EFFECT OF THE LASER EXPOSURE OF SEEDS ON THE YIELD AND CHEMICAL COMPOSITION OF SUGAR BEET ROOTS

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A b s t r a c t. The purpose of the research was to characterize the effect of the pre-sowing laser biostimulation of sugar beet seeds on the biometric features, yielding and chemical composition of sugar beet roots. Four varieties of sugar beets were studied: Colibri, Evita, Kawetina, and Maria. Their seeds were biostimulated during free falling with divergent He-Ne laser beams (40 mW), placed one upon another. The experiments were conducted acc. to the split-plot method in 3 repetitions. Before the harvesting, 20 plants were measured biometrically for the length of leaves, weight of leaves, sticking out of roots over the surface of soil, length, weight, diameter, and circumference of roots. During the harvest, the yield of roots and leaves was specified and after the harvest the chemical analysis was made to check the plant dry mass, the content of sugar, soluble ash, alpha-amine nitrogen, P, K, Ca, Mg, Na, Fe, Zn, Mn, Cu. The results of the research showed beneficial effects of the laser pre-sowing stimulation of sugar beet seeds. In all the combinations concerning the biostimulated seeds, the yield of roots was elevated from 3,2 to 4,5 t/ha, which means an 8-10 % increase when compared to the control (non-biostimulated) seeds. The sugar content was also elevated after the laser biostimulation, which caused an increase in the biological yield for about 1 t/ha independently of the variety in comparison with the control.

K e y w o r d s: laser biostimulation, yielding of sugar beet roots, chemical composition of sugar beet roots

INTRODUCTION

Pre-sowing laser biostimulation is one of methods used which has given hope for an increase in the crop yield of sugar beet without causing detrimental damage to natural environment. The goal of the study was to define the influence of pre-sowing He-Ne laser irradiation of sugar beet seeds on the biometric characteristics, yield and chemical composition of the sugar beet roots of some sugar beet varieties. The experiments carried out on seeds and sugar beet roots showed that this type of operation stimulates plant growth and development [1,3-6,8,9,16]. The basis of the stimulation mechanism according to Bielozierskich and Zolotariewa [1] is the synergism between the polarized, monochromatic red laser beam and the phytochrome receptors of the sugar beet root as a result of seed irradiation photoactivation of the phytochromes which intensified the development of plant in later phases of growth.

The results of study show that there exists the possibility of the awakening of the physiologic processes of plants with the utilization of light stimuli [10]. The outcome of such treatment, among others, is an increase in the intensity of photosynthesis of plant pigments, amino acids, nucleic acids, proteins and consequently a rise in the crop yield. Many experiments carried out by Injuszin [3-6] indirectly confirm the justiness of the hypothesis put forth by Bielozierskich and Zolotariewa [1].

Many authors confirm the rise in germination energy and an equalization of sprouts [2,10,14]. It had also been observed that the laser treatment of sugar beet seeds influenced them in such a manner as to increase their resistance to disease. It must be emphasized that the plants from the laser treated seeds had an average leaf surface 28 to 30 % grater than the control plants [3], the root yield higher by 7-28 % [1,5,11,15] and the sugar content increased by 0,3-1,4 % [4,11-13].

METHODS

Four varieties of sugar beets were studied: Colibri, Evita, Kawetina and Maria, which are hybrid, triploid mono-seedling varieties with good germination energy. Their seeds were biostimulated during free falling with divergent He-Ne laser beams, provided by two lasers (40 mW), placed one upon another [7]. A schematic diagram of the device for the pre-sowing biostimulation is shown in Fig. 1. The whole device, constructed in the Department of Physics, Agricultural University in Lublin according to the patent of R. Koper and Z. Dygdala [1] is demonstrated in Fig. 2.

