Economic efficiency of using entomophages in protecting potatoes from the Colorado potato beetle

V F Pivovarov¹, A A Baykov¹, M V Dudov¹, E M Gins² and S V Zhevora²

¹ Federal State Budgetary Scientific Institution “Federal Scientific Center of Vegetable Growing”, Selektsonianaya14, setl. VNIISOK, Odintsovo district, Moscow region, 143080, Russia
² Federal State Budgetary Scientific Institution “All-Russian Research Institute of Potato Farming named after A.G. Lorkh”, », Lorkh Str., 23, letter “B”, setl. Kraskovo, Lyuberetsky district, Moscow region, 140051, Russia

E-mail: vniissok@mail.ru

Abstract. The Colorado potato beetle is a serious pest of Solanaceae crops in our country, especially potatoes. In order to reduce the chemical load in the field and prevent the development of resistance to chemicals in the Colorado beetle, this paper presents biological methods of protection using seasonal colonization by the predatory shield bug Picromerus and treatments with plant extract of amaranth of the Valentine variety (which, along with limiting the nutrition of the larvae of the Colorado beetle, stimulates growth and leads to an increase in the photosynthetic activity of protected plants). Additional treatment with amaranth extracts is recommended during the flowering period, which is critical for potatoes. Damage to potato leaves by Colorado potato larvae during this period can lead to significant decrease in productivity.

1. Introduction

Environmentally safe and biologically complete products are in high demand. The volume of the world market of eco-products is constantly increasing with an annual growth of 10-20%. The system of ecological farming provides for the rejection of the use of fast-acting mineral fertilizers and synthetic chemical plant protection products. For the cultivation of environmentally friendly products, fairly strict standards are introduced, for example, it is allowed to use only direct (entomophages and useful microorganisms) and relative (products of biological synthesis of animals and plants that have protective properties) biological agents, as well as sparing chemicals, such as: Bordeaux liquid, Burgundy liquid, ash, stone powder and others. Seed material is used only grown in accordance with the rules of ecological land use. It is forbidden to etch seeds with chemical pesticides, except for certain biological preparations. Tools for biological pest and disease control are being developed. These include biologically active substances (antifeedant, attractive, repellent actions, etc.), microbiological preparations, predatory and parasitic arthropods bred on an industrial scale. At the same time, the goal is to not to destroy phytophages completely, but to bring their number and harmfulness to a level where their activities do not adversely affect the state of the crop and its productivity. The protective effect is considered positive if the loss level does not exceed the acceptable level.

In relation to the Colorado potato beetle (Leptinotarsa decemlineata Say), it was found that damage to potato bushes with a degree of damage in the budding phase exceeding 15% reduces the
yield of tubers [1]. Therefore, to protect potatoes from the Colorado potato beetle, it is necessary to preserve 85% of the leaf surface. This value characterizes the protective effect that must be achieved when using biological methods. The economic threshold of harmfulness of the Colorado potato beetle usually lies at the settlement of potato plantings of 10-15% of bushes with an average number of 15-20 larvae per plant [2]. To assess the state of stress in potato plants, it is proposed to use indicators of total antioxidant content (TAC) and slow fluorescence induction (SFI) [3-4]. It is shown that plant extracts of amaranth stimulate growth and lead to an increase in the photosynthetic activity of potato plants and at the same time protect them by limiting the nutrition of Colorado beetle larvae [4]. However, in terms of mortality and nutritional restriction, plant extracts of amaranth cannot compete independently with most synthetic insecticides specifically developed to control the Colorado potato beetle. As at the potato the period recommended for the use of amaranth as a biological stimulant for foliar treatment coincides with the period when the larvae of the Colorado beetle are present on the foliage, it was decided to test the effectiveness of joint protection using a preparation from *Amaranthus tricolor* L. of the Valentine variety and the predatory shield bug *Picromerus (Picromerus bidens* L.), which was the purpose of this work.

2. Materials and methods

The experiments were carried out in 2017-2018 at the site of the Experimental Production Department of the FSBI FRCVG (Moscow region). The soil of the site is sod-podzolic medium loam. The Zhukovsky potato early variety was grown. The width of the aisles is 140 cm. The distance between the tubers in the ridge is 20 cm. Scheme of field experience: 1 – without additional processing; 2 – protection with the use of predatory shield bug *Picromerus*; 3 – protection with the use of plant extract of amaranth of the Valentine variety and *Picromerus* ovipositors. *Picromerus* was applied at the stage of oviposition in the amount of one oviposition per potato plant (100 thousand eggs per hectare) in the stage of 4-6 leaves in the twenties of June. At the same time treatment with 4% water extract obtained from dried leaves of amaranth variety Valentina, in the amount of 2 liters per 100 sq. m. was carried out for the first time, two subsequent treatments were carried out on 14th and 28th days.

