**SISTEMA DE PROTEÇÃO DA BATATA CONTRA PRAGAS E DOENÇAS PARA
OBTER PRODUTOS ECOLOGICAMENTE LIMPOS****SYSTEM OF PROTECTION FOR POTATO FROM PESTS AND DISEASES TO GET
ECOLOGICALLY CLEAN PRODUCTS****СИСТЕМА ЗАЩИТЫ РАСТЕНИЙ КАРТОФЕЛЯ ОТ ВРЕДИТЕЛЕЙ И БОЛЕЗНЕЙ
ДЛЯ ПОЛУЧЕНИЯ ЭКОЛОГИЧЕСКИ ЧИСТОЙ ПРОДУКЦИИ**BUTOV, A. V.¹; ZUBKOVA, T. V.^{2*}^{1, 2} Bunin Yelets State University. Russian Federation.

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Received 16 June 2020; received in revised form 26 June 2020; accepted 04 July 2020

RESUMO

A batata compreende uma cultura alimentar estrategicamente importante na Federação Russa. A quimiocalização aprimorada da produção de batata, protegendo-a de pragas e doenças, permite obter altos rendimentos, mas ao mesmo tempo afeta significativamente a qualidade biológica dos produtos. A cadeia varejista frequentemente recebe muitos tubérculos com excesso de nitratos, enquanto contém os chamados pesticidas "de longa duração". Ao entrar no corpo humano com produtos, as substâncias tóxicas causam doenças graves. Há um problema agudo de fornecer às crianças produtos ecologicamente corretos. Essa pesquisa desenvolveu uma importante tarefa de neutralizar o acúmulo de inseticidas e fungicidas tóxicos em tubérculos pelo início da colheita ao cultivar variedades de batatas de médio porte. Isto foi conseguido quando se utiliza o inseticida Celest TOP (Tiametoxame, classe de risco 2) em normas reduzidas em 25%, em combinação com o uso de preparações biológicas Siliplant ou Albit e reduzidas em 40% em normas de fungicidas. O sistema de proteção incluiu: para tubérculos: Celestino 0,3 l/ha + Albite TPS 0,1 l/t; para os tops: Ridomil ouro MC VDG 1,5 kg / ha primeiro, segundo e terceiro tratamentos; Shirlan SK 0,24 l / ha 4-5º tratamento + Albit TPS 2 vezes para vegetação 0,05 l / ha ou Siliplant BP 2 vezes para vegetação 1,0 l / ha. As análises laboratoriais revelaram quantidades residuais de pesticidas e nitratos em tubérculos. Os produtos resultantes, com o sistema de proteção de plantas desenvolvido, atenderam às exigências de nutrição infantil e dietética. O método voltamétrico invertido foi usado para determinar a concentração de pesticidas em tubérculos. Os nitratos foram determinados usando um eletrodo seletivo de íons. Está estabelecido que o Prestige (Imidacloprid, classe de risco 1) é impraticável de usar na produção de batatas ecologicamente limpas. O uso de Celest (Thiamethoxam, classe de risco 2) em combinação com Albit ou Siliplant aumentou o rendimento e reduziu o conteúdo de substâncias tóxicas nos tubérculos.

Palavras-chave: *pesticidas modernos, agentes biológicos, nitratos.***ABSTRACT**

Potatoes comprise a strategically important food crop in the Russian Federation. Enhanced chemicalization of potato production, while protecting it from pests and diseases, allows you to get high yields, but at the same time significantly affects the biological quality of products. The retail chain often receives lots of tubers with excess nitrates, while containing the so-called "long-playing" pesticides. Getting into the human body with products, toxic substances cause severe diseases. There is an acute problem of providing children with environmentally friendly products. This research developed an important task of neutralizing the accumulation of toxic insecticides and fungicides in tubers by the beginning of harvesting when cultivating medium-early varieties of potatoes. This was achieved when using the insecticide Celest TOP (Thiamethoxam, hazard class 2) in reduced by 25% norms, in combination with the use of biological preparations Siliplant or Albit and reduced by 40% norms of fungicides. The protection system included for tubers: Celestine 0.3 l/ha + Albite TPS 0.1 l/t. For tops: Ridomil gold MC VDG 1.5 kg / ha first, second and third treatments. Shirlan SK 0.24 l / ha 4-5-th treatment + Albit TPS 2 times for vegetation 0.05 l / ha or Siliplant BP 2 times for vegetation 1.0 l / ha. Laboratory analyses revealed residual amounts of pesticides and nitrates in tubers. The resulting products, with the plant protection system developed by us, meet the requirements for children's and dietary nutrition. The inversion voltammetric method was used to determine