Four laser irradiations variants were used: single, double, triple and quadruple [9]. The seeds were biostimulated three days before sowing. The control seeds were not biostimulated. The experiments were performed acc. to the split-plot method in three repetitions [16]. In autumn, for the winter tillage, 40 t/ha of stable manure was used along with a potassium-phosphorus fertilizer (120 kg/ha P_2O_5 and 200 kg/ha K_2O). A nitrogen fertilizer was used in the spring in the amount of 160 kg/ha in two doses. Autumn and spring cultivations had been carried out according to the correct rules of agrotechnics. The seeding depth was 3 cm and the plant spacing was 45 cm. Following the gapping, the density of plants was about 80 thousand/ha. The sowing of the sugar beet seeds took place on April 18. During the plant vegetation period mechanical nursing operations had been carried out three times. Before the harvest of 20 plants from each experimental plot biometric measurements had been performed. The leaf and root harvest had been carried out from October 10-20. After the harvest, measurements of leaf and root yield along with harvest index had been taken. Moreover, the chemical
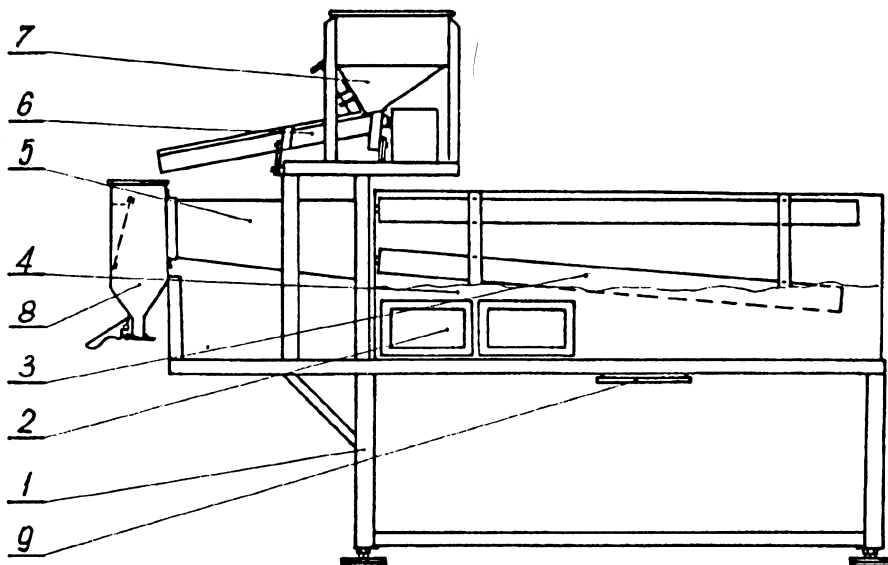

Fig. 1. Schematic diagram of the device for the pre-sowing biostimulation, equipped with two He-Ne lasers of 40 mW each: supporting structure 1, laser power supplies 2, lasers 3, casing of lasers and laser power supply 4, laser beam casing 5, seed vibratory conveyor 6, charging hopper 7, sack for seeds 8, laser casing filter 9.
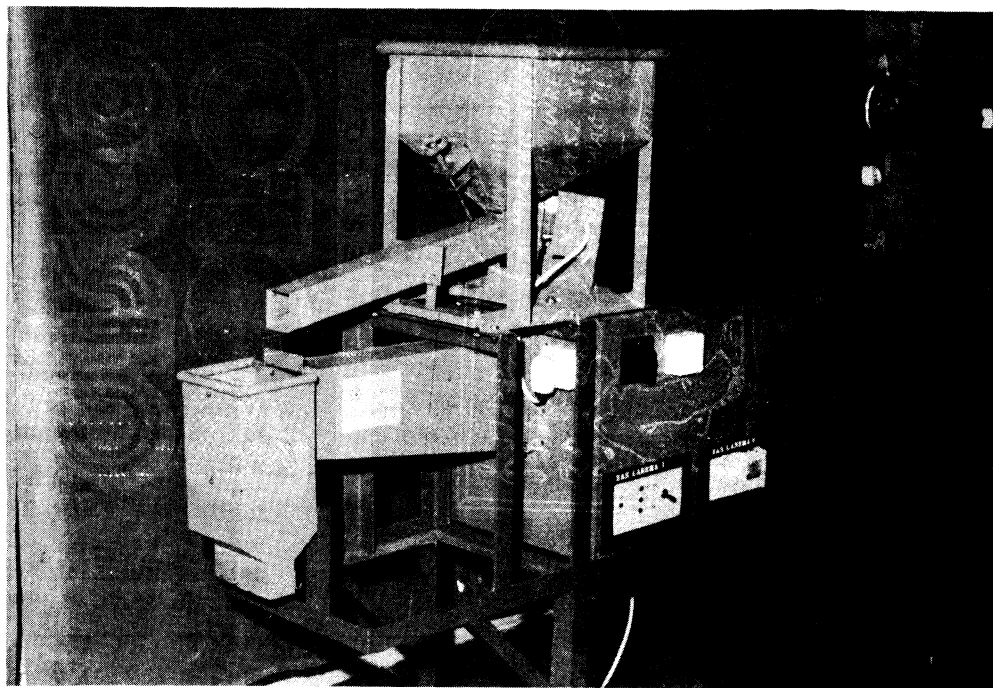
Fig. 2. The device for the pre-sowing laser biostimulation.

