mass. **Results and Discussion:** It was used high concentrations of the inorganic chemical compound for revealing the genetic diversity of seeds. Reactions of genotypes of sugar beet on the provocative factor (the inorganic chemical substance) were different from each other. The inorganic chemical compound is used as a provocative factor and agrotechnical method, and the characteristics of seedling length and seedling mass are taken into account as indicators of the heterogeneity of hybrids and lines in the early stages of plant development. **Conclusions:** The study allows to reveal the genetic diversity of sugar beet seeds according to the criteria "germination energy" and to assess the heterogeneity of hybrids and lines at early stages of plant development according to the characteristics of seedling length, and seedling mass.

Keywords: *seeds diversity, germinative energy, seedling length, seedling mass*.

АННОТАЦИЯ

Предпосылки: Разнокачественность семян проявляется в их неоднородности по морфологическим признакам и посевным качествам, которые зависят от генотипа и условий выращивания. Одним из главных показателей разнокачественности семян свеклы является энергия прорастания и всхожесть, зависящие от генотипа. Влияние агротехнических факторов на разнокачественность семян превышает генетические. **Цель:** Целью исследования являлось выявить действие предпосевной обработки неорганическим химическим соединением на разнокачественность семян гибридов и линий сахарной свеклы (*Beta vulgaris* L.). **Методы:** Под показателями разнокачественности семян понимались энергия прорастания, длина проростка, масса проростка. Представлен способ выявления генетической разнокачественности семян гибридов и линий *Beta vulgaris*, включающий обработку семян водным раствором неорганического химического вещества в концентрации 10 % с экспозицией 15 с, подсчет критериев разнокачественности семян: энергии прорастания, длины проростка, массы проростка. **Результаты и Обсуждение:** Для выявления генетического разнообразия семян используются высокие концентрации неорганического химического соединения. Реакции генотипов сахарной свеклы на провокационный фактор (неорганическое химическое вещество) отличались друг от друга. Неорганическое химическое соединение используется в качестве провоцирующего фактора и агротехнического приема, а признаки «длина проростка», «масса проростка» учитываются как индикаторы разнородности гибридов и линий на ранних стадиях развития растения. **Выводы:** Исследование позволяет выявить генетическую разнокачественность семян сахарной свеклы по критерию «энергия прорастания» и произвести оценку разнородности гибридов и линий на ранних стадиях развития растения по признакам «длина проростка», «масса проростка».

Ключевые слова: *разнокачественность семян, энергия прорастания, длина проростка, масса проростка*

1. INTRODUCTION

In connection with climate changes and environmental conditions, the introduction into production of a new generation of hybrids, soil cultivation methods, and fertilization systems, the emergence of preparative forms of chemical and bacteriological agents for the fight against the pathogenic microflora, researches in this direction is an urgent task. Every year, scientific achievements that promote a significant increase in yield of agricultural crops and reduce their cultivation technology expenses are more and more introduced into agricultural production practice. When cultivating sugar beet, many disease agents can affect plants even at initial growth, and development stages accumulate in soil of crop rotations. Long-term practice of sugar beet cultivation has shown that control of pathogenic microflora is one of the major tasks of the crop yield and technological qualities' increase.

It is known that the use of various chemicals, growth regulators, natural stimulants significantly accelerates the flowering of plants, and some agents also facilitate their adaptation to fluctuations in weather conditions, protect against various diseases (Bashmakov *et al*., 2012; Denisov *et al*., 2014 b). The use of some biological growth regulators makes it possible to obtain a crop with a lower content of lead and cadmium ions (Titov *et al*., 2011). Attempts are being made to apply the effect of "pre-adaptation" to increase plant resistance based on species-specific and non-specific reactions (Oudalova and Geras'kin, 2012; Pozolotina *et al*., 2010a, b). One example of species-specific reactions to external environmental factors (and internal factors of the organism) is the diversity of seeds.

The diversity of seeds manifests in their heterogeneity according to morphological characteristics and sowing qualities (Vostrikova, 2011), depending on the genotype and growing conditions. The influence of agrotechnical factors on the diversity of seeds exceeds genetic (Balagura and Levshakov, 2013). Seeds diversity can be tested by cytogenetic (Kalaev *et al*., 2006; Yakymchuk, 2015; Baranova and Kalaev, 2017; Burmenko *et al*., 2018a,b) molecular-genetic (Popov *et al*., 2011; Baranova *et al*., 2018; Fachi *et al*., 2019) and functional: physiological (Welbaum, 1998; Ivanov, 2011; Lyanguzova, 2011; Opalko and Opalko, 2015; Kuzemko, 2016; Bome *et al*., 2015), biochemical (Neverova, 2004; Vetchinnikova, 2004; Bukharina, 2011; Gar'kova *et al*., 2011; Lapshina, 2016) characteristics.