the concentration of pesticides in tubers. Nitrates were determined using an ion-selective electrode. It is established that Prestige (Imidacloprid, hazard class 1) is impractical to use in producing ecologically clean potatoes. Using Celest (Thiamethoxam, hazard class 2) in combination with Albit or Siliplant increased the yield and reduced the content of toxic substances in tubers.

Keywords: *modern pesticides, biological agents, nitrates.*

АННОТАЦИЯ

Картофель - стратегически важная продовольственная культура в Российской Федерации. Усиленная химизация производства картофеля при защите его от вредителей и болезней, позволяет получать высокие урожаи, но при этом значительно страдает биологическое качество продукции. В торговую сеть нередко поступают партии клубней с превышением нитратов, содержащие при этом, так называемые, «долгоиграющие» пестициды. Попадая в организм человека с продукцией, отравляющие вещества, вызывают тяжелые заболевания. Возникает острая проблема по обеспечению экологически чистой продукцией детей. Нашими исследованиями решена важная задача по нейтрализации накопления токсичных инсектицидов и фунгицидов в клубнях к началу уборки при возделывании среднераннего сорта картофеля. Это достигается при использовании инсектицида Селеста ТОП (по тиаметоксаму 2-й класс опасности) в уменьшенных на 25% нормах, в сочетании с применением биопрепаратов Силиплант или Альбит и сниженными на 40% нормами фунгицидов. Система защиты включала по клубням: Селест Топ 0,3 л/га + Альбит ТПС 0,1 л/т. По ботве: Ридомил Голд МЦ ВДГ 1,5 кг/га первая, вторая и третья обработки. Ширлан СК 0,24 л/га 4-5-я обработки + Альбит ТПС 2 раза за вегетацию 0,05 л/га или Силиплант ВР 2 раза за вегетацию 1,0 л/га. Лабораторными анализами выявлены остаточные количества пестицидов и нитратов в клубнях. Полученная продукция, при разработанной нами системе защиты растений, отвечает требованиям предъявляемым к детскому и диетическому питанию. Для определения концентрации пестицидов в клубнях использовали инверсионный вольтамперометрический метод. Определение нитратов проводили с помощью ионоселективного электрода. Установлено, что Престиж (по имидаклоприду 1-ый класс опасности) нецелесообразно применять в производстве экологически чистой продукции. Применение инсектофунгицида Селест (по тиаметоксаму 2-й класс опасности) в сочетании с биопрепаратами Альбит или Силиплант повышало урожайность и уменьшало содержания токсических веществ в клубнях.

Ключевые слова: *современные пестициды, биопрепараты, нитраты.*

1. INTRODUCTION:

Potatoes comprise a strategically important food crop in the Russian Federation. The population even calls it a "second bread". Pests and diseases may severely damage potatoes. The fight against some of them has become a routine in potato cultivation. These dangers primarily include the Colorado potato beetle, wireworm (elaterid larva), dangerous fungal diseases (late blight), bacterial rot, and various viral diseases. The annual under-harvest of potatoes because of these factors depends on the variety and ranges from 20 to 30%. In adverse years, the under-harvest can be exceeded by 50% (Tulcheev and Yagforov, 2014). An integrated system for the protection of potatoes from diseases, pests, and weeds is a set of measures, among which the chemical method is the primary one (Zeyruk *et al.*, 2019b). The enhanced chemicalization of potato production allows for getting high yields, but the biological quality of the product can suffer greatly (Butov, Zakharov, and Zubkova,

