Effect of low intensity laser radiation on sugar content in sugar beet root crops obtained from seeds treated with a quantum generator

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Abstract. In the modern world the question of obtaining environmentally friendly food products with the best possible performance is increasingly raised not only in the scientific community but also among the citizens of cities and rural areas. There are many theories and experiments that prove the advantage of the chosen method of exposure to seeds and plants in order to obtain the best result of the final product. One of these areas is the influence of low-intensity laser radiation on plants and their seeds. This article examines the effect obtained from such an impact. And in particular, the authors are talking about increasing the sugar content of root crops obtained from sugar beet seeds treated with low-intensity laser radiation.

1. Introduction
At the present stage of development of science and technology a large number of various experimental facts are known and, in a sense, investigated, which confirm the positive effect of low-intensity laser radiation, i.e. electromagnetic field on seeds and plants, which is expressed in the acceleration of field germination, seed germination energy, plant development, increased immunity and resistance to the influence of various kinds of negative factors (diseases, etc.) [1-8]. And this, in turn, leads to an increase in yield and environmental friendliness of the resulting product, which certainly affects the economic efficiency, i.e. obtaining an environmentally friendly product with minimal impact on the environment, and even with a positive economic effect in the form of profit from the additional harvest [9-12].

In works [2-6] we have shown the effectiveness of the action of a laser with a wavelength of 890 nm on coated sugar beet seeds, as well as the favorable modes of such action.

The technological features of the processing of pelleted seeds using the optical stratifier of seeds OSS-10 are described. In the course of this experiment, unexpected, but very positive effects were revealed, i.e. an increase in the sugar content of root crops obtained from sugar beet seeds treated with low-intensity laser radiation [3].

2. Materials and methods
Our experimental research is based on a device developed to mechanize the process of seed treatment with low-intensity laser radiation - an optical stratifier of seeds OSS-10, with a capacity of 10 sowing units per hour (1 sowing unit = 100,000 seeds) [2-6], which was manufactured in Michurinsky State agrarian university, its diagram is shown figure 1 and the photo is shown in figure 2.
Figure 1. Scheme of optical stratifier of seeds OSS-10: 1- device body; 2- input capacity; 3- seed tube; 4- control unit; 5- irradiator; 6- tray; 7- limiters of radiation flow; 8- vibrator; 9- adjustable partition; 10- receiving part of the tray; 11- outlet capacity; 12- seeds; 13- active zone; 14- adjustable device.

Figure 2. Photo of the optical stratifier of seeds OSS-10 with the side wall removed.

The most important indicator of sugar beet is its sugar content, measured in % of its weight. The results of field studies on the effect of radiation on sugar content in root crops are shown in table 1.

Table 1. Results of field tests of the influence of irradiation regimes on the sugar beet yield, "Uchkhoz-breeding plant" Komsomolets", Michurinsky district, Tambov region.