A direct relationship was found between the yield of root crops and the size of seeds, only when comparing the extreme fractions (2.5-3.0 and 4.5-5.5 mm). However, when sowing with seeds of fractions of 3.25-3.5 mm, the productivity of male-sterile hybrids was practically the same as when sowing with seeds of fractions 3.5-4.5 mm (Balagura, Levshakov, 2013). A similar pattern was obtained for sugar content (Balan, 2000). One of the leading indicators of the different quality of beet seeds is the germinative energy and the germinating capacity, which depend on the genotype (Balagura, Levshakov, 2013).

The effect of different planting schemes for the male-sterile maternal component and the pollinator in the production of hybrid sugar beet seeds on the seed yield, as well as the germinating capacity, the germinative energy, and the yield properties of the obtained seeds, has been established (Tsareva, 2010, 2013).

The results of studying the effect of low temperatures on the germinative energy and the germinating capacity of seeds of O-type sugar beet lines, which are directly dependent on temperature, are presented (Polishchuk, 2013). However, it is noted that in breeding work, when creating hybrids that are adapted to growing conditions using intensive technologies, an important feature of the initial breeding material is the provision of the high germinative energy and the seed germinating capacity at low temperatures, which makes it possible to sow heterotic sugar beet hybrids in earlier terms (Polishchuk, 2013).

Thus, the main criteria for determining the different quality of beet seeds are the size of seeds, germinative energy, germinating capacity, and indicators of the growth activity of early stages of the development (seedling) are not taken into account. Also, as provocative backgrounds for the study of the reaction of the sugar beet as a field crop to external influences, meteorological conditions, and agrotechnical methods, other than the use of chemical compounds, are often used. Preparations based on the colloidal silver, surface modified with various biologically active surfactants and polymers, are created and studied by specialists of Chemistry and Biology Faculties of Moscow State University named after M. V. Lomonosov, with the support of AgroKhimProm Group of Companies. They are suitable for use in agriculture as plant growth stimulators, effective contact fungicides and bactericides for leaf treatments, dressing agents for grain and tubers both before planting and before storage. The preparation "Zerox" is based on chemically modified highly dispersed silver as an element of the effective fight against bacterial and fungal epiphytoties of agriculturally significant plants (Zherebin *et al*., 2014). Colloidal silver has an eliciting effect that belongs to immunizing fungicides. It affects metabolism, increases the concentration of reactive oxygen forms in plant tissues (Zherebin *et al*., 2014, 2015).

A promising active ingredient for such preparations is the colloidal silver, which combines the high bactericidal and fungicidal activity against a wide range of phytopathogenic microorganisms with low toxicity in relation to humans, animals, and higher plants (Jo *et al*., 2009; Kim *et al*., 2012).

Pure silver is slightly soluble in water. The toxicity of soluble silver compounds is a well-known fact. At the same time, all types of silver nanoparticles are characterized by low or zero toxicity. Silver nanoparticles have a large specific surface area that increases the area of contact of the element with pathogenic organisms and improves its bactericidal effect (Krutyakov *et al*., 2008; Zherebin *et al*., 2014, 2015). Silver nanoparticles of 2-4 nm in the high-colloidal solution contain 6%, 4-6 nm – 15 %, 6-8 nm – 19 %, 8-10 nm – 18 %, 10-12 nm – 7 %, 12-14 nm– 4 %, 14-16 nm – 2 %, 16-18 nm – 1 % (Denisov *et al*., 2014 b; Elansky *et al*., 2014). Silver nanoparticles contained in the preparation are fixed and retained on the cell walls of phytopathogenic microorganisms. Silver nanoparticles oxidize and release silver ions, which disrupt the function of membrane proteins, especially transport proteins, that lead to the death of the pathogen. The gradual oxidation of silver nanoparticles provides a prolonged action of the preparation (Krutyakov *et al*., 2008; Elansky *et al*., 2014). Synthesis, biosynthesis, and properties of silver nanoparticles are described previously in other studies (Krutyakov *et al*., 2008). An effective agent against bacterial burns of fruit and vegetable crops, Zerox® is in the registration process (Lisichkin, 2019). The silver surface in the preparation was modified by amphoteric surfactant – ampholac – natrium amphopolycarboxyglycinate (Lisichkin, 2019). In order to produce the preparation, an aqueous solution of a silver salt (silver nitrate, acetate, citrate, chloride, bromide, iodide and sulfate) was mixed under rapid agitation with a solution of amphoteric surfactant and a solution of a reducing agent (sodium borohydride $NaBH_4$) (Denisov *et al*., 2014 a).

It is known the fungicidal and bactericidal preparation with a wide spectrum of action against phytopathogenic fungi, oomycetes, and bacteria, the active substance of which are nanosized particles of silver, the surface-modified with the ecologically safe biodegradable amphoteric surfactant. In vitro studies have shown the high efficiency of the preparation "Zerox®" (high-colloidal solution) in concentrations from 3 to 30 mg/l for silver against a wide range of fungal pathogens of potatoes (Zherebin *et al*., 2015). This is the inorganic chemical compound.