analysis was made to check the plant dry mass, the content of sugar, soluble ash, alpha-amine nitrogen, P, K, Mg, Ca, Na, Cu, Mn, Zn, Fe. The content analysis was performed in the laboratories of the Lublin Sugar Factory. The results gained underwent statistical analysis, determining the substantial differences utilizing the T. Tukey test.

The seeds of Maria variety were obtained from Sugar Beet Breeding in Kutno, the rest of the seeds - from Sugar Mills in Lublin and Krasnystaw.

EXPERIMENTAL RESULTS

The results of the experiment indicate that pre-sowing laser seed treatment favorably influenced yields of roots and leaves of the sugar beet (Tables 1 and 2). With two exceptions (Evita variety after a single and double laser treatment and Kawetina variety after quadruple laser treatment) in most combinations concerning the biostimulated seeds in 1994, the yield of roots was elevated by 1.2 to 12.3 t/ha, which means an increase of 1.1-27.8 %

when compared to the control (non-biostimulated) seeds. The most significant influence was found for double, triple and quadruple laser treatment of Maria variety seeds (21.6 and 27.8 %, respectively; Table 1).

The yield of leaves was similar. A reduction of leaf yields was observed for Evita variety (single to quadruple biostimulations) and for Colibri variety double and triple biostimulated. The leaf yield was elevated by 0.2 t/ha (Colibri variety after single biostimulation) to 20.1 t/ha (Maria variety after triple biostimulation), which means an 0.5-64.6 % increase (Table 1). The meteorologic conditions had an important effect on the leaf yield during the vegetation period.

The sugar content was also elevated after the laser biostimulation, which caused an increase in the biological yield by about 1 t/ha, independent of the variety in comparison with the control.

The best results were obtained after triple laser treatment of Evita variety seeds (2.7 % increase). A small reduction of sugar content

T a b l e 1. Yield of roots and leaves, sugar and soluble ash content, biological yield of sugar and harvest index for varieties of sugar beet studied

