Study of Laser Radiation Effect on Quality of Forage Potatoes

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Abstract. The paper describes modern methods of increasing the yield of potatoes – the leading crop in the world market for crop production. An alternative method of stimulating potato growth is proposed: the effect of non-ionizing radiation with 650 nm wave length, 150 MW radiation power, 30 s exposure. Gala forage potatoes were used as a research object. To evaluate the efficiency of laser radiation effect, the yield was calculated, feed qualities (content of dry matter, carbohydrates and toxic elements) were assesed. There was an increase in the yield by 47%, starch by 28.2%, and sugars by almost 2 times. At the same time, potato keeping quality increased by 4.3%.

1. Introduction

Potatoes are one of the main vegetable crop widespread both in Russia, and the world. The growth of the world's population leads to an increase in the consumption of crop products thanks to their rapid production from the moment of planting to harvest. Potatoes are quite versatile and unpretentious to natural and climatic conditions, this fact allows collecting a high-calorie crop from a unit of land area. Russia is among the top ten leaders in the world potatoes production market. At the same time, land under cultivation is growing annually in the country and the output yield of potatoes is noticeably increasing.

However, harvesting remains unstable in regions. Among all regions the central and central black earth zones are leading in the potato production, while the northern regions and the territory of the Far East are lagging behind. In addition to germination conditions, seed quality is important as well as the absence of pathogenic and opportunistic flora. These and many other conditions help obtain high quality yield, which makes the industry attractive to investments.

Against the background of the high-yielding industry development, ways of using the yield itself are important, since potatoes are food, fodder and technical crop. It is for this reason that provision of a high-quality, environmentally safe product will help the production profitability, since the crop will be classified as a food group.

During 40 years new techniques and technologies have been developed aimed at increasing in the crop quality and decreasing in chemical burden due to the reduction of using fertilizers and plant chemical protection products. They include the treatment of tubers before planting, new bio-fertilizers, covering materials, technologies of organic agriculture [1–4]. In addition, it is urgent to develop and implement new methods of electrophysical impact which help activate growth processes in plants.
without the DNA structure disturbance, and to obtain the improved crop in the conditions of the North-West of Russia [5]. One of such methods is laser radiation which allows plants to switch photosynthesizing system and trigger anabolism, as a result, an improved crop is obtained [6].

Long-term studies have proved the high efficiency of laser using as an epigenetic factor. Due to the transfer of energy into the cell, a change in protein synthesis occurs without a change in the nucleotide sequence of DNA. For plants, light is an activator of life processes; under the influence of red spectrum light with a wavelength of 620–680 nm, photosynthesis A switches to photosynthesis B. Photoreceptors involved in the absorption of light transfer the received energy to the mitochondria, activating the electron transport chain and the synthesis of energy in the form of ATP molecules. This significantly increases the consumption of carbon dioxide and water, which are substrates for glucose synthesis [7–9].

2. The experimental part

The study of the effect of laser radiation on the yield, the quality of tubers and the safety of potatoes was carried out in a field experiment on sod-podzolic light loamy medium-cultivated soil of the cultivated areas of the Novgorod Research Institute of Agriculture – a branch of the St. Petersburg Federal Research Center of the Russian Academy of Sciences.

Potato of Gala variety, 3–4 reproductions, became an experimental object of field testing of the laser beam control device. Gala potato is classified as early-ripening variety with small oval yellow tubers resistant to mechanical damage, which makes it convenient for mechanical harvesting and transportation.

Potatoes of this variety are actively used as seed material due to their relatively short ripening term, which allows them to be widely used practically in all regions of the country. At a relatively low air temperature Gala gives good shoots, forming plants resistant to low temperatures.

Tubers were planted in the second decade of May. The average daily temperature at the time of planting was within +7 ... +15°C, at night +7°C. During planting, tubers were treated with Komrad with a working fluid flow rate of 200-300 l / ha. During the growing season, mechanical processing was carried out according to the generally accepted method - inter-row processing with rotary harrows and hilling. In addition, treatment against weeds with Zenkor was carried out at a dosage of 0.5–1.0 + 0.3 kg / ha, treatment against late blight was also done.

On June 21, 2020, laser treatment was carried out in the dark with a red semiconductor laser with the following parameters: 650 nm length of radiation wave, 150 MWT radiation power, 30 s exposure.

In the first growth cycle, plants with formed 4–6 leaves were treated with a laser using a diffraction grating (figure 1).

Figure 1. Potato seedlings at the time of irradiation and projection of a laser beam through a diffraction grating (in motion), 21.06.2020.
After the harvest on August 28, 2020, control measurements of tubers were carried out. To determine the quality of tubers, samples were selected in accordance with Feed. Sampling GOST (State Standard) ISO 6497-2014 [10], a qualitative and toxicological analysis was carried out in the FGBU (Federal State Budgetary Institution) Novgorodskaya Station of Agrochemical Service laboratory.