The purpose of the study is to identify the effects of the pre-sowing treatment of the inorganic chemical compound on the diversity of sugar beet (*Beta vulgaris* L.) seeds for lines and hybrids. As the signs of the seeds, diversity is understood germinative energy, seedling length, seedling mass.

2. MATERIALS AND METHODS

The object of the studies were non-pelleted seeds of 8 sugar beet hybrids and lines from the collection of the A. L. Mazlumov All-Russian Research Institute of Sugar Beet and Sugar: O-type 709, MS 709, Karioka, Mitika, Michelle, Granate, Zephyr, Murray, Portland, Tinker, and Veitura. They were soaked in 10 %, 20 %, and 30 % aqueous solution of the silver preparation (high-colloidal solution) for 15 seconds.

To obtain a silver solution, tap water was used. In order to obtain a 10% aqueous solution of the preparation, 10 ml of it was diluted with 90 ml of water. In a 20% aqueous solution, the proportion of components was 20 ml of it and 80 ml of water, in 30 % aqueous solution – 30 ml and 70 ml accordingly.

Seeds sprouted on a filter paper in plastic containers in four replications with 100 seeds per replication. The containers were kept under laboratory conditions at a constant temperature range of 22-25 °C. As a control, seeds of the same hybrid were used. They were soaked in tap water. Analysis of the solution influence on sugar beet seed sowing qualities – germinative energy, seedling length, seedling mass – were carried out. To study the emergence rate of seeds, seedlings were counted four days after the beginning of seed sprouting according to Russian Standards of seed germination (GOST 22617.2-94). The germinative energy of seeds is the germination speed expressed as the percent of emerged seeds (the ones that have formed roots that length is half of the seed length and seedlings) within the period determined by preliminary seed sprouting experiments. For field crops, it varies in the range from 3 to 15 days (Geister, 1934). A seedling is a plant at one of the initial ontogenesis stages, in the period from the moment of seed germination (that is, the moment when the developing embryo breaks through seed coat) till the moment when the leaf of the main shoot (the shoot developed from embryo bud) appears (Korovkin, 2007). The seedling length was measured with the help of a ruler four days after the experiment starts. The seedling mass was determined at four days using an electronic balance.

Statistical processing of the results was conducted using the Stadia software package. The procedure of data grouping and processing is stated in A. P. Kulaichev (2006) work. Average values of seedling lengths and seedling mass were compared using Student's *t*-test. The emergence rate of seeds in control and experimental variants were compared using Z-test for equality of frequencies. An increase in sugar beet emergence rate, length of seedlings, and mass of seedlings in the experiment as compared to the control (%) were calculated. The influence of the factor "treatment with the chemical compound" in different concentrations upon the listed traits was determined using a one-way analysis of variance. Power of influence was calculated according to Snedecor (%).

3. RESULTS AND DISCUSSION:

The influence of the preparation on the germinative energy, seedling length, and seedling mass is presented in Tables 1 and 2. Analyzing Table 1, it was noted an increase in the germinative energy after the treatment of sugar beet seeds with a 10% aqueous solution of the chemical compound in the studied hybrids compared to the control (P<0.05). The exceptions were Karioka, Mitika, Michelle, Veitura, characterized by high (93-100%) germinative energy in the control variant and lower in the experiment, Portland (81%), and Tinker (92 %). 20 and 30 % concentration of the solution in some variants inhibited seed germination (Table 2). In general, the increase of the germinative energy in the experimental variant of 10 % concentration was 4-12% concerning the control.

Table 1 shows an increase of the seedling length in hybrids, including Carioca and Portland, compared to the control (P<0.05, P<0.01), after seed treatment with a 10% nanosilver solution, except such as Mitika, Michelle, Veitura. The increase in the average length of the seedling in the O-type 709 hybrid was 37.8%; for MS 709 – 67.5%; Karioka – 38.1%; from Granate and Zephyr – 22.2%; Portland – 22.4% and Tinker – 16.1% concerning the control.

However, a decrease in the seedling length was revealed in comparison with the control variant (P<0.05) in the Murray hybrid, which showed an increase in germinative energy. This indicates a different reaction of the embryo of hybrids to the treatment factor with the preparation: positive in seeds with lower germinative energy and, conversely, negative – in seeds with high sowing qualities, which is evidence of the genetic diversity of seeds.

Seedling mass was not in all cases associated with length. For example, an increase of the seedling length in the experimental variant (P<0.05) did not cause a corresponding increase of the mass in hybrids Pomegranate, Zephyr, Tinker (Tables 1 and 2). This indicates the heterogeneity of the hybrids in their properties. The seedling mass change corresponded to the length in the remaining hybrids after seed treatment with a 10% solution, which is not typical in cases of 20 and 30% concentration for the same variants (Table 2). The increase of the average seedling mass in the experimental variant of 10% concentration in the O-type 709 hybrid was 23.1%; for MS 709 - 60%; Karioka – 28.6% concerning the control. The seed treatment with 20 and 30% solution of the preparation more often had a depressing effect on the seedling length and the seedling mass.