2019). Often the over-nitrated tubers containing so-called "long-lasting" pesticides arrive at shops and markets (Damodaran, Tarkin, and Fennema, 2012). These pesticides may cause serious illnesses in human beings when consumed (Kaplin, 2007). They also have an allergenic and carcinogenic effect and may destroy human immunity (Chernikov and Sokolov, 2014). Chemophobia is becoming more popular among the population. People are wary of products grown industrially and they do not tend to learn more about the technological processes, it is enough for them to know about the use of pesticides and fertilizers in agriculture (Edelev, Grebenkin, Baranov, and Royev, 2013). This may undermine not only the physical but also the spiritual health of a person (Lysenko and Dogadina, 2015). Another urgent problem is the poor preservation of tubers in the post-growing season (Simakov, Starovoitov, and Anisimov, 2013). A complete rejection of pesticides at the current level of agronomic science development is impossible. However, it is quite possible to reduce significantly their

negative impact (Fokina, Ogorodnikova, Olkova, Skugoreva, and Lyalina, 2015). Potato cultivation in the Central black-earth region of the Russian Federation is becoming increasingly complex from year to year and requires serious measures and financial influx to control pests and diseases (Fedotov, Butov, and Goncharov, 2005). The most dangerous is the Colorado potato beetle (*Leptinotarsa decemlineata*) and late blight disease. Without proper measures on protecting, these pests and diseases can cause huge damage to the yield of the crop. They may reduce the yield by 60-70%, and destroy it (Zeyruk *et al.*, 2019a). Recently, there appeared modern, highly effective pesticides with a hazard class lower than the previous generation. There is a need to develop a new system for protecting potato plants from diseases and pests with a reduced rate of pesticides in combination with biological agents (Zeyruk *et al.*, 2019a; Rabinovich and Fomicheva, 2018). Around thirty years ago, there was outstripping growth in population demand for ecologically clean products in Western Europe and North America (Kochurko, Abarova, and Zuev, 2013). Russian Federation does not have legislation, certification, and policy of financial support for ecologically clean products. Producers of biologically high-quality potatoes need clear recommendations for guaranteed production of a sufficiently good, ecologically clean tuber crop (Butov and Boeva, 2013).

The purpose of the study was to establish methods of effective protection of potato plants from pests and diseases. It is needed to reduce pesticides and get ecologically clean products. Besides, it was aimed to substantiate the methods of using Celest (with a hazard class lower than the previously used agent Prestige) in combination with Albit and Siliplant.

The scope of the research included the development of an effective and environmentally friendly system for the comprehensive protection of potatoes from economically significant pests and pathogens in the black-earth forest-steppe of the Russian Federation using modern plant protection products and methods.

The scientific novelty of the research is the development of combining Celest (a modern insectofungicide) with Albit, Siliplant at reduced pesticide rates to obtain ecologically clean, a good level of the potato harvest.

2. MATERIALS AND METHODS:

Field experiments were carried out in 2015-2017 at the educational experimental farm of Bunin Yelets State University (Lipetsk region, Russian Federation). The soil of the plots was leached black-earth, medium loamy with a 5.8% humus content (according to Tyurin). The area of the experimental plot was 54 m², and the repetition of the experimental cases was 4-fold/ Potato variety is mid-season Nevsky. The planting density of tubers is 54–55 thousand/ha at potato spacing - 75 cm. Mineral fertilizers in a dose of N₇₅P₁₅₀K₁₂₀ were applied in the general background in spring, after separating the experiments following the research program. Nitrogen dose (N₇₅) in full mineral fertilizer was reviewed in the previous studies on nitrates in experiments with fertilizers (Butov *et al.*, 2019). In the spring, the soil underwent the pre-planting treatment upon the onset of its physical ripeness. Potato planting during the years of the experiments depended on weather conditions and occurred from May 11 to May 14. Harvesting and accounting of the crop were in the third decade of August.

The inversion voltammetric method (GOST R 51301–99) was used to determine the concentration of pesticides in tubers. Nitrates were determined according to the procedure based on the extraction of nitrates from the analyzed material with a solution of aluminum-potassium alum, followed by measuring their concentration in the resulting extract using an ion-selective electrode (Mineev, 2011). The analysis-of-variance method by Dospekhov (2012) was applied to process the crops mathematically.

