Change in potato productivity under the impact of viral diseases

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Abstract. In 2014-2019 as part of comprehensive tests of the antiviral activity of a number of products in the field, a comparative assessment of the productivity of healthy potato plants and generations of plants of different varieties previously artificially inoculated with phytopathogenic viruses Y, S, M was carried out. During the testing period, in small-plot field experiments on a site at the Russian State Agrarian University - Moscow Timiryazev Agricultural Academy named after K.A. Timiryazev Plant Protection Station (Moscow), the yield of the Ilyinsky plants infected Potato virus M decreased on average by 48,8%, of the Red Scarlet plants infected with Potato virus Y – by 54,9%, of the Adretta plants infected with Potato virus S – by 52,3%. In 2016 under the production conditions of Lipetsk region the yield loss of the potato variety Ramos was 31,8%, and in the Astrakhan region the yield of the potato variety Impala decreased by 36%. The effect of viruses on the content of photosynthetic pigments in infected plants was studied. In comparison with healthy plants the percentage of total chlorophyll in the wet weight of the leaves of the Ilyinsky plants decreased by 23,2%, of the Red Scarlet plants – by 19,7%, of the Adretta plants – by 15,8%. Varietal differences were revealed in the changes in the activity of antioxidant enzymes in tubers, starch and dry matter content from various viral pathogens.

1. Introduction

Viral and viroid diseases of potatoes can be considered the most dangerous. This is because they practically do not respond to treatment and accumulate in all subsequent generations of tubers. Viruses have a complex inhibitory effect on potato plants. Disorders of growth processes occurring (stunting, dwarfing), leaf apparatus deformation and tubers leads to reduction of yield and product quality, and subsequently to varieties degeneration [1, 3]. Reduction in yields of potatoes from viruses can reach 88%.

At present in the world more than 50 different viruses infecting potatoes have been identified, among which the most harmful are: Potato virus Y (PVY); Potato virus X (PVX); Potato virus S (PVS); Potato virus M (PVM) and Potato leaf roll virus (PLRV, virus L).

PVX can cause losses of 10–40% (on average – 25%) in single infections and is particularly damaging in combination with potato viruses Y or A. This is due to its synergism with both potyviruses leading to tuber yield losses of up to 80% [2]. For example, productivity of plants infected
with PVX and PVM at the same time decreases to 60%, and when its infected with a complex of PVX + PVM + PVY – by 83.7%, i.e. plants practically do not yield.

Almost all viruses, upon infection, reduce the starch content of tubers [4]. In infected potato tubers, the content of dry matter and vitamins is reduced in comparison with healthy ones. Other physiological and biochemical changes also occur: there is a decrease in the size of starch grains in the affected tissues, acidity of starch and amylase content [5].

Some viral pathogens can reduce the commercial quality of tubers. For example, the Tobacco rattle virus causes pulp necrosis, and the PLRV causes net necrosis of tubers [6], whereby also reduced starch content. The negative effect of viruses on the plants with latent infection is also noted. According to Ambrosov (1975), the starch content in tubers decreased by 0,3-0,8% with PVY latent infection of plants.

The losses in potato production from viruses are not the same; they are associated with climatic conditions, the characteristics of cultivation technologies and the resistance of the variety, the level of spread of a specific virus and their combinations, and the means of plant protection used [7]. Therefore, to organize effective protection of a crop from viruses, it is necessary to regularly monitor the composition of the viral pathocomplex, assess the harmfulness of viroses, taking into account the changing technologies of cultivation of crops and modern potato varieties.

The objective of the research carried out within of testing the antiviral properties of a number of products in the field [7, 8] was to clarify the changes in the productivity of plants infected with certain viruses in comparison with the productivity of healthy plants.

2. Materials and Methods
In the period from 2014 to 2019 at the site of the plant protection laboratory of the RSAU-Moscow Agricultural Academy named after K.A. Timiryazev was started a series of small-plot field experiments. In the course of these experiments, the effect of viral infections on the yield indicators of infected plants was assessed.