The biological effectiveness of protection against the Colorado potato beetle was calculated using the formula
\[
BE = \left(1 - \frac{K_o N_o}{N_o K_o}\right) \cdot 100\% , \text{ where } K - \text{ average number of larvae and imagos in the control variant, and } N - \text{ average number of larvae and imagos in the studied variant on 0 and n days after colonization by *Picromerus* [5].}
\]

The total content of antioxidants was determined by the amperometric method. To obtain the extracts, bidistillate was used; the plant material crushed in solution was centrifuged at 10000 g 15 min at 4°C. The supernatant aliquot was used to determine the content of antioxidants, diluting if necessary. Gallic acid (GA) was used as the standard and the result was expressed in mg. eq. GC/g [3].

The slow fluorescence induction (SFI) parameter was the ratio \(F_M - F_T\)/\(F_T\), where \(F_M\) is the value corresponding to the maximum of the fluorescence induction curve, and \(F_T\) is the stationary level of fluorescence [4].

3. Results

In order to identify the connection in the “protection-harvest” system, the variants of the experience were analyzed. It was found that the studied methods of protection had an impact on productivity. Active development of Colorado beetle larvae took place in early July, with a maximum number of larvae on plants on the 14th day of the experiment (from the beginning of the placement of eggs of the *Picromerus* shield bug). However, on experimental plants, the number of larvae of the Colorado beetle then decreased sharply and did not exceed the economic threshold of harmfulness, while on control plants, the number of larvae per threshold of harmfulness decreased by 35th day. By this time, the biological effectiveness of protection against the Colorado potato beetle on experimental plants...
The predatory shield bug completely cleared the protected plant from the pest on 42th and 49th days, respectively (variants 2 and 3).

Table 1. Biological effectiveness of protection against the Colorado potato beetle, %.

| Variant of experience | Days after colonization by Picromerus |
|-----------------------|--------------------------------------|
|                       | 7     | 14    | 21    | 28    | 35    | 42    | 49    |
| 2                     | 2.1±0.4 | 11.5±0.3 | 23.3±0.4 | 55.9±0.4 | 85.2±0.3 | 96.2±0.3 | 100±0.4 |
| 3                     | 5.3±0.3 | 21.3±0.3 | 33.5±0.4 | 80.1±0.3 | 97.1±0.3 | 100±0.4 | 100±0.3 |

The development of Colorado beetle larvae led to a decrease in the total content of antioxidants in potato leaves (table 2). A similar effect was observed when strawberry leaves were damaged by Atlantic spider mites and it was associated with peroxidation of membrane lipids [6-7]. The study of the action of regurgitant (oral secretions) of age IV Colorado beetle larvae on mechanically damaged common bean leaves showed that the oxidative explosion associated with the formation of hydrogen peroxide by NADPH oxidase and superoxide dismutase is a necessary link (along with biosynthesis and ethylene reception), leading to an increase in the activity of peroxidase and polyphenol oxidase in leaves [8]. This confirms that the antioxidant system is involved in the primary response of the plant and is a sensitive indicator of the impact of the Colorado potato beetle. In the variant of the experiment with Picromerus (2), the decrease in the total content of antioxidants was less expressed compared to the control and on 35th day it turned into an increase, which corresponded to 85% of the biological effectiveness of protection against the Colorado potato beetle. In the variant with additional treatment with amaranth extract (3), the total content of antioxidants increased after treatments: 0 day of treatment – an increase on the 7th day is registered, on 14th day treatment – an increase on the 21th day and on the 28th day treatment - an increase on the 35th day and then the TAC remained almost at the same level.

The development of damage on control plants led to a decrease in the parameter of slow fluorescence induction for control plants, while in protected plants (variants 2 and 3), the SFI index exceeded the initial values on 35th day in variant 2, and in variant 3, as in the case of TAC, growth was observed after treatment with amaranth extract (table 3). Changes in the total antioxidant content and slow fluorescence induction correlated with each other in variants 2 and 3 with a correlation coefficient of 0.94±0.03.

Changes in the indicator \((F_{M}-F_{T})/F_{T}\) under various effects on plants correspond to changes in photosynthetic activity of the leaf as a percentage [9], which in turn allows connecting the observed changes in slow fluorescence induction and the indicators of development of potato plants and crops. Plants whose leaves showed a greater slow induction of fluorescence gained more mass and growth and were more productive (table 3), which indicates the effectiveness of the applied methods of biological protection.