In the experiments, the following agents were applied: Ridomil Gold MZ (Mancozeb), which is a systemic fungicide against potato diseases, Revus (Mandipropamide + Difenconazole), which is a translaminar fungicide, Shirlan (Fluazinam), which is a contact fungicide, and Prestige SC (Imidacloprid + Pentacuron), which is an insectofungicidal agent. The Imidacloprid pesticide has the highest, first hazard class. Celest TOP, SC (Thiamethoxam + Fludioxonil + Difenconazole) has the second hazard class, which is less than that of Prestige. Prestige SC and Celest TOP are combined insecticidal fungicide protectants for seed potato tubers. Albit is an effective complex biological agent, a universal plant growth regulator, with the properties of a fungicide and

complex fertilizer. Siliplant is a complex fertilizer; its active substance is bioactive silicon in chelated form, supplemented with trace elements (iron, zinc, magnesium, copper, boron).

Spraying seed tubers with dressing agents was done directly in the combined seed planter "Grimme" during planting. Following the research scheme, knapsack sprayers were used to treat the studied agents in vegetating plants. Tuber samples were analyzed for residual fungicides in case 3, where full pesticide rates were applied.

3. RESULTS AND DISCUSSION:

Economically significant pests and pathogens of diseases can significantly reduce the potential yield of potatoes (Zeyruk *et al.*, 2019a). Account of the tuber yield in the harvesting experiment showed that the modern means and methods of plant protection had a noticeable effect on its value (Table 1). Thus, the first control case with plant protection only against the Colorado potato beetle (*Leptinotarsa decemlineata*) (fungicides were not used) delivered a yield of 23.5 t/ha. The yield increased to 34.1 and 34.9 t/ha respectively with an intensive system of plant protection against pests and diseases in combination at full rates of pesticides and new biological agents for cases 4 and 6. All other cases, except for the control case, envisage measures to control the Colorado potato beetle (*Leptinotarsa decemlineata*) by applying insectofungicides to tubers (in the planter's opener) when planting.

The modern insectofungicide Celest Top was more effective than Prestige. The yield increase in case 3 (Celest) was 1.7 t/ha compared with case 2 (Prestige). Adding Albit at full pesticide rates to the plant protection system in case 4 increased the yield by 3.4 t/ha, compared to the similar case 3, which did not have biological agents. Case 6 with Siliplant demonstrated a slightly higher yield (0.8 t/ha) than with Albit (case 4). However, this difference did not exceed the experimental error (1.6 t/ha) i.e. it is not reliable. The cases 5 and 7 with reduced by 40% rates of fungicides and Celest Top demonstrated yield decrease by 25%. The case 5 with Albit demonstrated yield decrease (in comparison with the case 4) by 2.6 t/ha. The case 7 with the Siliplant demonstrated

yield decrease by 1.8 t/ha (in comparison with the case 6).

However, despite a significant decrease, the yield level at reduced pesticide rates, but in combination with Albit or Siliplant biological agents, remained at a fairly high level - 31.5-33.1 t/ha against 23.5 t/ha for the control case. A slight decrease in yield can be neglected, when the production will be tasked with obtaining ecologically clean from pesticides potato products for baby and diet nutrition. The results of laboratory studies showed that the residual amount of insecticide in the tubers of the first (control) case was not detected when processing only on tops 40 days after the last spraying (Table 1).

Analyzes of the residual pesticide content in the tubers, according to the test cases, were done 4 times during the growing season with an interval of 10 days. The previously widely used Prestige (case 2), due to the Imidacloprid content, belongs to the first, highest class of danger. Besides, when determining Imidacloprid residual amounts in tubers, it turned out that its content was significantly higher in all cases of determination than the Thiamethoxam (Celest) content, which was used in case 3.