Viral potato plants of Ilyinsky, Red Scarlet and Adretta varieties were obtained from the generation of previously inoculated plants with phytopathogenic viruses PVY, PVM, PVS. In 2014, 2015 and 2019 revitalized (certified) plants of Ilyinsky and Red Scarlet varieties were planted with the inoculated plants at the same time to compare the development of plants and their yield. During the growing season the plantings were treated preventive and eradicating with insecticides against insect vectors. A comparative assessment of the productivity of plants healed from viruses and infected (ordinary reproduction with a high prevalence of PVY, PVM, PVS and their combinations) was carried out in the production conditions of the Lipetsk and Astrakhan regions (2016). Plant infections of viruses were confirmed using serological tests (ELISA), analysis of the physiological state (content of chlorophyll, antioxidant enzymes) – by appropriate methods [9, 10]. Biometric records of plant growth were performed; yield was assessed by weight method.

3. Results and Discussion
The growth and development of potato plants, the quality of tubers largely depend on weather conditions during the growing season. In general, insufficient rainfall during the initial growth period in 2014 and 2019 negatively affected the development and productivity of plants. The most optimum weather conditions developed in 2015.

Typical symptoms of viroses were observed annually on almost all plants infected with viruses.

On average, over the years, the yield of the Ilyinsky variety decreased by 48.8%, the Red Scarlett variety – by 54.9%, the Adretta variety – by 52.3% from the maximum values of 2015 (table 1).
The dynamics of reduction in yields of plants infected with viruses, Russian State Agrarian University-Moscow Agricultural Academy named after K.A. Timiryazev, 2014-2019.

| Variety of potato | Associated virus | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|-------------------|------------------|------|------|------|------|------|------|
| Ilyinsky          | PVM              | 1,80 | 2,15 | 1,46 | 1,40 | 1,15 | 1,10 |
| Red Scarlet       | PVY              | 1,51 | 2,35 | 1,93 | 1,36 | 1,20 | 1,06 |
| Adretta           | PVS              | 3,03 | 4,53 | 3,29 | 2,73 | 2,34 | 2,16 |
| Ilyinsky          |                  | 2,05 | 2,77 |      |      |      | 2,56 |
| Red Scarlet       |                  | 3,20 | 3,76 |      |      |      | 3,51 |

During the period of the experiment the maximum reduction in yields was revealed in 2019 from the \( PVY \) on the Red Scarlet variety – 10,6 on conversion to t/ha. On the Adretta variety, due to the long-term negative effect of the \( PVS \) on plants, the yield decreased to 21,6 t/ha. The yield loss of the Ilyinsky variety infected with the \( PVM \) accounted for 10,5 t/ha from 2015 to 2019.

On the count tubers from each bush, it was found that their number varied slightly depending on the climatic conditions of the year of research and, on average, conformed to the commercial characteristics of the varieties. Reduction in yields was mainly due to the strong degeneration of tubers. Many tubers were deformed, had an ugly shape and low mass, its visually very different from the required standard; pulp necrosis was indicated in tubers infected with the \( PVY \). Analysis of the fraction composition of the yield of tubers obtained from the tested plants confirmed an increase in the fraction of tubers weighing < 80g to 25% on Ilyinsky plants, on Red Scarlet plants the fraction of tubers weighing < 60g was 34%, the number of tubers weighing < 90g increased to 27% on Adretta plants.

The production experiments were performed in 2016 under the conditions of the 2nd and 3rd soil-climatic zones (Lipetsk, Astrakhan regions). Data available from these experiments were also confirmed a reduction in commercial yield of potatoes.

In the trial field in the Lipetsk region, during surveys and sampling leaves, it was found that potato variety Ramos was infected with a complex viral infection \( (PVY, PVM+PVS) \). The commercial productivity of potatoes was 16,1 t/ha, while the yield on the plot with revitalized plants was 23,6 t/ha.

