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STRESS METHOD FOR PRE-SOWING STIMULATION OF SEEDS AND DETERMINATION OF THEIR BIOENERGY CAPACITY BY CALORIMETRY

Introduction. *To date, many different devices and methods have been developed for pre-sowing stimulation of seeds in order to increase yields and to maximize the seed bioenergy capacity.*

Problem Statement. *However, the conventional methods for pre-sowing stimulation of seeds with subsequent determination of germination require a wide range of equipment and consumables plus long research time. Developing new methods of pre-sowing treatment and the development of new methods for determining the bioenergy capacity of sowing material is a promising field of research.*

Purpose. *The purpose of this research is to study the stress method for pre-sowing stimulation of seeds and determination of its bioenergy capacity by the calorimetry method.*

Materials and Methods. *To determine the bioenergy capacity of seed material, two batches of Myronivska-808 variety wheat seeds are taken, one of which is subjected to a stress in the form of impact on a rigid surface. The bioenergy capacity of the seed has been determined with the use of the calorimetric device B-08 M, according to DSTU ISO 1928:2006.*

Results. *It has been shown that the bioenergy capacity before and after impact is 10842 kJ/kg and 12649 kJ/kg, respectively, the difference between them is 1807 kJ/kg. This indicates that as a result of the stress treatment of the seeds, their bioenergy capacity increases by 14.3%. At the same time, no seed damages caused by falling of the seed mass from a height of 3 m on a motionless surface have been found.*

Conclusions. *An increase in the bioenergy capacity of seeds after impact by 14—15% indicates that the stress method of pre-sowing stimulation is rather effective. The use of calorimetry methods may be recommended as a way to control the quality of the stress method of pre-sowing stimulation of seed material.*

Keywords: nodule bacteria, inoculation, legume-rhizobial symbiosis, strain, bacterial preparations, Rhizostym.

Currently, many different devices and methods have been developed for pre-sowing stimulation of seed mass, for example, exposure to electromagnetic fields, optical radiation, thermal energy, and many others in order to increase the yield. However, the conventional methods for studying the effect of exposure to radiation are limited to determining the

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germination energy of non-irradiated and irradiated seeds in accordance with GOST 12038-84. This GOST for the determination of germination energy provides a wide range of equipment and consumables, time-consuming determination, with all operations performed manually. Therefore, it is promising to develop a resource-saving stress method for pre-sowing stimulation by hitting the seeds at a rigid surface and to determine the results of this effect with the use of rapid calorimetric methods. In this research, we have evaluated the reaction of the seed material, namely its bioenergy capacity, on the calorimetric bomb before and after the stress treatment.

Therefore, the study of the stress method for pre-sowing stimulation by dropping the seed mass on a rigid surface and the determination of the seed bioenergy capacity before and after the stress treatment with the use of calorimetric methods are an urgent task.

To date, there are the three main theories of the interaction of optical radiation and seeds: the photoresonant, the bactericidal, and the stress ones [1]. The authors of the photoresonance theory have suggested that radiation stimulates the initial growth processes. The biostimulating effect of radiation on seeds is based on the structural and functional rearrangement of membrane formations and intracellular organelles. As a result, the level of lipid oxidation (pH) changes, which leads to increasing bioenergy capacity [1].

Another theory of plant growth stimulation focuses on the bactericidal action of radiation. The analysis of the literature on the seed irradiation technologies has shown that low doses cause a slight increase in the germination and do not have a significant effect on the seed microflora. High doses of radiation provide a greater effect against phytopathogens, but they are usually phytotoxic and reduce the seed germination. Ultraviolet radiation (UV) has a destructive and lethal effect on live plant and bacterial viruses [1].

The stress theory of the interaction of radiation and seed mass assumes the mobilization of genetically inherited reserves of the seeds to grow. At the same time, the seeds receive an unusually powerful effect that puts them in a state of stress. While relaxing from the stress the seeds mobilize their hidden resources. Since there are no unfavorable factors, these resources are used to enhance seed growth and development [1].

