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IMPACT OF LASER LIGHT AND MAGNETIC FIELD STIMULATION ON THE PROCESS OF BUCKWHEAT SEED GERMINATION

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K e y w o r d s: buckwheat, germination, laser stimulation, magnetic field, simulation model.

A b s t r a c t

This paper presents the results of research on the influence of laser and magnetic field stimulation and the combination of both stimulants on the process of germination of buckwheat cv. "Kora" seeds. Germination tests were carried out in a controlled environment chamber with a stable temperature of 21^{o}C, stable humidity and without a source of light. The curves obtained during the experiment were described based on a simulation model. The applied physical stimulation factors affected the germination rate of buckwheat seeds, but they did not increase the final number of germinated seeds.

ANALIZA WPŁYWU ŚWIATŁA LASEROWEGO I POLA MAGNETYCZNEGO NA PROCES KIEŁKOWANIA NASION GRYKI

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S ł o w a k l u c z o w e: gryka, kiełkowanie, stymulacja laserowa, pole magnetyczne, model symulacyjny.

S t r e s z c z e n i e

W pracy przedstawiono wyniki badań nad wpływem światła laserowego, pola magnetycznego oraz kombinacji tych czynników na proces kiełkowania nasion gryki odmiany Kora. Testy kiełkowania przeprowadzono w komorze klimatycznej w stabilnej temperaturze 21^{o}C, stałej wilgotności i bez dostępu światła. Krzywe doświadczalne otrzymane na podstawie eksperymentu opisano za pomocą modelu symulacyjnego. Poddanie badanych nasion działaniu fizycznych czynników stymulacyjnych wywarło wpływ na tempo ich kiełkowania, jednak nie odnotowano zwiększenia końcowej liczby wykiełkowanych nasion.

Introduction

Plant production requires seeds which meet adequate qualitative standards. The obtained seeds are both the means of the production process and its goal (GRZESIUK, KULKA 1981), which is why the use of good quality material determines the germination process and affects the height and quality of the yield. Factors which play the most important role in the germination process include genetic and environmental conditions (hydration, access to air, adequate temperature) as well as seed growth conditions. Seeds have to be adequately prepared prior to sowing with the application of chemical agents (seed dressing, growth regulators) or physical factors (VASILEWSKI 2003) (magnetic and electric field, ionizing, microwave and laser radiation) which usually have a positive effect on the germination process and the yield.

The authors of this study aimed to analyze the impact of stimulation with a He-Ne laser beam (CIUPAK i in. 2006), magnetic field and a combination of the above factors on the process of buckwheat seed germination. Physical stimulation factors have already been applied to various vegetables, including tomatoes (GŁADYSZEWSKA 1998, GŁADYSZEWSKA, KOPER 2002a, GŁADYSZEWSKA, KOPER 2002b, KOPER i in. 2001) onions (PIETRUSZEWSKI i in. 2002a, PROKOP i in. 2001, PROKOP i in. 2002), cabbage (PIETRUSZEWSKI i in. 2002b), radishes (PIETRUSZEWSKI i in. 2002c, PROKOP i in. 2002a), spinach (PIETRUSZEWSKI i in. 2002c), sugar beets (KOPER i in. 2002, PIETRUSZEWSKI 2000), pulse crops – faba beans (PODLEŚNY 2002, PODLEŚNY, PODLEŚNA 2007, PODLEŚNY, PODLEŚNA 2004), cereals – wheat (KORDAS 2002, KOMARZYŃSKI i in. 2004, PIETRUSZEWSKI 1999, PIETRUSZEWSKI i in. 2002c), barley (RYBIŃSKI i in 2004, RYBIŃSKI i in 2002), oat (DROZD i in. 2004), maize (ROCHALSKA 1997, ROCHALSKA 2002), flax (OLCHOWIK, GAWDA 2002) and plants of the family Brassicaceae, including thale cress (QIN i in. 2006) and woad (used in the production of indigo pigment) (YI-PING CHENA i in 2005). The results of many research studies indicate that vegetable seeds are more susceptible to stimulation. The effect of pre-sowing simulation on the germination of buckwheat seeds (which is classified as a cereal only due to a similar farming technology) and the extent to which it affects the germination process have not been investigated to date.

