The effect of leaf treatment \((Solanum tuberosum {L.} cv \ Zhukovsky)\) with an early leaf extract \((Amaranthus tricolor \ L. \ cv \ Early \ splendor)\) on the photosynthetic indicators of potato plants and the feeding of the Colorado beetle larvae

V F Pivovarov\(^1\), E M Gins\(^2\), and A A Baikov\(^1\)

\(^1\)Federal Scientific Center for Vegetable Growing, 14 Seleksionnaya str., VNIISSOK Village 143080 Russia
\(^2\)Lorch Potato Research Institute, 23 Lorcha str., 140051 Kraskovo Russia

Email: physiol@inbox.ru

Abstract. Processing potatoes with water extract from the amaranth of \textit{Early splendor} variety leads to an increase in the parameter \((F_M - F_T)/F_T\) of slow induction of leaf fluorescence up to 51\%. At the same time, the effectiveness of restricting the nutrition of larvae of the Colorado potato beetle on the treated plants reaches a maximum of 64\%. Laboratory experiments show a decrease in larval survival on treated plants. Due to its dual properties as a biostimulant and insecticide, as well as low toxicity to vertebrates, amaranth extracts can be recommended for integrated pest management programs.

1. Introduction

The Colorado potato beetle \((Leptinotarsa decemlineata \ Say)\) is a serious pest of solanaceous crops in our country, especially for potatoes. The use of synthetic insecticides to combat this pest has led to resistance in virtually all classes of insecticides, including organophosphates, carbamates, pyrethroids, and neonicotinoids \cite{5}. The development of biological methods of protection is to reduce the chemical load in the field and prevent the development of resistance to chemicals in the Colorado potato beetle \cite{4}. The use of plant extracts is promising. They stimulate growth and lead to an increase in the photosynthetic activity of plants \cite{2}. At the same time, they protect them by restricting the nutrition of the larvae for the Colorado potato beetle. The evidence of luminescent research methods used in the work is that, as a rule, they make it possible to reveal changes in the photosynthetic equipment at early stages of one or another factor, even before the appearance of characteristic morphological changes \cite{1}.

2. Materials and Method

For the processing of Zhukovsky ranniy potato variety, water extracts obtained from dried leaves of Amaranth of the Early splendor variety, were used.

The activity of the photosynthetic apparatus of potato plants at the leaf level was analyzed by recording the fluorescence and thermoluminescence curves \cite{1, 3}. As a slow fluorescence induction parameter (SFI), the following relationship was used: \((F_M - F_T)/F_T\), where \(F_M\) is a value corresponding to the maximum fluorescence induction curve, and \(F_T\) is the stationary fluorescence level. As a
parameter of high-temperature thermoluminescence, the light sum S was used to reflect an area under the TL curve in the range from +60 to +100 °C.

As a parameter describing the effect of treating potato leaves with amaranth extracts on the nutrition of larvae of the Colorado potato beetle, an index of nutritional inhibition was used. FDI = \((S_c - S_t)/(S_c + S_t)\), where \(S_c\) and \(S_t\) are the areas of control and treated leaves eaten [4].

3. Results
Spraying potato plants with amaranth extracts with a concentration of 2-8% led to an increase in the SFI values (Table 1). This parameter changes in proportion to the specific (in terms of chlorophyll) photo-synthetic activity of \(\Delta O_2/(\Delta t \cdot \text{chlorophyll})\). The data obtained indicate an increase in the functional activity of the photosynthetic apparatus of potato plants during the treatment with phytoextracts [2].

At the same time, we observed a decrease in the light sum of the high temperature thermoluminescence \(S_{[60;100]}\) in the experimental plants (Table 2). The magnitude of the temperature peak of thermoluminescence characterizes the resistance of plant tissues (chloroplast membranes) to stressors [1], [3]. Amaranth extracts have a rich antioxidant composition, including phenolic compounds [2]. Probably, exogenous antioxidants prevented lipid peroxidation of thylakoid membranes, which led to a decrease in high temperature thermoluminescence. We can assume that the resistance of chloroplast membranes will increase in the experimental plants under the stress of the action of the larvae of the Colorado potato beetle.