Power of influence of the factor “sugar beet seed treatment with an aqueous solution of the chemical compound” on the germinative energy, the seedling length, and weight were evaluated according to the results of one-way analysis of variance (Tables 3, 4, 5). The power of influence of the factor “sugar beet seed treatment with an aqueous solution of the chemical compound” on emergence rate was lower than on seedling length and mass.

Thus, the different reaction of the embryo to the factor of seed treatment with the chemical substance of the same solution concentration to different hybrids indicates the genetic diversity of seeds. This is manifested in unequal changes of the studied traits: germinative energy, seedling length, seedling mass. Treatment of seeds of sugar beet hybrids with germinative energy below 92% by an aqueous solution of the preparation in 10% concentration allows to reveal their variability and improve sowing qualities.

Previously conducted experiments have shown suppression of radial growth of colonies of all the fungi species investigated when adding the modified colloidal silver in concentration (active substance) more than 10 ppm (1 ppm = 1 mkg/ml = 1 mg/l) (Mitsa *et al.*, 2014). Fungicidal properties have been evaluated on agar pea medium with the addition of Zerox in the concentrations of 0.1, 1, 10, and 100 mg/l (active substance). The fungicide effectiveness evaluation on the nutrient medium under laboratory conditions has shown that the stabilized colloidal silver is effective against strains of all the investigated species of fungi and oomycetes (EC_{50} <19 ppm) (Elansky *et al.*, 2014).

The colloidal silver fungicidal effect evaluation results were similar to the data obtained during the evaluation of fungicidal effectiveness of silver nanoparticles in other laboratories of the world (Elansky *et al.*, 2014; Mitsa *et al.*, 2014). In works of other authors, similar EC_{50} values for unmodified silver nanoparticles were presented: *Alternaria alternata* (EC_{50}=38 mg/l), *A. solani* (about 10 mg/l), *Fusarium* (from 9 to 55 mg/l in different species), *Pithium* (about 2 mg/l), *Colletotrichum* (from 8 to 100 mg/l in different species) (Lamsal *et al.*, 2011; Kim *et al.*, 2012). Effective concentrations (EC_{50}) for silver nanoparticles concerning sclerotium-forming species (6-7 mg/l) (Min *et al.*, 2009) exceed the EC_{50} for the preparation regarding the same species (0.4-3.9 mg/l, accordingly) (Elansky *et al.*, 2014; Lamsal *et al.*, 2011; Kim *et al.*, 2012; Min *et al.*, 2009). Synergism of antibiotics and the silver preparation effect concerning the strains resistant to antibiotics has been revealed, though, with the addition of the silver preparation, no intensification of effective antibiotics’ influence has been registered (Khodykina *et al.*, 2014). There are used more concentrations: 300-900 mg/l (active substance) for revealing the genetic diversity of seeds in our experiments. Reactions of genotypes of sugar beet on the provocative factor (chemical compound) were different from each other.

A method of pre-sowing treatment for seeds of agricultural plants by spraying the seeds with a solution of the biologically-active substance in which a source of silver ions was the colloidal solution of silver nanoparticles AgBion-2 before sowing is known; the concentration of the substance in the working solution is 0.0047 %, and the rate of its application is 10 l/ton of seeds (Usanova *et al.*, 2012). However, the method of treatment by spraying seeds with a solution of the biologically-active substance has a disadvantage: an uneven distribution of the compound over the seed surface is possible. To avoid it, an additional device (generator) for even distribution of the compound is necessary (Pshechenkov *et al.*, 2016). Soaking of seeds in an aqueous solution of the silver preparation promotes even distribution of the compound over seed surface and allows the entire use of its potentialities with minimal material inputs.

4. CONCLUSIONS:

Thus, the direction of the research on the effect of the pre-sowing seed treatment with a silver solution is to study the response of genotypes of different lines and hybrids of sugar beet seeds and the systemic formation of a biologically active nutrient and fungicidal environment on the seed surface with a complex effect on growth processes in the embryo, suppression of pathogenic principles on the surface of seeds that enter the soil. All of the above leads to an increase in the field germination, the activation of seedlings in the early stages of growth and the development, as a result, to an increase in yield. In this regard, it is relevant to study compounds that can be used as pesticides and growth regulators and provoking factors to identify genetic heterogeneity at the early stages of plant development.