We consider the process of hitting the seed mass at a stationary surface as one of the options of the stress theory and assume approximately this impact completely inelastic. Then, according to Carnot's theorem on the greatest loss of kinetic energy in the case of such an impact [2, 3, 11–14], we may state that the potential energy transforms into the kinetic energy, and the latter is converted into heat. The seed undergoes heat stress, to get out of which it mobilizes hidden resources and "direct" them to enhance the growth and development of seeds. No damage of the seed outer surface has been reported.

Therefore, the study of the stress method for pre-sowing stimulation of wheat seeds by hitting them at a stationary surface is a further development of the stress theory of interaction with the seed mass.

Studies by Adamtsevich A. O. [4] and Fomina M. M. [5] have given examples of the use of calorimetric methods in construction. These developments provide a solution to the research and practical problem and the introduction of new methods for operational forecast of cement system strengthening. This is the justification of new methods for determining the effectiveness of additives that change the kinetics of rigidening of materials based on cement binders, without the use of standard methods of strength control.

Fedotov V. A. and Ochirova V. D. [6] have studied the bioenergy capacity of wheat seeds and determined it by measuring electrical signals of the treated seeds with the use of DSO 2100 electronic oscilloscope (Fig. 1, *b*) [6].

According to the authors, the oscillograms show that the treated seeds have a bioenergy potential. The comparison with the reference seeds is given to demonstrate that the untreated seeds are

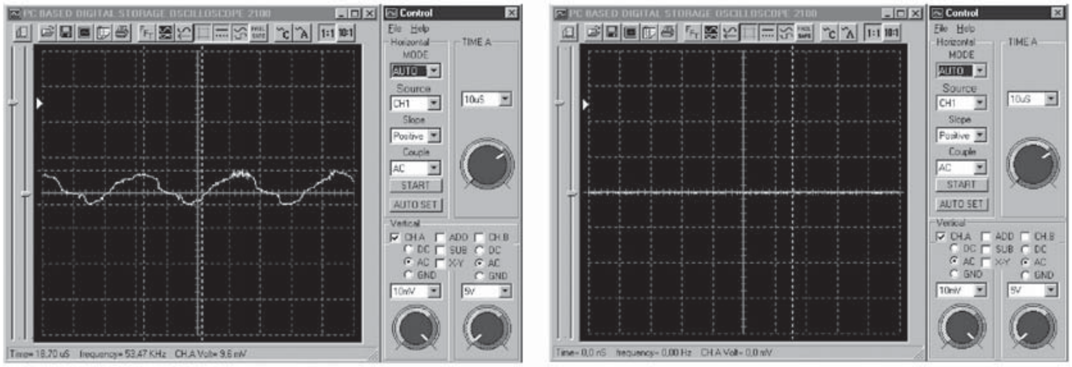

Fig. 1. Oscillograms of bioenergy capacity of wheat seeds in a day: *a* — the treated seeds; *b* — the reference seeds

dormant. The authors have shown in graphical form the effectiveness of seed exposure to radiation.

Vasilenkov V. E. and Gudzenko M. M. [7] have shown an example of the application of calorimetric method in the study of the results of seed material exposure to an electric field. The analysis of the results has shown that the germination of non-irradiated and irradiated seeds is 82% and 88%, respectively, and the energy value is 10 842 kJ/kg, and 11 985 kJ/kg, respectively, i.e. in the case of exposure, it increases by 10.5%. The experimental dependence has been established: to increase germination by 1% it is necessary to increase the energy value of seed mass by approximately 1.83%. This result has proven the efficiency of seed treatment by exposing it to electric field, with the use of calorimetry methods instead of the conventional methods of germination control.

The authors of research [7] have expanded the technological capabilities of calorimetry on the example of stress method for pre-sowing stimulation of seed mass to quantitatively determine the bioenergy capacity of seeds before and after treatment. The results have been presented in the form of an integrated graph of the results of changes in the temperature and a histogram.

The purpose of this research is to study the stress method of pre-sowing stimulation of seed mass and to determine its bioenergy capacity by the calorimetric method.

The materials and research methods are based on using the direct methods for direct measurement of moisture content and combustion heat of different types of samples with the application of the methods of theory of heat transfer, thermodynamics, thermophysics, and theory of measurements in stationary conditions. The theoretical and experimental components of studying the seed mass bioenergy capacity have been implemented with the use of a B–08 M type calorimetric bomb.