| N  | Radiation pulse power P, W | Exposure time t, s | Weight with tops Vm, kg | Weight without haulm Vm0, kg | Sugar content Vz, % |
|----|---------------------------|--------------------|-------------------------|----------------------------|-------------------|
| 0  | 0                         | 0                  | 1.4                     | 0.9                        | 15.8              |
| 0  | 0                         | 0                  | 1.6                     | 1.2                        | 15.6              |
| 0  | 0                         | 0                  | 1.5                     | 1                          | 15.7              |
| 0  | 0                         | 0                  | 1.2                     | 0.8                        |                   |
| 1  | 0.409                     | 1                  | 4                       | 3.5                        | 17.1              |
| 1  | 0.409                     | 1                  | 3.6                     | 2.8                        | 17.2              |
| 1  | 0.409                     | 1                  | 2.5                     | 2                          | 17.1              |
| 1  | 0.409                     | 1                  | 3.2                     | 3                          |                   |
| 1  | 0.409                     | 4                  | 2.4                     | 1.8                        | 18.1              |
| 1  | 0.409                     | 4                  | 2                       | 1.5                        | 18.5              |
| 1  | 0.409                     | 4                  | 1.6                     | 1.2                        | 18.1              |
| 1  | 0.409                     | 4                  | 2.6                     | 2.4                        |                   |
| 1  | 0.409                     | 8                  | 2.4                     | 2                          | 18.8              |
| 1  | 0.409                     | 8                  | 4.2                     | 3.6                        | 18.5              |
| 1  | 0.409                     | 8                  | 4.3                     | 3.8                        | 18.8              |
| 1  | 0.409                     | 8                  | 2.6                     | 2                          |                   |
| 1  | 0.409                     | 12                 | 2.2                     | 1.8                        | 17.6              |
| 1  | 0.409                     | 12                 | 2.6                     | 2.2                        | 17.5              |
| 1  | 0.409                     | 12                 | 3                       | 2.6                        | 17.8              |
| 1  | 0.409                     | 12                 | 2                       | 1.5                        |                   |
| 1  | 0.409 | 24   | 3.2  | 2.8  | 17.9 |
|----|-------|------|------|------|------|
| 1  | 0.409 | 24   | 3    | 2.2  | 17.5 |
| 1  | 0.409 | 24   | 3.4  | 2.4  | 17.5 |
| 1  | 0.409 | 24   | 2.8  | 2    | 17   |
| 1  | 0.409 | 48   | 2.8  | 2    | 17   |
| 1  | 0.409 | 48   | 2.2  | 1.6  | 16.9 |
| 1  | 0.409 | 48   | 3.4  | 2.8  | 17   |