The objective of this study was to determine the impact of laser beam and magnetic field stimulation on the process of buckwheat seed germination and to verify the possibility of applying the simulation model to the description of the germination process.

Materials and methods

The experimental material comprising buckwheat cv. Kora seeds (harvested in 2003) was subjected to laser stimulation (in 3 series during the free fall of seeds from the charging hopper chute) with a He-Ne laser beam with a wavelength of λ=630 nm and density power of 4 mW/cm^2 (group L), magnetic field stimulation with an intensity of 30 mT (group M) and a combination of the above factors (groups LM and ML). The time of exposure to a variable magnetic field with a frequency of 50 Hz was 8 seconds. The germination of buckwheat seeds (placed in a controlled environment chamber) was observed at a stable temperature of 21^{o}C, with stable humidity and without a source of light. Each group was represented by 400 seeds sown on Petri dishes (on stimulation day) in 4 samples of 100 seeds each. Germinated seeds (showing germs with a minimum length of 2 mm) were counted every 1–2 hours beginning from the appearance of the first germ (when germination was most intense). The time intervals in which germs were counted were gradually extended due to decreasing germination intensity. As a point of reference for further analysis, the study involved control groups of non-stimulated buckwheat seeds. Based on the obtained results, the percentage of germinated seeds N_k was calculated with the use of the below formula:

$$N_k = \frac{n_k}{n_c} \cdot 100\%$$

where:
n_k – number of germinated seeds,
n_c – total number of sown seeds

The germination rate S_k (seed/h) of buckwheat seeds was calculated with the use of the below formula:

$$S_k = \frac{n_{\max}}{\Delta t}$$

where:
$n_{\max}$ – maximum number of germinated seeds recorded during the count,
Δt – time interval between two successive counts.

The relative germination rate coefficient W_k was determined with the use of the below formula:

$$W_k = \frac{n(t)}{n_{\text{control}}}$$

where:
$n(t)$ – number of seeds germinated in time t,
n_{control} – number of control group seeds germinated in given time t.

A simulation model (Gładyszewska 1998, Gładyszewska, Koper 2002a, Gładyszewska, Koper 2002b) was applied for the mathematical description of experimental results. The change in the $n(t)$ number of germinated seeds in a given time interval is described with the following formula:

$$n(t)=n_k \cdot \left(1-\frac{\alpha \cdot e^{-\lambda_1(t-t_0)}+\beta \cdot e^{-\lambda_2(t-t_0)}+\gamma \cdot e^{-\lambda_3(t-t_0)}}{\alpha+\beta+\gamma}\right)$$

where:

$\alpha=\lambda_2 \cdot \lambda_3 \cdot (\lambda_2-\lambda_3)$

$\beta=\lambda_3 \cdot \lambda_1 \cdot (\lambda_3-\lambda_1)$

$\gamma=\lambda_1 \cdot \lambda_2 \cdot (\lambda_1-\lambda_2)$

Parameters λ_1, λ_2, λ_3 indicate the probability of seed evolution from one growth phase to another; n_k is the final number of germinated seeds; t is the germination time (h); t_0 is time between the end of the latent development phase and the beginning of germ formation phase.

Results and discussion

Common buckwheat (Fagopyrum esculentum Moench) is characterized by high heat requirements and frost sensitivity. According to professional literature (Grzesiuk, Kulka 1981), the most favorable growth environment for the common buckwheat is at a temperature range of 20–25°C. For this reason, the authors of this study decided to adopt the optimal temperature for the analysis of the germination process. When conducted at the above temperature range, the experiment produces results already after 24 hours from sowing.