5. REFERENCES:

1. Balagura, O. V., Levshakov, L. V. (2013). Diversity of sugar beet seeds and its significance. *Bulletin of the Kursk State Agricultural Academy*, 9, 52-54.
2. Balan, V. N. (2000). Diversity of seeds. *Sugar beet*, 1, 15-17.
3. Baranova, T. V., Kalaev, V. N. (2017). Comparative Cytogenetic Analysis of Indigenous and Introduced Species of Woody Plants in Conditions of Anthropogenic Pollution. In: Nourani, C. F., Zaikov, G. E., Weisfeld, L. I., Lisitsyn, E. M., Bekuzarova, S. A. (Eds.); Heavy Metals and Other Pollutants in the Environment: Biological Aspects. Oakville: Apple Academic Press Inc., 241-254.
4. Baranova, T. V., Kalendar, R. N., Kalaev, V. N., Sorokopudov, V. N., Burmenko, Yu. V. (2018). Relationship between cytogenetic characteristics and molecular-genetic differences in species of the genus Rhododendron L. when introduced. *Agricultural Biology*, *53(3)*, 511-520. DOI: 10.15389/agrobiology
5. Bashmakov, D. I., Pynenkova, N. A., Sazanova, K. A., Lukatkin, A. S. (2012). Effect of the synthetic growth regulator Cytodef and heavy metals on oxidative status in cucumber plants. *Russian Journal of Plant Physiology*, 59(1), 59-64.
6. Bome, N. A., Weisfeld, L. I., Bekuzarova, S. A, Bome, A. Y. (2015). Optimization of the Structurally Functional Changes in the Cultured Phytocoenoses in the Areas with Extreme Edaphic-Climatic Conditions. In: Weisfeld, L. I., Opalko, A. I., Bome, N. A., Bekuzarova, S. A. (Eds.); Biological Systems, Biodiversity, and Stability of Plant Communities, Oakville: Apple Academic Press Inc., 19-32.
7. Bukharina, I. L. (2011). Features of the dynamics of the content of ascorbic acid and tannins in the shoots of woody plants under the conditions of the city of Izhevsk. *Plant Resources*, *47(2)*, 109–117.
8. Burmenko, Yu. V., Baranova, T. V., Kalaev, V. N. (2018 a). Comparative Study of Cytogenetic Response of Silver Birch and *Rhododendron Ledebourii* Seeds to Urban Pollution in Voronezh. *Russian Journal of Forest Science*, *1*, 65-73. DOI: 10.7868/S0024114818010060
9. Burmenko, Yu. V., Baranova, T. V., Kalaev, V. N., Sorokopudov, V. N. (2018 b). Cytogenetic polymorphism of seed progeny of introduced plants on the example of Rhododendron ledebourii Pojark. *Turczaninowia*, 21 (1), *164–173.*

DOI: *10.14258/turczaninowia.21.1.16*

10. Denisov, A.N., Krutyakov, Yu.A., Kudrinsky, A.A., Zherebin, P.M., Elansky, S.N., Pobedinskaya, M.A., Klimov, A.I. (2014 a). Antiseptic preparation and methods for producing and using same: Patent WO2014200380 Russian Federation. International Application PCT/RU2013/000477, declared 10.06.13, published 18. 12.14.

11. Denisov, A.N., Krutyakov, Yu.A., Kudrinsky, A.A., Zherebin, P.M., Elansky, S.N., Pobedinskaya, M.A., Klimov, A.I. (2014 b). Fungicide and method of its use: Patent WO2014200379 Russian Federation. International Application PCT/RU2013/000476, declared 10.06.13, published 18. 12.14.

12. Elansky, S. N., Pobedinskaya, M. A., Kokaeva, L. Yu., Kutuzova, I. A., Pronicheva, I. S., Mytsa, E. D., Klimov, A. I., Kuznetsova, M. A., Kozlovsky, B. E., Zherebin, P. M., Denisov, A. N., Krutyakov, Yu. A. (2014). New preparate Zerox based on colloidal silver: laboratory test results. *Potato protection*, 1, 41–43.

13. Fachi, L. R., Krause, W., Duarte, H., Viana, A. P. (2019). Digital image analysis to quantify genetic divergence in passion fruit (*Passiflora edulis*) seeds. *Genetics and Molecular Research*, *18(3)*. DOI: 10.4238 / gmr18331

14. Gar'kova, A. N., Rusyaeva, M. M., Nushtaeva, O. V., Aroslankina, Y. N., Lukatkin, A. S. (2011). Treatment with the herbicide granstar induces oxidative stress in cereal leaves. *Russian Journal of Plant hysiology*, *58(6)*, 1074-1081.

15. Geister, A. I. (1934). Agricultural Dictionary. Moscow–Leningrad: Selkhozgiz.

16. GOST 22617.2-94. (1994). Sugar beet seeds. Methods for determining germination, single sprout and good quality. Interstate Council for Standardization, Metrology and Certification. Minsk.

17. Ivanov, V. B. (2011). Using the roots as test objects for the assessment of biological action of chemical substances. *Russian Journal of Plant Physiology, 58(6)*, 1082-1089.