Thus, when determining 65-75 days after the treatment of tubers in the samples from the case 2, the content of Imidacloprid was 16.1% and 15.8% more than in the same periods for Thiamethoxam in the case 2 (Celest). In 95 days after the treatment of the tubers, at the end of the growing season and before harvesting, the content of Imidacloprid (case 2) in the samples was small, but it was 3 times higher than the content of Thiamethoxam in the case 3. This means that Prestige, in comparison with Celest, not only initially belongs to the first, highest hazard class, but it also significantly exceeds the toxicants content in tubers compared to cases with Celest throughout the growing season. This indicates that the Prestige (Imidacloprid) is a "long-lasting" pesticide. It is impractical to use it in the cultivation of potatoes to get ecologically clean products. Adding Celest, Albit, and Siliplant to the plant protection system effected positively not only by increased yields but also by a reduced content of toxic substances in tubers. Albit and Siliplant in combination with Celest effectively neutralized the level of toxic substances accumulation in tubers. This is especially noticeable when Celest's doses are reduced by 25% and when fungicides of various

classes are reduced by 40%. When treating seed tubers with Albit RP and then using it during the following two treatments at the vegetating plants as in the case 4, the level of the residual amount of Thiamethoxam decreased compared to the case 3, without Albit. Thus, Thiamethoxam content decreased by 2.7% on the 65th day after the treatment of tubers; and its content decreased by 15.4% on the 75th day after the treatment of the tops. Before harvesting on the 95th day after the completion of treatments with biological agents, the insecticide concentration in case 4 decreased by 47.8% compared to case 3, without Albit. A decrease in pesticide rates (by 25% of insecticide and by 40% of fungicides) in case 5 with Albit contributed to a more significant decrease in Thiamethoxam content in potato tubers. In the first stages of determination, 65 and 75 days after the treatment of tubers in the case 5, Thiamethoxam content was 25.4-25.9% less than with the full rate of insecticides in the same period in the case 4. A similar trend continued further in terms of determination. Thiamethoxam was not found in the tubers on the 95th day in case 5 with reduced Thiamethoxam rates. At reduced pesticide rates and with Albit RP, a complete absence of the Thiamethoxam insecticide in the potatoes is achieved at the time of harvesting. This fully complies with strict requirements (*SanPin 2.3.2.1078-01*, 2002) for ecologically clean potato products intended for children and medical institutions.

The plant protection system in cases 6 and 7 with Siliplant was the most successful, not only in terms of yield but also in terms of the lowest content of harmful substances in tubers at all times of determination. In case 7 with Siliplant and at reduced pesticide rates as well as in case 5, the insecticide in the tubers was reliably absent before harvesting (95 days after). As for case 6 with Celest and at full rates of pesticides, only traces of the Thiamethoxam insecticide were found in 2015 on the 95th day before harvesting. In 2016 and 2017, there was no insecticide in tubers in case 6 before harvesting. It should be noted that starting from a period of 75 days after the treatment of tubers with pesticides, the residual amount of insecticides (from 0.038-0.032 to 0.028-0.017 mg/kg) in almost all (2-7) cases did not exceed Maximum permissible level (MAL) of 0.05 mg/kg in raw tubers. However, before harvesting, their concentrations in cases 2, 3, and 4 were significantly lower than MAL - from

0.007 to 0.0012 mg/kg. The yield of crops obtained on the indicated cases corresponds to sanitary and hygienic requirements and standards (*SanPin 2.3.2.1078-01*, 2002), as ecologically clean potatoes suitable for the nutrition of the adult population. Toxic substances were not found by the time of harvesting in cases 5, 6, and 7. Therefore, the system of plant protection from pests and diseases studied in these cases can be recommended for the production of ecologically clean potatoes.

Figure 1 shows the dynamics of Thiamethoxam decomposition in tops and tubers when using Celest TOP. Figure 1 shows that Thiamethoxam persists in the tops of potatoes after processing the tubers when planted with Celest TOP at the level of 0.069-0.031 mg/kg for 85-95 days. This provides a long-term protective effect of Thiamethoxam against an economically significant pest - the Colorado potato beetle (*Leptinotarsa decemlineata*). Such protection of vegetating plants from the pest is quite enough for the medium early variety Nevsky.

At the same time, two fungicides that are part of Celest TOP protect young seeds from black speck and other crop diseases starting from the date of planting tubers. The dynamics of Thiamethoxam decomposition, as follows from Figure 1, was parallel to the toxicant's decomposition in the tops, although not strictly proportionally. Thus, for example, on day 95, the tops of case 6 demonstrated the presence of 0.031 mg/kg. However, it was already absent from the tubers.