Number of biostimulations	Varieties				Mean
	Colibri	Evita	Kawetina	Maria	
Yield of roots (t/ha)					
0	56.2	53.4	56.0	44.3	52.5
1	58.0	52.2	60.5	57.5	57.0
2	60.7	46.8	61.5	53.9	55.7
3	58.4	54.4	57.0	56.6	56.6
4	60.6	54.0	55.8	52.7	55.8
Mean	58.8	52.2	58.2	53.0	55.5
Yield of leaves* (t/ha)					
0	36.4	46.7	49.3	31.1	40.9
1	36.6	43.7	51.3	47.3	44.7
2	35.1	43.4	53.2	44.1	44.0
3	36.0	42.8	55.9	51.2	46.5
4	44.3	41.5	55.1	46.9	47.0
Mean	37.7	43.6	53.0	44.1	44.6
Sugar content (%)					
0	18.4	16.3	18.1	17.5	17.6
1	16.2	18.1	18.9	18.2	17.8
2	16.8	17.5	17.5	17.3	17.3
3	18.6	19.0	19.0	17.8	18.6
4	18.8	17.2	17.3	18.4	17.9
Mean	17.8	17.6	18.2	17.8	17.8
Soluble ash content (%)					
0	0.414	0.367	0.461	0.476	0.430
1	0.456	0.373	0.337	0.409	0.394
2	0.423	0.426	0.322	0.410	0.395
3	0.433	0.388	0.394	0.546	0.440
4	0.456	0.355	0.377	0.428	0.404
Mean	0.436	0.382	0.378	0.454	0.413
Biological yield of sugar (%)					
0	10.34	8.70	10.14	7.75	9.23
1	9.40	9.45	11.43	10.46	10.18
2	10.20	8.19	10.76	9.32	9.62
3	10.86	10.34	10.83	10.07	10.52
4	11.39	9.29	9.65	9.70	10.01
Mean	10.44	9.19	10.56	9.46	9.91
Harvest index**					
0	0.607	0.533	0.532	0.587	0.564
1	0.613	0.544	0.541	0.548	0.561
2	0.633	0.518	0.536	0.550	0.559
3	0.618	0.559	0.505	0.525	0.551
4	0.577	0.565	0.503	0.529	0.543
Mean	0.609	0.544	0.523	0.546	0.555

* $LSD_{0.05}$: between varieties - 15.4; between number of biostimulations - 4.9; jointly: varieties x combinations - 9.2.

** $LSD_{0.05}$: between varieties - 0.09.

T a b l e 2. Some elements of the chemical composition of sugar beet roots

Specification	Number of biostimulations					Mean
	0	1	2	3	4	
Ash (%)	5.35	6.97	6.64	6.14	5.08	6.04
Crude fibre (%)	6.06	7.00	6.59	6.79	5.86	6.46
Total N (%)	1.25	1.25	0.98	1.02	1.15	1.13
P (%)	0.20	0.15	0.12	0.19	0.17	0.16
K (%)	1.13	1.00	0.92	0.92	0.76	0.95
Mg (%)	0.33	0.32	0.30	0.33	0.30	0.32
Ca (%)	0.061	0.062	0.066	0.053	0.054	0.059
Na (mg/kg d.m.)	1186	1130	986	10.32	974	1062
Cu (mg/kg d.m.)	11.5	9.6	9.5	11.4	10.8	10.6
Mn (mg/kg d.m.)	53.6	46.3	54.3	65.0	62.3	56.3
Zn (mg/kg d.m.)	52.3	52.9	41.1	50.2	57.0	50.7
Fe (mg/kg d.m.)	282.3	325.9	303.0	353.4	256.0	304.1

was observed for Colibri variety (single and double biostimulated), Kawetina va-riety (double and quadruple biostimulated) and Maria variety (double biostimulated, Table 1).

The amount of the soluble ash was found to be distincly lower for Kawetina variety, except of triple laser treatment. In the remaining varieties and combinations, the soluble ash content, in comparison with the control group, was somewhat higher (Table 1).

Biological yield of sugar was also more differentiated. Single laser treatment for Colibri variety, double laser treatment for Colibri and Evita variety and quadruple laser treatment for Kawetina variety unfavourably influenced the biological yield of sugar. In the remaining combinations, the biological yield of sugar was elevated by 5.0 to 35 %. The highest proportional increase in biological yield of sugar (35 %) was found for Maria variety after single laser treatment (Table 1).

Pre-sowing laser biostimulation of sugar beet seeds also had a favourable influence on the chemical contents of roots. Especially, the amount of total N, P, K, Ca and Na was reduced.

The negative influence of laser treatment was found on the content of ash and crude fibre. Non-characteristic effects were observed in the case of contents of Cu, Mn, Zn and Fe (Table 2).

Values of harvest index for all examined varieties of sugar beet seeds are shown in Table 1.

CONCLUSIONS

1. The results of investigations show beneficial effect of laser exposure of seeds on sugar beet yielding. However, the statistical analysis did not show any statistical significance of the pre-sowing laser biostimulation of sugar beet seeds, a considerable increase in the yield of roots was noted after double, triple and quadruple biostimulations.