| 1  | 0.409 | 48   | 2.4  | 1.6  | 18   |
| 1  | 0.409 | 96   | 4    | 3.2  | 18   |
| 1  | 0.409 | 96   | 3    | 2.4  | 17.8 |
| 1  | 0.409 | 96   | 2.4  | 1.5  | 17.7 |
| 1  | 0.409 | 96   | 3.2  | 2.6  | 18.8 |
| 2  | 0.303 | 1    | 2.4  | 1.8  | 17   |
| 2  | 0.303 | 1    | 2    | 1.8  | 17.1 |
| 2  | 0.303 | 1    | 4.8  | 3.8  | 17   |
| 2  | 0.303 | 1    | 3    | 2.6  | 19   |
| 2  | 0.303 | 4    | 3.2  | 2.4  | 18.8 |
| 2  | 0.303 | 4    | 2.6  | 2.2  | 19   |
| 2  | 0.303 | 4    | 2.2  | 1.8  | 19   |
| 2  | 0.303 | 4    | 2.6  | 2.4  | 16   |
| 2  | 0.303 | 8    | 3    | 2.6  | 16.1 |
| 2  | 0.303 | 8    | 3    | 2.4  | 16.2 |
| 2  | 0.303 | 8    | 1.8  | 1.4  | 16.2 |
| 2  | 0.303 | 8    | 2.2  | 1.8  | 18   |
| 2  | 0.303 | 12   | 1.8  | 1.3  | 17.7 |
| 2  | 0.303 | 12   | 2.6  | 2.4  | 17.6 |
| 2  | 0.303 | 12   | 2.2  | 1.6  | 17.8 |
| 2  | 0.303 | 12   | 2.2  | 1.9  | 18.5 |
| 2  | 0.303 | 24   | 2.2  | 1.5  | 18.6 |
| 2  | 0.303 | 24   | 2.2  | 1.7  | 18.4 |
| 2  | 0.303 | 24   | 2.3  | 1.8  | 18.5 |
| 2  | 0.303 | 24   | 2.6  | 2.4  | 19   |
| 2  | 0.303 | 48   | 4.6  | 3.3  | 18.6 |
| 2  | 0.303 | 48   | 3    | 2.8  | 18.8 |
| 2  | 0.303 | 48   | 2.3  | 1.7  | 18.8 |
| 2  | 0.303 | 48   | 2.1  | 1.8  | 18.5 |
| 2  | 0.303 | 96   | 2    | 1.6  | 18.5 |
| 2  | 0.303 | 96   | 3.2  | 2.8  | 18.6 |
| 2  | 0.303 | 96   | 2    | 1.7  | 18.7 |
| 2  | 0.303 | 96   | 1.9  | 1.4  | 19.2 |
| 3  | 0.263 | 1    | 3    | 2.6  | 19.2 |
| 3  | 0.263 | 1    | 1.6  | 1.4  | 19.5 |
| 3  | 0.263 | 1    | 3.2  | 2.6  | 19.2 |
| 3  | 0.263 | 1    | 1.6  | 1.2  | 19.4 |
| 3  | 0.263 | 4    | 3    | 2.4  | 19.4 |
| 3  | 0.263 | 4    | 4    | 3.2  | 19.1 |
| 3  | 0.263 | 4    | 2.6  | 2    | 19.2 |
| 3  | 0.263 | 4    | 3    | 2.3  | 19.2 |
| 3  | 0.263 | 8    | 3    | 2.3  | 19.5 |
| 3  | 0.263 | 8    | 2.2  | 1.8  | 19.7 |
| 3  | 0.263 | 8    | 3    | 2.4  | 19.4 |
| 3  | 0.263 | 8    | 3.2  | 2.6  | 18.9 |
| 3  | 0.263 | 12   | 3.6  | 3    | 18.7 |
| 3  | 0.263 | 12   | 2    | 1.6  | 18.7 |
| 3  | 0.263 | 12   | 1.8  | 1.6  | 18.5 |
| 3  | 0.263 | 12   | 3    | 2.2  | 18.5 |
| 3  | 0.263 | 24  | 2.6 | 1.8 | 19.3 |
|----|-------|-----|-----|-----|------|
| 3  | 0.263 | 24  | 3.2 | 2.4 | 18.9 |
| 3  | 0.263 | 24  | 1.8 | 1.2 | 19   |
| 3  | 0.263 | 24  | 3   | 2.4 |      |
| 3  | 0.263 | 48  | 3   | 2.4 | 19.5 |
| 3  | 0.263 | 48  | 2.1 | 1.5 | 19   |
| 3  | 0.263 | 48  | 1.4 | 1   | 19   |
| 3  | 0.263 | 48  | 1.5 | 1.1 |      |
| 3  | 0.263 | 96  | 1.4 | 1   | 18.1 |
| 3  | 0.263 | 96  | 2.6 | 1.8 | 18   |
| 3  | 0.263 | 96  | 2.8 | 2.8 | 18.2 |
| 3  | 0.263 | 96  | 1.2 | 0.8 |      |
| 4  | 0.203 | 1   | 2.2 | 1.8 | 17.4 |
| 4  | 0.203 | 1   | 2   | 1.4 | 17.5 |
| 4  | 0.203 | 1   | 1.8 | 1.5 | 17.1 |
| 4  | 0.203 | 1   | 1.6 | 1   |      |
| 4  | 0.203 | 4   | 2.6 | 1.8 | 18   |
| 4  | 0.203 | 4   | 2.8 | 1.8 | 18.1 |
| 4  | 0.203 | 4   | 1.8 | 1.4 | 18   |
| 4  | 0.203 | 4   | 2   | 1.2 |      |
| 4  | 0.203 | 8   | 3   | 2.6 | 18.7 |
| 4  | 0.203 | 8   | 2.6 | 2   | 19   |
| 4  | 0.203 | 8   | 2.8 | 2.2 | 18.6 |
| 4  | 0.203 | 8   | 2.2 | 1.6 |      |
| 4  | 0.203 | 12  | 2.6 | 2   | 16.1 |
| 4  | 0.203 | 12  | 2.2 | 1.6 | 16.5 |
| 4  | 0.203 | 12  | 2.6 | 2   | 16.3 |
| 4  | 0.203 | 12  | 2   | 1.4 |      |