In the Astrakhan region on potato variety Impala, also infected with a complex of viruses \( (PVM+PVS, PVM+PVS+PVY) \), decrease potato productivity by 9,0 t/ha was found as compared to that of the yield obtained on the plot with uninfected plants (table 2).

| Variants                  | Productivity, t/ha |
|---------------------------|--------------------|
|                           | Total              | Commercial        |
|                           | Lipetsk region     | Astrakhan region  |
| Ramos – \( PVY, PVM+PVS \)| 19,5               | 16,1              |
| Ramos – revitalized plants| 26,3               | 23,6              |
|                           | Least significant difference \( 0.05 = 4,3 \) |
| Impala – \( PVM+PVS, PVM+PVS+PVY \) | 18,9               | 15,5              |
| Impala – revitalized plants| 27,4               | 24,5              |
|                           | Least significant difference \( 0.05 = 4,2 \) |

With a viral pathological process, changes in metabolic processes occur in the affected tissues. Phytopathogenic viruses, in addition to systemic disturbances in the plant organism, often cause
physical deformations such as wrinkling, twisting and mosaic structure of leaves, thus reducing the useful area of the leaf apparatus. This leads to decrease in the intensity of photosynthesis – one of the most important factors in plant productivity.

The results of the analysis of the physiological state, carried out in 2016, showed decrease of the total chlorophyll in the wet mass of leaves of 30-day-old infected Ilyinsky plants by 23.2%, Red Scarlett plants – by 19.7%, and Adretta plants – by 15.8% as compared with the values of a similar indicator in healthy plants of the same age.

Plant resistance to pathogens largely depends on the efficiency of the antioxidant system, which consists of antioxidant enzymes and low molecular weight components. Peroxidase and catalase are the most important enzymatic components of the plant cell and tissue defense system, removing hydrogen peroxide and blocking the development of free radical processes that cause oxidative cell destruction. In our experiments varietal differences in the change in the activity of antioxidant enzymes under the effect of various viral diseases were revealed [11]. For example, PVY infection in Red Scarlet increased catalase activity. The dependence of the activity of the antioxidant system on the type of virus has been established on potato variety Adretta. The highest activity of catalase was observed during co-infection with PYS and PVM, and the same viruses in combination with PVY approximately contributed 2 times less enzyme activity. In Adretta plants the most significant decrease in starch content and an increase in sugar content were observed during co-infection with PVY and PVM. With simultaneous infection with these two viruses, there was a statistically significant decrease in catalase activity as compared to control (healthy tubers). Along with a sharp decrease in the amount of starch by 2.9% from the minimum varietal values, there was an increase of dry matter by 4.2% of the maximum allowable values for potatoes intended for processing into potato products. Also, under the impact of this combination of viruses, the lowest biochemical and physiological indicators of the viability of potato tubers were noted during storage [12].

Biochemical analysis of tubers of Adretta obtained in 2019, showed decrease in the amount of crude protein from 2% (minimum varietal value) to 1.4%, vitamin C – from 13.1 mg% to 3.64 mg%, while the indicators of the amount of starch (13.7%) and dry matter (22.68%) were at the level of average varietal values.

4. Conclusions

Based on the results of the research, it was found that the yield of potato plants artificially infected with Y, S, M viruses compared to virus-free plants decreased by 48.8-54.9%, depending on the variety. Under the conditions of the crop enterprises of the Lipetsk and Astrakhan regions, on the ordinary generation of potatoes with the spread of viruses up to 32-46% the yield decreased by 31.8-36.7% in comparison with the yield of healthy plants. Varietal differences in the changes in the activity of antioxidant enzymes in tubers, starch and dry matter content from various viral pathogens were revealed. The available results indicate the need to improve measures for protecting potatoes from viral diseases, taking into account modern varieties and production technologies of this crop.

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