The obtained data were applied to determine the final number of germinated buckwheat seeds N_k (in %) and to calculate the germination rate S_k. Five special time points (corresponding to successive germination days) were also identified in the observed process for which the change in the percentage of germinated seeds relative to the control group was analyzed. A comparison of the obtained results indicates that none of the applied stimulation methods reduced the time of germination of the first seeds. Germination time in all groups was 24 hours. As of that moment, an increase in the number of germinated seeds (Fig. 1) was also observed, and a 7% increase in that number was reported on the second day after sowing in respect of seeds which were subjected to laser beam stimulation followed by magnetic field stimulation (group LM) in comparison with control (71%). The number of germinated seeds was 11.5% higher for the same combination of stimulating factors (LM) than in the group of seeds where magnetic field was applied as the first stimulant – ML (66.5%). At the third point indicated on the time axis (hour 72 after sowing), the number of germs increased by 6% within 24 hours in the control group and group LM, and by 8.5% in group ML. The number of germinated seeds in group LM was also higher in comparison with the control group (77%) at the same time point (second

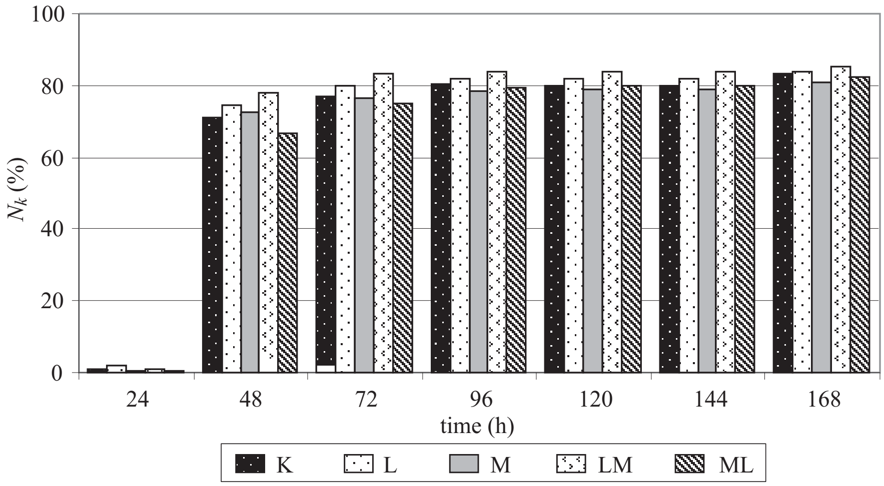

Fig. 1. Number of germinated seeds N_k (%) as a function of germination time

germination day). This was confirmed by a statistical analysis based on testing the hypothesis of the difference between two means (at a significance level of α=0.05). With a combination of factors where laser beam stimulation was followed by magnetic field stimulation (group LM), the final value N_k reached 84% as soon as in hour 48 of the germination process.

A minimum percentage increase in the number of germinated seeds was observed on the third day after the appearance of the first germs, i.e. in hour 96 after sowing, both in the group of stimulated seeds and in the control group. At the fifth time point, which marks the moment when the last germinated seeds were counted (sixth germination day), the final number of germinated seeds was determined. The obtained results indicate that the rate of the germination process was uniform at the end of the experiment (Fig. 1) and that none of the applied stimulation factors increased the final number of germinated seeds.

Based on observation data obtained in the first 24 hours of the germination process, the value of the relative germination rate coefficient W_k (Tab. 1)

Table 1

Relative germination rate coefficients

Hour	L	M	LM	ML
26	1.09	1	1.09	0.36
28	0.87	0.8	0.97	0.83
30	1.23	1.31	0.77	1.14
32	0.73	0.87	0.83	0.79
33	1.83	1.17	1.52	1.00
35	1.37	1.3	1.43	1.07
48	0.9	0.93	1.43	1.05

was determined and changes in that coefficient as a function of seed germination time were presented in graphic form (Fig. 2).