After harvesting, potatoes were laid for storage in a vegetable storehouse with placement in boxes without preliminary sorting and rejection of tubers with signs of diseases. Before laying the potatoes for storage, standard processing of the premises was carried out, the ventilation system was adjusted, the average storage temperature was +5°C. Calculation of the keeping quality of potatoes, and sampling were carried out on May 13, 2021 in accordance with GOST ISO 6497–2014.

3. Results and discussion

Harvesting was carried out with preliminary mowing of dry tops and subsequent harvesting of tubers after 4 days. The air temperature was +18°C, without precipitation, which made it possible to collect dry tubers.

The potato yield in the control group was 1.9 t / ha, that in the experimental group was 2.8 t / ha. It should be noted that tubers in both groups were of medium size, at the same time there are small tubers in the samples of the experimental group (figure 2). This can be explained by two facts: a high potential for tuber formation, the lack of additional fertilizers during the growing.

![Figure 2. Potato tubers of control and experimental groups, 28.08.2020.](image)

According to the requirements for fodder potatoes, the tubers were analyzed. On November 9, 2020, the selection of average samples was conducted in the storehouse.

| Table 1. Qualitative and toxicological analysis of potato tubers of the Gala variety, November 2020. |
|-------------------------------------------------|-----------------|-----------------|
| Controlled indicators                         | Control group   | Experimental group |
| Mass fraction of nitrogen                     | 0.24%           | 0.23%           |
| Mass fraction of crude protein                | 1.47%           | 1.45%           |
| Mass fraction of cadmium                      | 0.07 mg/kg      | 0.07 mg/kg      |
| Mass fraction of lead                         | 0.07 mg/kg      | 0.07 mg/kg      |
| Mass fraction of arsenic                      | <0.01 mg/kg     | <0.01 mg/kg     |
| Mass fraction of nitrates                     | 133 mg/kg       | 149 mg/kg       |
| Normative documents at the time of testing    | GOST 13496.4-2019 p.8 | GOST 13496.4-2019 p.8 |
Analysis of the data obtained showed that in the samples of the experimental group, the content of nitrates increases slightly (by 12%), but the indicator does not exceed the maximum permissible level (no more than 300 mg/kg). This phenomenon can be explained by the increasing growth rate of potatoes and, as a consequence, the consumption of residual nutrients from the soil.

In addition, the analysis of potatoes for the content of dry matter and carbohydrates was carried out at the beginning of storage and after its end, and the percentage of rot was also recorded (table 2).

**Table 2.** Analysis of potatoes for carbohydrate and dry matter content at the beginning and end of the storage term.

| Controlled indicators                                    | Test results          | Normative documents at the time of testing |
|----------------------------------------------------------|-----------------------|------------------------------------------|
|                                                          | Control group         | Experimental group                        |                                          |
| Mass fraction of dry matter (09.11.2020)                 | 18.8%                 | 18.5%                                    | GOST 31640-2012                          |
| Mass fraction of dry matter (13.05.2021)                 | 18.1%                 | 19.5%                                    | GOST 31640-2012                          |
| Mass fraction of sugar (09.11.2020)                      | 0.13%                 | 0.25%                                    | GOST 26176-2019 p.7.3.1; 7.3.2           |
| Mass fraction of starch at natural moisture (09.11.2020) | 11.0%                 | 14.1%                                    | GOST 26176-2019 p.8                      |
| Mass fraction of starch in dry matter (13.05.2021)       | 55.9%                 | 55.5%                                    | GOST 26176-2019 p.8                      |

It should be noted that the amount of dry matter did not differ significantly in the samples of the experimental and control groups after harvesting. However, in the process of storage, the same indicator decreased in the control group by 9.6%, and increased by 10.5% in the experimental group. At the same time, a higher content of starch and sugars was noted in the tubers of the experimental group (by 28.2% and almost 2 times, respectively). Such a useful economic feature as the accumulation of carbohydrates can be widely used by manufacturers, allowing them to obtain an emulsifying component - starch from a smaller amount of raw materials. This fact confirms the theory that laser radiation activates the process of glucose synthesis as a result of the transfer of energy into the cell. At the same time, the amount of free water decreases, which has a positive effect on the keeping quality of potatoes. A decrease in rot from 13.1% in the control group versus 8.8% in the experimental group was noted (note that the potatoes were not sorted before being stored).

At the same time, the mass fraction of starch in the dry matter of tubers of both groups differed slightly, which indicates a decrease in the rate of starch formation during storage. The glycolysis that occurs during storage ensures the maintenance of the energy balance in tubers. At the same time, the resistance of potatoes to pathogenic flora increases, which increases the yield of high-quality products.

4. **Conclusion**

Analysis of the data showed that the treatment of potatoes during the growing season with laser radiation has a positive effect on the growth and development of tubers, which leads to an increase in yield by 1.4 times. At the same time, useful economic characteristics increase, namely, the content of starch and sugars by 28.2% and 2 times, respectively.

During storage, the rate of starch formation decreases, the proceeding glycolysis ensures the resistance of potatoes to pathogenic flora, reducing losses by 4.3%. In addition, it should be noted that an increase in the number of small tubers can be a decisive factor when choosing a stimulating technology for micropropagation of potatoes.

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