18. Jo, Y. K., Kim, B. H., Jung, G. (2009). Antifungal activity of silver ions and nanoparticles on phytopathogenic fungi. *Plant. Dis.*, 93, 1037–1043.

19. Kalaev, V. N., Butorina, A. K., Sheluchina, O. Yu. (2006). Assessment of anthropogenic pollution in the districts of Stary Oskol based on cytogenetic indicators of seed seedlings of weeping birch. *Ecological genetics*, 4(2), 9–23.

20. Khodykina, M.V., Politiko, V.A., Kyrova, E.I., Krutyakov, Yu.A., Zherebin, P.M., Ignatov, A.N. (2014). Antibacterial activity of antibiotics in combined with Zerox® silver preparation against pathogens of a number bacterioses of plants. *Potato protection*, 2, 83–86.

21. Kim, S. W., Jung, J. H., Lamsal, K., Kim, Y. S., Min, J. S., Lee, Y. S. (2012). Antifungal effect of silver nanoparticles (AgNPs) against various plant pathogenic fungi. *Micobiology*, 40(1), 53–58.

22. Korovkin, O. A. (2007). Anatomy and morphology of higher plants: glossary. Moscow: Drofa.

23. Krutyakov, Yu. A., Kudrinskiy, A. A., Olenin, A. Yu., Lisichkin, G. V. (2008). Synthesis and properties of silver nanoparticles: advances and prospects. *Russ. Chem. Rev.*, 77 (3), 233–257 DOI: https://doi.org/10.1070/RC2008v077n03ABEH003751

24. Kulaichev, A. P. (2006). Methods, and tools for integrated data analysis. Moscow: FORUM: INFA-M.

25. Kuzemko, A. A. (2016). Influence of Anthropogenic Pressure on Environmental Characteristics of Meadow Habitats in the Forest and Forest-Zones. In: Bekuzarova, S. A., Bome, N. A., Opalko, A. I. (Eds.); Temperate Crop Science and Breeding: Ecological and Genetic Studies, Oakville: Apple Academic Press Inc., 385-404.

26. Lamsal, K., Kim, S. W., Jung, J. H., Kim, Y. S., Kim, K. S., Lee, Y. S. (2011). Application of silver nanoparticles for the control of Colletotrichum species in vitro and pepper anthracnose disease in field. *Mycobiology*, 39(3), 94–199.

27. Lapshina, L. A., Reunov, A. V., Nagorskaya, V. P. (2016). Effects of exogenous H_2O_2 on the content of

endogenous H_2O_2, activities of catalase and hydrolases, and cell ultrastructure in tobacco leaves. *Biology Bulletin*, *43(5)*, 419-425.

28. Lisichkin, G. V. (2019). Surface Compound Chemistry, and its applications. http://www.chemnet.ru/rus/SummerSchool2019/presentations/lisichkin.pdf

29. Lyanguzova, I. V. (2011). Effect of industrial air pollution on wild plant seed germination and seedling growth. *Russian Journal of Plant Physiology,* 58(60), 991-998.

30. Min, J. S., Kim, K. S., Kim, S. W., Jung, J. H., Lamsal, K., Kim, S. B., Jung, M., Lee, Y.S. (2009). Effect of colloidal silver nanoparticles on sclerotium-forming phytopathogenic fungi. *Plant Pathology Journal*, 25, 376–380.

31. Mita, E. D., Elansky, S. N., Kokaeva, L. Yu., Pobedinskaya, M. A., Ignatov, A. N., Kuznetsova, M. A., Kozlovsky, B. E., Denisov, A. N., Zherebin, P. M., Krutyakov, Yu. A. (2014). New pesticide Zerox – assessment of fungicidal and bactericidal properties in vitro. *Achievements of science and technology of the agro-industrial complex*, 28(12), 16–19.

32. Neverova, O. A. (2004). Ecological assessment of the state of woody plants and environmental pollution of an industrial city (by the example of Kemerovo): Thesis for the degree of Doctor of Biology: Moscow**.**

33. Opalko, A. I., Opalko, O. A. (2915). Anthropo-Adaptability of Plants as a Basis Component of a New Wave of the “Green Revolution”. In: Weisfeld, L. I., Opalko, A. I., Bome, N. A., Bekuzarova, S. A. (Eds.); Biological Systems, Biodiversity, and Stability of Plant Communities, Oakville: Apple Academic Press Inc., 3-18.

34. Oudalova, A. A., Geras’kin, S. A. (2012). The Time Dynamics and Ecological Genetic Variation of Cytogenetic Effects in the Scots Pine Populations Experiencing Anthropogenic Impact. *Biology Bulletin Reviews*, 2(3), 254–267.

35. Polishchuk, V. V. (2013). Seed quality, and productivity of sugar beet O-type lines at low temperatures. *Plant Varieties Studying and Protection*, 2, 20-22.