In the first period of determination, 65 days after planting in the case 6 with full pesticide rates, the content of insecticide in tubers was 28.6% higher than the MAL values (0.05 mg/kg). At the same time, in the case 7 with the reduced by 25% Celest rate, the residual amount of Thiamethoxam (exceeding MAL only by 2%) was actually at the maximum allowable level (MAL). A positive difference towards a lower content of residual insecticide with reduced Celest rates (case 7) persisted throughout the growing season. When analyzing samples 95 days after treatment, Thiamethoxam was not found in the tubers in the cases presented in Figure 1, which indicates complete decomposition of the toxicant. Thus, the present studies have solved the important task of neutralizing the accumulation of toxic insecticides in tubers by harvesting time when cultivating a medium

early variety of potato. This is achieved by using Celest TOP in rates reduced by 25%, in combination with Siliplant or Albit and fungicide in rates reduced by 40%. Production of ecologically clean potatoes is guaranteed with the most acceptable plant protection system in cases 5 and 7.

During the growing season, three types of fungicides were used in the recommended (*Directory of pesticides ...*, 1917, 2015, 2016) and reduced by 40% rates following the experimental design to protect plants from diseases on tops. These included Ridomil Gold MZ WDG (systemic product), Revus SC (translaminar product), and Shirlan SC (contact product). Ridomil Gold MZ WDG is a toxic fungicide because of Mancozeb content: the second hazard class for humans and the third hazard class for bees. The residual amount of Mancozeb (Ridomil Gold MZ WDG) in the samples of tubers taken 5 days after the treatment of potato plants amounted to 0.024 mg. After 10 days, it amounted to 0.002 mg, and after 20 days, this fungicide was not found. In this case, the acceptable value for Mancozeb is 0.1 mg/kg. Revus fungicide containing two active Mandipropamide 25% and Difenconazole 25% is not dangerous for the environment, humans, and bees because of low toxicity. The hazard class for mammals is three and for bees is also three. There are no restrictions on using it in the sanitary zone around fisheries. It quickly decomposes in plants (7-10 days) (*Directory of pesticides ...*, 1917, 2015, 2016). No residual amount of this fungicide was tested due to its low toxicity and rapid decomposition. Shirlan with the active substance of Fluazinam (500 g/l) is hazard class 2 for humans and hazard class 3 for bees. However, the agent is harmful to the inhabitants of water bodies. MAL for potatoes is 0.05 mg/kg. In the present studies, the tuber samples were taken 5 days after treatment contained 0.031 mg/kg of Fluazinam, 10 days after - 0.003 mg/kg, 20 days after - no fungicide was found. The results of analyzes on the residual amount of fungicides indicate a relatively rapid decomposition in tubers. Already 10 days after the last treatment, the amount of fungicides is only 0.002-0.003 mg/kg, and after 20 days, they are completely absent. Besides, the fungicides, which were studied, belong to medium or low toxic hazard classes (2 and 3). As a result, the fungicides used in the experiments did not create an obvious strain in fulfilling the task of obtaining ecologically clean potatoes. However, for guaranteed quality of

products supplied to children and medical institutions, it is advisable to reduce the rates of fungicides by 40%, as it is done in cases 5 and 7. In general, the level of chemicalization of cultivation should be significantly reduced when performing such a task to avoid inconsistencies and errors arising in large-scale production.