The highest germination intensity (42 germinated seeds in 1 hour) was reported in the group of seeds stimulated with a He-Ne laser beam in hour

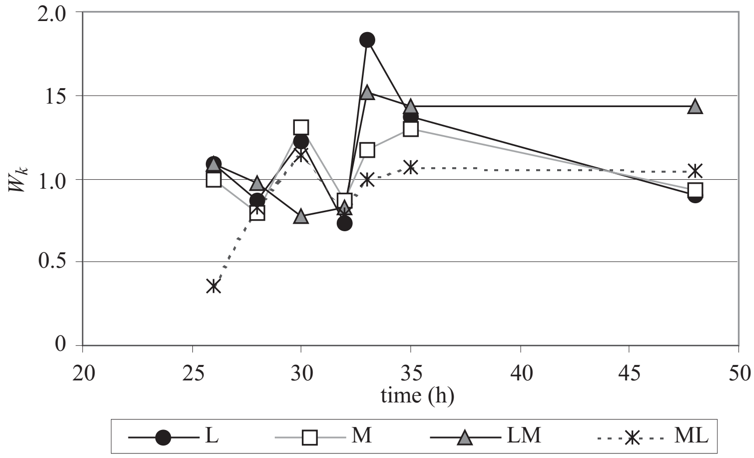

Fig. 2. Relative germination rate coefficient as a function of seed germination time

9 after the appearance of the first germs (the relative germination rate coefficient for that group of seeds relevant to control was 1.83). The value of W_k for seeds stimulated with a laser beam and, subsequently, a magnetic field reached 1.52 at the same time, and it remained at the highest level among all groups stimulated in successive hours of the count (Tab. 1).

Figure 3 presents the germination rate S_k of buckwheat seeds subject to the applied stimulation method. The curves representing particular seed groups illustrate changes in the number of germinated seeds in every time interval. They can be used for a detailed analysis of the initial phase of the germination process.

In comparison with the description of the control group, the shape of the presented curves points to certain changes which resulted from the applied stimulating factors. The maximum germination rate in the control group and in groups M and ML decreased in hour 8 of the analyzed process. A higher number of germinated seeds at that point was observed only in the control group. Nine hours after the appearance of the first germs, the highest S_k value was reported in the group of seeds stimulated with laser and in the laser and magnetic field combination group. In hour 24 of the process (48 hours after sowing), the germination rate was similar in all groups.

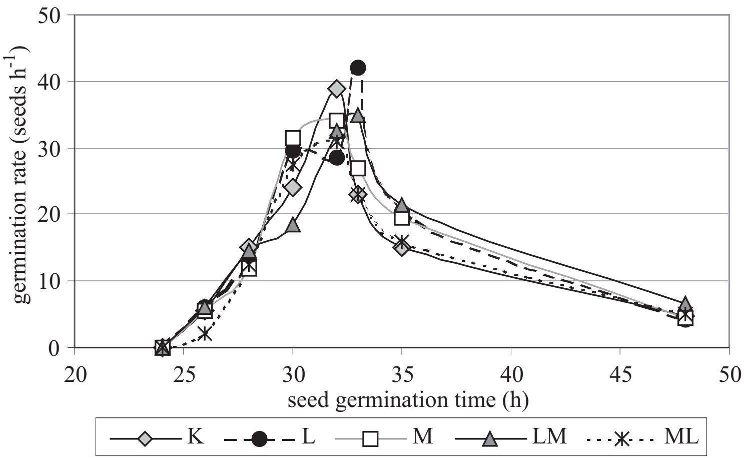

Fig 3. Seed germination rate

Table 2 presents curve parameters which describe the experimental data from the simulation process. The analysis of the course of the curves presented in Figure 4 indicates that the applied model adequately represents the germination process of buckwheat seeds, including both the stimulated and control groups.

Table 2.

Parameters for adjusting the simulation curve to experimental points at a temperature of 21°C

Simulation model					
Stimulation factor	λ_1	λ_2	λ_3	t_o (h)	n_k
Control	0.100	0.96	0.98	23.8	324
Laser	0.120	0.78	0.82	23.8	331
Magnetic field	0.140	0.92	0.96	24.4	316
Laser + Magnetic field	0.140	0.50	0.52	24.4	341
Magnetic field + Laser	0.086	0.96	0.98	24.0	320

A statistical analysis based on testing the hypothesis of the difference between two means with the use of Student's t-test (at a significance level of α=0.05) showed that the applied stimulating factors did not increase the final number of germinated buckwheat seeds.