| 4  | 0.203 | 24  | 3.6 | 2.8 | 17   |
| 4  | 0.203 | 24  | 4.6 | 3.8 | 17.2 |
| 4  | 0.203 | 24  | 3.4 | 2.6 | 17.4 |
| 4  | 0.203 | 24  | 3.2 | 2.4 |      |
| 4  | 0.203 | 48  | 2.2 | 1.6 | 17.7 |
| 4  | 0.203 | 48  | 2.6 | 2   | 18   |
| 4  | 0.203 | 48  | 2.6 | 2.2 | 18.2 |
| 4  | 0.203 | 48  | 2.2 | 1.6 |      |
| 4  | 0.203 | 96  | 3.2 | 2.6 | 18.5 |
| 4  | 0.203 | 96  | 2.4 | 1.6 | 18.2 |
| 4  | 0.203 | 96  | 3.2 | 2.4 | 18.5 |
| 4  | 0.203 | 96  | 3.6 | 2.8 |      |
| 5  | 0.203 | 1   | 3.4 | 2.4 | 18.6 |
| 5  | 0.203 | 1   | 2.6 | 2   | 18.2 |
| 5  | 0.203 | 1   | 2.4 | 2   | 18.5 |
| 5  | 0.203 | 1   | 3.8 | 3   |      |
| 5  | 0.203 | 4   | 2.6 | 2   | 17.5 |
| 5  | 0.203 | 4   | 3   | 2.2 | 17.3 |
| 5  | 0.203 | 4   | 2.9 | 2.1 | 17.2 |
| 5  | 0.203 | 4   | 3.3 | 2.4 |      |
| 5  | 0.203 | 8   | 2.1 | 1.7 | 19.4 |
| 5  | 0.203 | 8   | 3.5 | 2.6 | 19.2 |
| 5  | 0.203 | 8   | 2   | 1.2 | 19.7 |
| 5  | 0.203 | 8   | 2.1 | 1.4 |      |
| 5  | 0.203 | 12  | 3.8 | 3   | 18.5 |
| 5  | 0.203 | 12  | 2   | 1.7 | 19   |
| 5  | 0.203 | 12  | 2.2 | 1.6 | 18.8 |
| 5  | 0.203 | 12  | 2.5 | 1.8 |      |
|   |      |   |   |   |   |
|---|------|---|---|---|---|
| 5 | 0.203 | 24 | 1.6 | 1 | 18.5 |
| 5 | 0.203 | 24 | 2  | 1.5 | 18.3 |
| 5 | 0.203 | 24 | 2  | 1.6 | 18.5 |
| 5 | 0.203 | 24 | 1.7 | 1.1 |  |
| 5 | 0.203 | 48 | 4  | 3.2 | 17.6 |
| 5 | 0.203 | 48 | 3  | 2.2 | 17.5 |
| 5 | 0.203 | 48 | 5  | 4.3 | 17.7 |
| 5 | 0.203 | 48 | 2.7 | 2.1 |  |
| 5 | 0.203 | 96 | 3  | 2.4 | 18.5 |
| 5 | 0.203 | 96 | 2.4 | 1.8 | 18.3 |
| 5 | 0.203 | 96 | 1.8 | 1.3 | 18.4 |
| 5 | 0.203 | 96 | 3.2 | 2.6 |  |
| 6 | 0.13  | 1  | 4.8 | 4.1 | 17.5 |
| 6 | 0.13  | 1  | 2.2 | 1.6 | 17.3 |
| 6 | 0.13  | 1  | 2.1 | 1.7 | 17.2 |
| 6 | 0.13  | 1  | 2  | 1.4 |  |
| 6 | 0.13  | 4  | 3  | 2.5 | 18.1 |
| 6 | 0.13  | 4  | 1.6 | 1.2 | 18.3 |
| 6 | 0.13  | 4  | 2.6 | 2  | 18.3 |
| 6 | 0.13  | 4  | 3.8 | 2.2 |  |
| 6 | 0.13  | 8  | 3  | 2.2 | 17.5 |
| 6 | 0.13  | 8  | 1.6 | 1.3 | 17.4 |
| 6 | 0.13  | 8  | 2  | 1.6 | 17.7 |
| 6 | 0.13  | 8  | 2.4 | 2  |  |
| 6 | 0.13  | 12 | 2.4 | 2  | 19.5 |
| 6 | 0.13  | 12 | 2.2 | 1.7 | 19.2 |
| 6 | 0.13  | 12 | 1.8 | 1.2 | 19.1 |
| 6 | 0.13  | 12 | 1.9 | 1.3 |  |
| 6 | 0.13  | 24 | 2.2 | 1.5 | 17.6 |
| 6 | 0.13  | 24 | 2  | 1.4 | 17.4 |
| 6 | 0.13  | 24 | 2.1 | 1.4 | 17.2 |
| 6 | 0.13  | 24 | 1.5 | 1  |  |
| 6 | 0.13  | 48 | 2.6 | 2.1 | 18.2 |
| 6 | 0.13  | 48 | 3.2 | 2.8 | 18.5 |
| 6 | 0.13  | 48 | 1.8 | 1.5 | 18.3 |
| 6 | 0.13  | 48 | 1.5 | 1  |  |
| 6 | 0.13  | 96 | 2  | 1.6 | 19.1 |
| 6 | 0.13  | 96 | 1.8 | 1.3 | 19 |
| 6 | 0.13  | 96 | 1.5 | 1  | 19 |
| 6 | 0.13  | 96 | 1.9 | 1.3 |  |
| 7 | 0.108 | 1  | 1  | 0.8 | 20.7 |
| 7 | 0.108 | 1  | 1  | 0.6 | 20.6 |
| 7 | 0.108 | 1  | 1.8 | 1.4 | 20.6 |
| 7 | 0.108 | 1  | 1.5 | 1  |  |
| 7 | 0.108 | 4  | 1.6 | 1.1 | 20 |
| 7 | 0.108 | 4  | 1.1 | 0.8 | 20.3 |
| 7 | 0.108 | 4  | 1.9 | 1.4 | 20 |
| 7 | 0.108 | 4  | 1.8 | 1.4 |  |
| 7 | 0.108 | 8  | 1.6 | 1  | 20.5 |
| 7 | 0.108 | 8  | 1.9 | 1.4 | 20.3 |
| 7 | 0.108 | 8  | 1.8 | 1.2 | 20.5 |
| 7 | 0.108 | 8  | 1.6 | 1.1 |  |
| 7 | 0.108 | 12 | 1.7 | 1.3 | 16 |
| 7 | 0.108 | 12 | 1.6 | 1.2 | 16.1 |
| 7 | 0.108 | 12 | 1.8 | 1.3 | 16 |
| 7 | 0.108 | 12 | 1.2 | 0.8 |  |
3. Results and discussion