Nitrates are a significant hazard to human and animal health. Nitrites are formed from nitrates in the gastrointestinal tract of humans and warm-blooded animals. Nitrites cause severe illness in people due to the formation of methemoglobin in the blood. This is especially dangerous for children. The approved MAL of nitrates in potatoes for children and medical institutions set by the Russian Federation standards is not more than 80 mg/kg per raw tubers. MAL for adults is set at 250 mg/kg (*SanPin 2.3.2.1078-01*, 2002). The World Health Organization (WHO) has established the maximum non-dangerous daily dose of nitrates for humans with their systematic intake in the range of 3.65 mg per 1 kg of body weight (Edelev *et al.*, 2013). Developed countries of the European Union set the maximum allowable level of nitrates in potatoes for baby food within 3 mg% (30 mg/kg) (Damodaran *et al.*, 2012). Some researchers predict in advance nitrate accumulation in tubers by analyzing their content in potato leaves during the growing season (Dreyer, Bohm, and Dresow, 2011). Tubers were sampled in the experiment for analyzing nitrate content along the diagonal of the plot. This related to the general background of mineral fertilizers in the experiments, which was the dose of $N_{75}P_{150}K_{120}$. In 2015, the average experimentally observed nitrate content was 71.7 mg, in 2016 - 65.4 mg, in 2017 - 78.5 mg/kg of raw tubers. On average, over three years, with a predominance of 2 times in the proportion of phosphorus and of 1.6 times in potassium over nitrogen in the mineral fertilizer ($N_{75}P_{150}K_{120}$), the nitrate content in tubers was 71.9 mg/kg at MAL equaling to 80 mg/kg for children and medical institutions. The predominance of the proportion of phosphorus and potassium over nitrogen in the fertilizer in a ratio of N:P:K equal to 1:2:1.6 inhibits the accumulation of nitrates in potato tubers. This fact underlines the importance of introducing increased doses of phosphorus to obtain potatoes with low nitrate content. If being guided by the standards of the European Union in terms of the nitrates content in potato products intended for children and diet food, when the content should not exceed 3 mg% (30

mg/kg), it is recommended to follow the previous studies (2011-2013). These studies found that only the dose of $N_{30}P_{90}K_{60}$ with a nitrate content of 20.8 mg/kg meets the EU requirements. Since the subsequent dose of $N_{60}P_{90}K_{60}$ results in 47.7 mg/kg of nitrates (Butov *et al.*, 2019).

4. CONCLUSIONS:

1. There is a system in the Central Black Earth region of the Russian Federation, which has been developed to protect plants from pests and diseases for the medium-early variety of potatoes and which ensures a good level of yield and ecologically clean products. This goal can be achieved by using modern plant protection agents, a hazard class lower than the previous ones, in combination with new Albit and Siliplant, and reduced pesticide rates.

2. The protection system should include the treatment of tubers when planted with Celest TOP insectofungicide at a rate of 0.3 l/t reduced by 25% in combination with Albit RP 0.1 l/t or Silipant WS 0.04 l/t. For vegetative plants, fungicide rates are reduced by 40%, in combination with biological agents, including Ridomil Gold MZ WDG 1.5 kg/ha - the 1st treatment; Revus SC 0.36 l/ha - 2nd and 3rd treatments; Shirlan SC 0.24 l/ha - 4th and 5th treatments; Siliplant 2 times during the growing season 1.0 l/ha or Albit 2 times during the growing season 1.0 l/t. Such a plant protection system is guaranteed to ensure the production of medium early potato products, which are ecologically clean from pesticides and which are intended for children and medical institutions.

3. A good yield of 31.5-33.1 t/ha, with a nitrate content of 71.9 mg/kg, not exceeding the MAL for children and dietary nutrition of 80 mg/kg, was obtained against the background of the application rate of mineral fertilizers in a dose of $N_{75}P_{150}K_{120}$ kg/ha with a ratio of N:P:K equal to 1:2:1.6. Reducing the nitrate content in tubers to EU standards of 3 mg % (30 mg/kg) can be successfully achieved by reducing the dose of nitrogen (N_{75}) in full mineral fertilizer by at least two times.

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Table 1. Yields and residual insecticides in potato tubers at a different system of plant protection from pests and diseases. Background – $N_{75}P_{150}K_{120}$. 2015-2017. Source: the authors