Table 2. TAC in potato leaves, mg. eq. GC/g.

| Variant of experience | Days after colonization by Picromerus |
|-----------------------|--------------------------------------|
|                       | 7     | 14    | 21    | 28    | 35    | 42    | 49    |
| 1                     | 0.65±0.03 | 0.54±0.03 | 0.56±0.03 | 0.55±0.03 | 0.58±0.03 | 0.60±0.03 | 0.65±0.03 |
| 2                     | 0.77±0.04 | 0.72±0.02 | 0.71±0.02 | 0.78±0.04 | 0.80±0.02 | 0.79±0.02 | 0.80±0.02 |
| 3                     | 0.87±0.03 | 0.80±0.02 | 0.90±0.02 | 0.85±0.02 | 0.90±0.02 | 0.88±0.02 | 0.87±0.02 |
5. from the Colorado beetle at times, which determines the economic efficiency of the use of entomophages in protecting potatoes. The difference in price between biological products and conventional food differs in the prevention of a number of diseases and in this regard has a sufficiently high content of antioxidants, potatoes can play an important role in the health of human diet. The variant with the use of plant extract of amaranth of the Valentine variety and Picromerus ovipositors allowed getting the maximum yield with an increased content of antioxidants. In the collection: Trends in the development of agrophysics: from current problems of agriculture and technological principles of the use of microbial prerates in the protection of open ground plants (In the book Biological regulation of the number of harmful organisms) 139-162.

4. Summary
The data obtained in the experiment indicate a high efficiency of using biological methods of protection. The variant with the use of plant extract of amaranth of the Valentine variety and Picromerus ovipositors allowed getting the maximum yield with an increased content of antioxidants. Having a sufficiently high content of antioxidants, potatoes can play an important role in the prevention of a number of diseases and in this regard is one of the most valuable products in a healthy human diet. The difference in price between biological products and conventional food differs at times, which determines the economic efficiency of the use of entomophages in protecting potatoes from the Colorado potato beetle.

5. References
[1] Likhovidov V E, Korchmar N D, Sklyarova N A, Dima S G, Radul M M 1986 *Ecological bases and technological principles of the use of microbial-prerates in the protection of open ground plants* (In the book Biological regulation of the number of harmful organisms) 139-162.
[2] Shpaar R, Bykin A, Dreger D, Zakharenko A, Ivanyuk V, Kalenskaya S, Kyrutsinger V, Kurtsinger B, Postnikov A, Shkalikov V, Schumann P, Shcherbakov V, Yaster K, Elmer F 2010 *Potatoes (Cultivation, harvesting, storage)* M: LLC “DLV Agrodelo” 452
[3] Dudov M V, Gins M S, Baykov A A 2017 *Change in the total content of antioxidants in potato plants when affected by the Colorado beetle* (In the collection: Trends in the development of agrophysics: current problems of agriculture and crop production to technologies of the future. Materials of the International scientific conference dedicated to the 85th anniversary of the Agrophysical Research Institute) 253-257
[4] Gins M S, Gins V K, Dudov M V, Karavaev V A, Baykov A A, Levykina I P, Soldatenko A V. 2018 *Effect of potato leaf treatments with amaranth extracts on the photosynthetic apparatus of plants and nutrition of Colorado beetle larvae* (New and non-traditional plants and prospects for their use) 13 253-256
[5] Volkov O G, Meshkov Yu I, Yakovleva I N 2013 *Development and predation of Picromerus bidens (Heteroptera: Pentatomidae) on Leptinotarsa decemlineata (Coleoptera: Chrysomelidae)* (Russian Entomological Journal) 22 1 43-50
[6] Baikov A A, Kvitka A Yu, Popov S Ya, Gins M S, Solntsev M K 2012 *Effects of biotic stress (spider mite injury) on leaf water status, total antioxidant capacity and lipid peroxidation in strawberry plants* (News of the Timiryazev Agricultural Academy) 7113-115
[7] Baikov A A, Karavaev V A, Levykina I P, Solntsev M K, Tikhonov A N, Popov S Y, Kvitka A Y 2013 *Luminescence characteristics of strawberry leaves at early stages of injury by spider mite* (Biophysics) 58 2 234-239

[8] Pakhnenko E P, Vatsadze N S, Glazunova S A, Karavaev VA, Baikov A A, Solntsev M K 2012 *Early diagnostics of physiological state of plants under various nutrition conditions using luminescent methods* (Moscow University Soil Science Bulletin) 67 (2) 60-64

[9] Zelenkov V N , Ivanova M I , Potapov V V 2019 *Hydrothermal nanosilica in the grotechnology of radish cultivated in the conditions of low positive temperature* (AIP Conference Proceedings Proceedings of the II International conference) 040069