During the study, a visual three-dimensional representation of the weight gains of root crops $\Delta V_b$ by exposure time $t$ and power of the radiation pulse $P$ (figure 3) and its contour graph (figure 4) were obtained. The maximum increase in the mass of root crops falls on the temporary exposure zone $4<t<64$ seconds and power of the radiation pulse $P>0.3 \; \text{W}$.

According to the obtained experimental data, the following functional dependences were obtained:

The trend in the increase in sugar content from the power of the radiation pulse is expressed by the regression equation of the 1st degree:

$$Y_c(P) = 17.8 - 8.3P, \; P = 0, 0.1, ..., P_m,$$

where $P$ is the current (continuous) value of the radiation pulse power; $P_m = 0.5 \; \text{W}$ - maximum power value.

A visual representation of the approximation of mass by power was also obtained (figure 5). The increase in sugar relative to the control group, i.e. root crops obtained from unirradiated seeds decreases with increasing pulse power. In the power range $0.5>P>0.1 \; \text{W}$, the increase in sugar relative to the control group is always positive.

The trend of an increase in sugar content from the time of exposure of seeds, when treated with a laser, is expressed by the regression equation of the 1st degree:

$$Y_c(t) = 16.2 - 0.012t, \; t = 0, 0.1, ..., T_m,$$

where $t$ is the current (continuous) exposure value; $T_m=100 \; \text{s}$ - maximum exposure value.
Figure 5. Regression of the increase $Y_z(P)$ of the sugar content $\Delta V_z$ according to the power $P$ of the radiation pulse.

A representation of the approximation of the increase in sugar content over the exposure time has been obtained (figure 6). The increase in sugar relative to the control group with increasing exposure time remains practically constant, i.e. virtually independent of exposure. Over the entire exposure range, the increase in sugar relative to control, i.e. root crops obtained from uneradicated seeds are always positive.

4. Conclusion
Thus, low-intensity laser radiation has an effect on the sugar content of sugar beets. When processing the data obtained, the following conclusions were obtained: a decrease in the increase in the sugar content of the root crop relative to the increase in its mass. The increase in sugar relative to the control group, i.e. root crops grown from uneradicated seeds are always positive. Even if the increase in the mass of the root crop is negative (for one reason or another), then a positive increase in sugar in the root crops obtained from laser-treated seeds still takes place. The average increase in sugar content relative to control can be more than 15%.

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