Case	Yield t/ha	The residual amount of insecticides in tubers. Numerator: the number of days from treatment. Denominator: insecticide content in tubers, mg/kg (MAL = 0.05 mg/kg).			
1. <i>Control</i> : Without treating tubers and tops with fungicides. Actara SC only, 0.06 l/ha was applied to tops 2-3 times during the growing season to protect from Colorado potato beetle (<i>Leptinotarsa decemlineata</i>), if necessary.	23.5	Thiamethoxam (Actara)			
		10 /0.081	20 /0.028	30 /0.0027	40/not found
2. <i>Prestige SC</i> : Full pesticide rates, old agent. Prestige SC 0.7 l/t to tops. To vegetation. Ridomil Gold MZ WDG was applied at a rate of 2.5 kg/ha at the 1st treatment, Revus SC was applied at a rate of 0.6 l/ha at the 2nd and 3rd treatments, Shirlan, SC was applied at a rate of 0.4 l/ha at the 4th and 5th treatments. Hazard class - 1.	29.0	Imidacloprid (Prestige)			
		65 /0.087	75 /0.038	85 /0.016	95 /0.007
3. <i>Celest Top</i> : Full rates. New agent Celest Top SC was applied at a rate of 0.4 l/t to tubers To vegetation: Ridomil Gold MZ WDG, 2.5 was applied at a rate of kg/ha at the 1st treatment, Revus SC was applied at a rate of 0.6 l/ha at the 2nd and 3rd treatments. Shirlan SC was applied at a rate of 0.4 l/ha at the 4th and 5th treatments. Hazard class - 2.	30.7	Thiamethoxam (Celest)			
		65 /0.073	75 /0.032	85 /0.017	95 /0.0023
4. <i>Albit (+)</i> : Full rates. Celest Top was applied at a rate of 0.4 l/t + Albit RP was applied at a rate of 0.1 l/t to tubers. To vegetation: Ridomil Gold MZ WDG was applied at a rate of 2.5 kg/ha at the 1st treatment, Revus SC was applied at a rate of 0.6 l/ha at the 2nd and 3rd treatments. Shirlan SC was applied at a rate of 0.4 l/ha at the 4th and 5th treatments + Albit RP was applied 2 times during the growing season at a rate of 1.0 l/ha	34.1	Thiamethoxam (Celest)			
		65 /0.071	75 /0.027	85 /0.015	95 /0.0012
5. <i>Reduced rates of pesticides</i> to tubers and tops. To tubers: Celest Top was applied at a rate of 0.3 l/ha + Albit RP was applied at a rate of 0.1 l/t. To tops: Ridomil Gold MZ WDG was applied at a rate of 1.5 kg/ha at the 1st, 2nd, and 3rd treatments. Shirlan SC was applied at a rate of 0.24 l/ha at the 4th and 5th treatments + Albit RP was applied 2 times during the growing	31.5	Thiamethoxam (Celest)			
		65 /0.053	75 /0.020	85 /0.011	95/not found

season at a rate of 0.05 l/ha					
6. <i>Siliplant(+)</i> : Full rates. To tubers: Celest Top was applied at a rate of 0.4 l/t + Siliplant WS was applied at a rate of 0.04 l/t. To vegetation: Ridomil Gold MZ WDG was applied at a rate of 2.5 kg/ha at the 1st treatment, Revus SC was applied at a rate of 0.6 l/ha at the 2nd and 3rd treatments, Shirlan SC was applied at a rate of 0.4 l/ha at the 4th and 5th treatments + Siliplant WS was applied 2 times during the growing season at a rate of 1.0 l/ha.	34.9	Thiamethoxam (Celest)			
		65 /0.070	75 /0.028	85 /0.013	95/not found
7. <i>Reduced rates of pesticides</i> : To tubers: Celest Top SC was applied at a rate of 0.3 l/t + Siliplant WS was applied at a rate of 0.04 l/t. To vegetation: Ridomil Gold MZ WDG was applied at a rate of 1.5 kg/ha at the 1st treatment. Revus SC was applied at a rate of 0.36 l/ha at the 2nd and 3rd treatments. Shirlan SC was applied at a rate of 0.24 l/ha at the 4th and 5th treatments, Siliplant WS was applied 2 times during the growing season at a rate of 1.0 l/ha.	33.1	Thiamethoxam (Celest)			
		65 /0.051	75 /0.017	85 /0.010	95/not found
Least significant difference ₀₅ (average) t/ha.	1.6

Figure 1. The dynamics of Thiamethoxam decomposition (Celest TOP) in tops and tubers. MAL is 0.05 mg/kg