36. Popov, V. N., Eprintsev, A. T., Maltseva, E. V. (2011). Activation of genes encoding mitochondrial proteins involved in alternative and uncoupled respiration of tomato plants treated with low temperature and reactive oxygen species. *Russian Journal of Plant Physiology*, *58(5)*, 914-920.

37. Pozolotina, V. N., Antonova, E. V., Bezel, V. S. (2010 a). Long-Term Effects in Plant Populations from Zones of Radiation and Chemical Pollution. *Radiological Biology. Radioecology,* 4, 414–422.

38. Pozolotina, V. N., Antonova, E. V., Karimullina, E. M. (2010 b). Assessment of Radiation Impact on Stellaria graminea coenopopulations in the Zone of the Eastern Ural Radioactive Trace. *Russian Journal of Ecology*, 41(6), 459–468.

39. Pshechenkov, K. A., Zeyruk, V. N., Elansky, S. N., Maltsev, S. V., Pryamov, S. B. (2016). Potato storage. Moscow: Agrospas**.**

40. Titov, V. N., Smyslov, D. G., Dmitrieva, G. A., Bolotova, O. I. (2011). Plant growth regulators as a biological factor in reducing the level of heavy metals in a plant. *Vestnik OrelGAU*, *31(4),* 4–6.

41. Tsareva, L. E. (2010). Influence of seed planting schemes on the yield and properties of sugar beet seeds. *Bulletin of Altai State Agrarian University*, 3(65), 21-24.

42. Tsareva, L. E. (2013). Technique of improving yielding features of seeds in reproduction of sugar beet hybrids. *Bulletin of Altai State Agrarian University*, 1 (99), 17–19.

43. Usanova, Z. I., Shalnov, I. V., Ivanyutina, N. N., Sutyagina, T. I., Babich, N. V. (2012). Method of presowing treatment of seeds of agricultural plants. Patent 2463757, Russian Federation, FSEI HPE "TGSA" (RU), 29.

44. Vetchinnikova, L. V. (2004). Birch: questions of variability (morphophysiological and biochemical aspects) (Ed.); Titov, A. F., M.: Science.

45. Vostrikova, T. V. (2011). Ecological and biological features of rhododendrons during introduction in the conditions of the Central Chernozem region. *Bulletin of*

Krasnoyarsk State Agrarian University, 4, 27–30.

46. Welbaum, G. E., Bradford, K. J., Yim, K.-O. Booth, D. T. (1998). Biophysical, physiological and biochemical processes seed germination. *Seed Science Research*, *8(02),* 161–172.
47. Yakymchuk, R. A. (2015). Cytogenetic After-Effects of Mutagen Soil Contamination with Emissions of Burshtynska Thermal Power Station. In: Opalko, A. I., Weisfeld, L. I., Bekuzarova, S. A., Bome, N. A., Zaikov, G. E. (Eds.); Ecological Consequences of Increasing Crop Productivity: Plant Breeding and Biotic Diversity: New Jersey: Apple Academic Press Inc., 217-227.
48. Zherebin, P. M., Ignatov, A. N., Elansky, S. N., Pobedinskaya, M. A., Lisichkin, G. V., Denisov, A. N., Krutyakov, Yu. A. (2014). “Zerox”-silver-based preparate for an effective control of bacterial and fungal epidemic diseases of agricultural plants. *Potato protection*, 2, 43–45.
49. Zherebin, P. M., Krutyakov, Yu. A., Kudrinsky, A. A., Klimov, A. I., Elansky, S. N., Pobedinskaya, M. A., Ignatov, A. N. (2015). "Zerox": a new bactericide and fungicide of wide spectrum of action based on colloidal silver. *Young scientist*, 9.2, 25-26.

Table 1. *Qualities of seeds and seedlings from sugar beet treated with 10 % aqueous solution of the inorganic chemical compound*

No	Line/ hybrid	Control (tap water)			10 % solution		
		GE, %	length, cm	mass, g	GE, %	length, cm	mass, g
1	O-type 709	83	3,7±0,1	1,3±0,02	95*	5,1±0,1**	1,6±0,02*
2	MS 709	81	4,0±0,1	1,0±0,01	85*	6,7±0,2**	1,6±0,02**
3	Karioka	93	4,2±0,1	1,4±0,02	87*	5,8±0,2**	1,8±0,02*
4	Mitika	98	5,4±0,2	2,0±0,03	96	3,8±0,1**	1,4±0,02**
5	Michelle	100	7,1±0,3	2,4±0,03	96	6,8±0,3	1,8±0,03*
6	Granate	81	5,4±0,1	1,9±0,02	92*	6,6±0,2*	1,5±0,02*
7	Zephyr	92	5,4±0,2	1,6±0,02	97*	6,6±0,3*	1,5±0,02
8	Murray	90	6,8±0,3	2,0±0,03	98*	6,0±0,2*	1,9±0,03
9	Portland	81	4,9±0,1	1,8±0,02	81	6,0±0,3*	2,0±0,03
10	Tinker	92	5,6±0,2	2,4±0,03	93	6,5±0,3*	2,3±0,03
11	Veitura	97	6,3±0,3	2,0±0,02	87*	3,5±0,2**	1,4±0,02**