Table 1. Values of the SFI parameter of potatoes of the variety Zhukovsky ranniy variety in control and experience groups.

| Day after treatment | Control (F_M-F_T)/F_T, mean ± standard error (% of control) | Amaranth water extracts Early splendor variety |
|---------------------|----------------------------------------------------------|-----------------------------------------------|
|                     |                                                          | 2%                                            | 4%                                            | 8%                                            |
| 2                   | 0.71±0.03 (100%)                                         | 0.81±0.03 (114%)                             | 0.89±0.04 (125%)                             | 0.89±0.04 (125%)                             |
| 5                   | 0.73±0.03 (100%)                                         | 0.93±0.04 (127%)                             | 1.10±0.04 (151%)                             | 1.04±0.04 (142%)                             |
| 10                  | 0.70±0.03 (100%)                                         | 0.84±0.03 (120%)                             | 0.99±0.04 (141%)                             | 0.97±0.04 (139%)                             |
| 15                  | 0.72±0.03 (100%)                                         | 0.79±0.03 (110%)                             | 0.90±0.04 (125%)                             | 0.83±0.03 (115%)                             |

Table 2. Values of a light sum \(S_{[60;100]}\) in potato leaves of the Zhukovsky ranniy variety in the control and experience groups.

| Day after treatment | S_{[60;100]}, mean ± standard error (% of control) | Amaranth water extracts Early splendor variety |
|---------------------|------------------------------------------------------|-----------------------------------------------|
|                     |                                                      | 2%                                            | 4%                                            | 8%                                            |
| 2                   | 35±2 (100%)                                           | 28±2 (80%)                                    | 26±2 (74%)                                    | 25±2 (71%)                                    |
| 5                   | 33±2 (100%)                                           | 37±2 (82%)                                    | 23±2 (70%)                                    | 23±2 (70%)                                    |
| 10                  | 37±2 (100%)                                           | 33±2 (89%)                                    | 27±2 (73%)                                    | 28±2 (73%)                                    |
| 15                  | 36±2 (100%)                                           | 36±2 (81%)                                    | 29±2 (79%)                                    | 28±2 (78%)                                    |

Treatment of potato leaves with amaranth extracts resulted in restriction of the nutrition of larvae of
the Colorado potato beetle on them (Fig. 1). Such action of extracts can be associated with the presence of phenolic compounds in them that inhibit enzymes, as well as receptor sites in neuroendocrine GABAergic and dopaminergic systems of insects [5].

4. Discussion
The optimal stimulating effect on the photo-synthetic apparatus of potato plants was achieved using 4% extract of amaranth of the Early splendor variety, while the maximum was reached on day 5 after processing. In terms of high temperature thermoluminescence, a minimum was also observed on day 5, while an increase in the concentration of the extract to 8% did not lead to a significant increase in the effectiveness of the action. The effect decreased by 15 days, and (if necessary) the treatment can be repeated.

In terms of the stimulating effect on potato leaves and food restriction for the larvae of the Colorado potato beetle, the use of 4% water amaranth extract of the Early splendor variety is the most promising. At the same time, the mortality of the larvae in the experiment with 4% extract of Early splendor was 53 ± 10%.

5. Conclusion
In terms of mortality and food restriction, amaranth plant extracts cannot compete on their own with the most synthetic insecticides specifically designed to combat the Colorado potato beetle. First of all, they should be considered as biostimulants, and insecticidal properties are a bonus that should be considered when choosing a comprehensive program for pest control. The period recommended for the application of amaranth as a biostimulant for out-of-root cultivation in potatoes coincides with the period when the larvae of the Colorado potato beetle are present on the foliage, which makes it possible to increase the effectiveness of biological methods of protecting potatoes, for example, using the Picromerus predatory bug (Picromerus bidens L.).

References
[1] 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) pp 234-239
[2] Karavaev V A, Glazunova S A, Levykina I P, Gunar L E, Myakinkov A G, Gins M S, … Lepeshkin F D
2012 Slow fluorescence induction and productivity of barley treated with a supercritical fluid extract of amaranth *Biophysics* 57(4) pp 502-503

[3] Pakhnenko E P, Vatsadze N S, Glazunova S A, Karavaev V A, Baikov A A, and 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) pp 60-64

[4] Pavela R 2010 Antifeedant activity of plant extracts on *Leptinotarsa decemlineata* Say. and *Spodoptera littoralis* Bois. larvae *Ind Crop Prod* 32 pp 13-319

[5] Wang Z, Zhao Z, Cheng X, Liu S, Wei Q, and Scott I V 2016 Conifer flavonoid compounds inhibit detoxification enzymes and synergize insecticides *Pestic. Biochem. Physiol* 127 pp 1-7