2. The best results in the root yield were obtained after double and triple laser treatment for Maria variety.

3. The highest increase of leaf yield was observed for all laser biostimulations of Maria variety.

4. The sugar content was elevated especially after triple laser treatment of Evita variety.

5. The amount of soluble ash was distincly lower for Kawetina variety after single and double laser treatment.

6. The highest increase in biological yield of sugar was found for Maria variety after single laser treatment.

7. Pre-sowing laser biostimulation caused the reduction of such elements as N, P, K, Ca and Na in roots of beets.

8. The positive effects of using the device for the pre-sowing laser biostimulation of seeds suggest that the technology, based on the application of small power lasers, should be videly applied in the plant production.

REFERENCES

1. **Bielozierskich M.P., Zolotariewa T.A.:** Laser treatment of seeds (in Russian). Sugar Beet, 2, 32-33, 1981.
2. **Gorbunowa T.A.:** The influence of laser treatment of seeds on sugar beet yielding (in Russian). Problems of Plant Photoenergetics and Crop Increasing. All-Union Conf. Lvov, 1984.
3. **Injuszin W.M., Iljasov G.U., Fiedorowa N.N.:** Laser as a stimulant of plant growth (in Russian). Kainar Publ., Alma-Ata, 1973.
4. **Injuszin W.M.:** Laser technology in agricultural services. An attempt of using a new optic-quantum generator (in Polish). New Agriculture, 21/22, 21-26, 1977.
5. **Injuszin W.M.:** Laser light and crop (in Russian). Kainar, Alma-Ata, 1981.
6. **Injuszin W.M., Fiedorowa N.N.:** The application of lasers in agricultural farms (in Russian). Electronic technique. Electronics 1, 12, 133-139, 1972.
7. **Koper R., Dygdala Z.:** Set-up for the pre-sowing laser biostimulation (in Polish). Patent No. 162588, 1993.
8. **Koper R.:** Pre-sowing laser biostimulation of seeds of cultivated plants and its results in agrotechnics. Int. Agrophysics, 8, 593-596, 1994.
9. **Koper R., Grochowicz J.:** Equipment of the pre-sowing laser biostimulation of seeds of cultivated plants and the effects of biostimulation. Proc. of XII World Cong. Agric. Eng., 1224-1229, 1994.
10. **Krousky J., Ruml M.:** The influence of stimulation of sugar beet seeds on seedlings, growth and yielding (in Czech). Plant Production 36, nr 1, 89-98, 1990.
11. **Macucina L.B.:** The alterations of sugar beet root quality due to pre-sowing laser biostimulation (in Russian). Problems of Plant Photoenergetics, 1, 114, Alma-Ata, 1974.
12. **Nijazbekow B.N., Kasymirzanow S.Ch., Macucina L.B., Plochich W.B.:** Laser agrotechnics of sugar beet in Taldy-Kurganskaja region (in Russian). Problems of Plant Photoenergetics and Crop Increasing. Proc. of All-Union Conference, Lvov, 218-219, 1984.
13. **Sizow J.M., Ceiliew W.J., Czerwko W.P.:** The increase in yielding and the sugar content as a result of laser stimulation of seeds in agricultural farms in Kujbyszew region (in Russian). Proc. of All-Union Conference, Lvov, 1980.
14. **Swawolia J.I., Jakobienczuk W.F., Iwaniw M.S.:** Laser biostimulation of sugar beet seeds in agricultural farm in Lvov region (in Russian). Proc. of All-Union Conference, Lvov, 209-210, 1984.
15. **Tkaczuk W.N., Bokowoj W.I:** The estimation of laser biostimulation of sugar beet seeds influence on their quality and yielding (in Russian). Theory and Practice of Pre-sowing Seeds Treatment, J. Abstracts, Kiev, 97-101, 1984.
16. **Wójcik S.:** Effects of laser exposure of seeds on the yield and chemical composition on sugar beet roots. Proc. Int. Conf. Phys. Prop. Agric. Mat., Bonn: Paper No. 93-1211, 1993.