*Note: GE – seed germinative energy; length – seedling length; mass – seedling mass; * –differences with the control are reliable (P<0.05); ** – differences with the control are reliable (P<0.01).*

Table 2. *Qualities of seeds and seedlings from sugar beet treated with 20 and 30 % aqueous solution of the inorganic chemical compound*

No	Line/ hybrid	Control (tap water)			20 % solution			30 % solution		
		GE, %	length, cm	mass, g	GE, %	length, cm	mass, g	GE, %	length, cm	mass, g
1	O-type 709	83	3,7±0,1	1,3±0,02	79	4,7±0,1*	1,2±0,01	84	3,6±0,1	1,4±0,02
2	MS 709	81	4,0±0,1	1,0±0,01	72*	4,7±0,1*	1,0±0,01	85*	4,1±0,1	1,2±0,01
3	Karioka	93	4,2±0,1	1,4±0,02	95	4,9±0,1*	1,5±0,02	90	4,4±0,2	1,2±0,01
4	Mitika	98	5,4±0,2	2,0±0,03	90*	4,1±0,1*	1,4±0,02**	96	3,6±0,1**	1,5±0,02*
5	Michelle	100	7,1±0,3	2,4±0,03	92*	6,0±0,3*	1,8±0,03*	86*	5,1±0,2**	1,4±0,02**
6	Granate	81	5,4±0,1	1,9±0,02	91*	4,2±0,1*	1,5±0,02*	84	4,2±0,2*	1,2±0,02**
7	Zephyr	92	5,4±0,2	1,6±0,02	96*	5,6±0,2	1,4±0,02	95	4,0±0,1*	1,2±0,02*
8	Murray	90	6,8±0,3	2,0±0,03	90	5,0±0,2*	1,4±0,02**	80*	4,7±0,2*	1,2±0,01**
9	Portland	81	4,9±0,1	1,8±0,02	81	4,8±0,2	1,3±0,02*	82	5,8±0,3*	1,3±0,02*
10	Tinker	92	5,6±0,2	2,4±0,03	92	3,3±0,1**	1,3±0,01**	76*	4,1±0,1*	1,1±0,01**
11	Veitura	97	6,3±0,3	2,0±0,02	90*	4,2±0,2**	1,3±0,02**	68*	3,0±0,1**	1,0±0,01**

*Note: GE – seed germinative energy; length – seedling length; mass – seedling mass; * –differences with the control are reliable (P<0.05); ** – differences with the control are reliable (P<0.01).*

Table 3. *Power of influence of the factor "sugar beet seed treatment with an aqueous solution of the chemical compound" on germinative energy (%)*

No.	Line / hybrid	With control	Without control
1	O-type 709	4.0**	4.5**
2	MS 709	3.0**	3.7**
3	Karioka	2.9**	3.2**
4	Mitika	3.4**	3.1**
5	Michelle	3.8**	3.3**
6	Granate	3.6**	3.4**
7	Zephyr	2.7**	-
8	Murray	3.1**	3.5**
9	Portland	-	-
10	Tinker	3.0**	3.3**
11	Veitura	4.7**	4.4**

*Note: ** – the influence of factor is reliable (P<0.01).*

Table 4. *Power of influence of the factor "sugar beet seed treatment with an aqueous solution of the chemical compound" on seedling length (%)*

No.	Line / hybrid	With control	Without control
1	O-type 709	6.0**	6.5**
2	MS 709	7.3**	7.1**
3	Karioka	6.5**	6.3**
4	Mitika	6.7**	6.1**
5	Michelle	5.8**	4.3**
6	Granate	6.5**	6.8**
7	Zephyr	6.4**	6.9**
8	Murray	5.7**	5.2**
9	Portland	6.1**	6.3**
10	Tinker	5.0**	6.3**
11	Veitura	6.8**	4.4**

*Note: ** – influence of factor is reliable (P<0.01).*

Table 5. *Power of influence of the factor "sugar beet seed treatment with an aqueous solution of the chemical compound" on seedling mass (%)*

No.	Line / hybrid	With control	Without control
1	O-type 709	4.0**	4.5**
2	MS 709	6.3**	6.0**
3	Karioka	5.5**	5.2**
4	Mitika	5.7**	5.1**
5	Michelle	6.8**	5.3**
6	Granate	5.5**	5.8**
7	Zephyr	5.4**	5.9**
8	Murray	4.7**	3.2**
9	Portland	4.5*	4.8**
10	Tinker	6.0**	7.3**
11	Veitura	7.8**	5.4**

*Note: ** – influence of factor is reliable (P<0.01).*