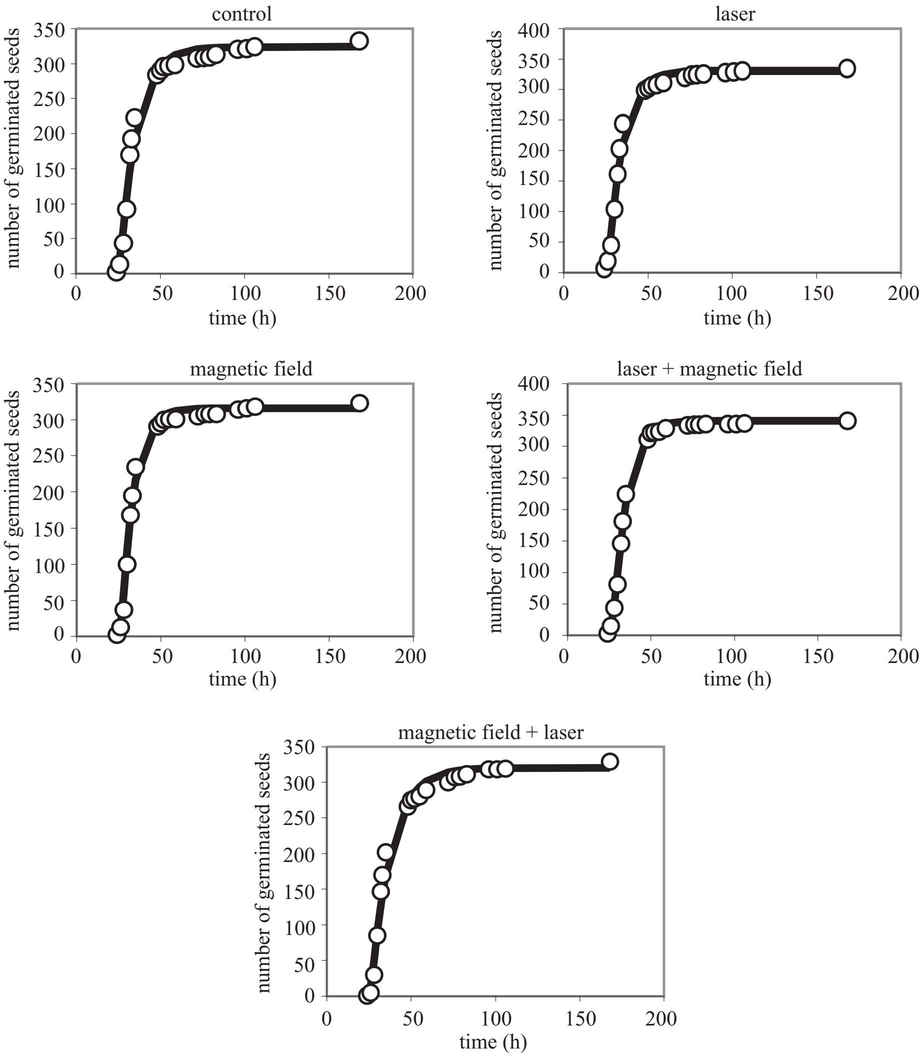

Fig. 4. Experimental germination curves (o) and model curves (-) generated based on the simulation model at a temperature of 21°C

Conclusions

1. The course of curves mapping the germination rate of stimulated seeds point to a certain dependency on the applied physical factors.

2. None of the applied stimulating factors accelerated the beginning of the germination process of buckwheat seeds.

3. There were no statistically significant differences in the final number of germinated seeds which were subjected to stimulation.

4. A 7% increase in the number of germinated seeds subjected to laser stimulation followed by magnetic stimulation was observed (in comparison with control) at the initial germination stage (48 hours after sowing).

5. The highest germination intensity expressed by the value of coefficient W_k was observed in hour 33 and 35 after sowing.

6. The applied simulation model is highly effective in describing experimental points for both the control and stimulated seed groups.

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