To conduct the experiments, a batch of seeds from warehouse storage of Agronomic Research Station research farm (a separate subdivision of NULES of Ukraine) is taken. The seed moisture is controlled at the laboratory of the Department of Heat Power Engineering, with the use of a WILE-55 moisture meter (*Farmcomp*, Finland), in accordance with DSTU 4811:2007. The measurement error of the WILE-55 moisture meter does not exceed 0.4%. The moisture content of the samples is 13–14%, which corresponds to DSTU ISO 6322-1:2004 *Storage of Cereals and Legumes*.

Table 1. **Device and Sample Measurements**

Parameter	Notation	Value	Value	Unit
Wheat grain	—	Untreated wheat seeds	Stressed wheat seed	—
Crucible weight	m_T	8.7	8.7	g
Bag weight	$m_П$	0.075	0.075	g
Seed sample weight	G_T	1.4	1.2	g
Heat storage capacity	K	1646.5	1646.5	cal/g
Igniter's wire material	—	copper	copper	—
Igniter's wire weight	$G_{ПР}$	0.15	0.14	g
Combustion heat off igniter's wire	$q_{пр}$	500	500	cal/g

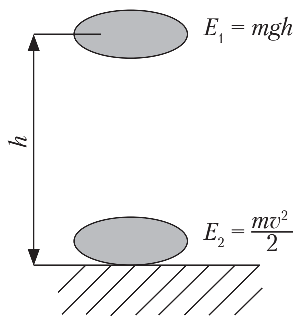

Fig. 2. The scheme of the stress method for pre-sowing stimulation of wheat seeds by hitting them at a rigid surface

To determine the bioenergy capacity of seed material, 2 samples of *Myronivska-808* wheat seeds with a moisture content of 14% are taken: the reference sample and the sample treated by the stress method. 0.5 kg wheat seeds in a plastic bag are dropped from a height of 2, 3, and 4 meters on a wooden floor, the temperature of the seed mass is (+ 20 °C).

The further calorimetric studies have been made with the help of a B–08 M calorimetric device, that is stabilized to a temperature of 25 °C. The initial data are presented in Table 1.

The reference and the treated wheat seed samples are alternately placed in a crucible and burnt in a calorimetric bomb by methods [8, 9]. The obtained data have been mathematically processed and graphically interpreted with the use of *Microsoft Excel* 2003 software package, according to the method described in [10].

The stress method of pre-sowing stimulation of wheat seeds in the form of hitting the seeds at a rigid surface, i.e. dropping the seed mass from a certain height is realized according to the experiment scheme in Fig. 2. At a certain height, 0.5 kg seed mass in a plastic bag is at rest. Its potential energy is equal to mgh. Until it falls on a rigid surface, the seed mass has a kinetic energy equal to $mv^2/2$.

Fig. 2 shows the two positions: at a certain height (the first one) and until falling on a rigid surface (the second one). On the rigid surface, the potential energy is equal to zero.

We have suggested that the seed should be considered a sufficiently inelastic body with a surface shape in the form of an ellipsoid of rotation [11].

The research is based on the classical theory of contact interactions. In this case, the dynamics of energy conversion in absolutely inelastic collision, given Carnot's theorem on the largest loss of kinetic energy in such a collision [11—14], have the following form:

$$E_{pot.} \rightarrow E_{kin.} \rightarrow Q, \quad (1)$$

where $E_{pot.}$; E_{kin} are potential and kinetic energies, respectively, J; Q is heat energy, J.

Having substituted the mathematical definitions of the energies into expression (1) we get:

$$mgh = mv^2/2 = cm\Delta t, \quad (2)$$

where m is the mass of seeds, kg; h is the height from which the seed mass is falling on a rigid sur-

Table 2. **Thermometer Readings in the Periods for Wheat Seeds Before and After the Impact**

No.	Thermometer readings, by periods °C					
	Initial period		Main period		Final period	
	Before impact	After impact	Before impact	After impact	Before impact	After impact
0	25.06	25.06	25.06	25.19	27.31	27.44
1	25.13	25.19	25.13	25.31	27.31	27.44
2	25.06	25.25	25.31	25.63	27.31	27.44
3	25.06	25.25	25.75	25.88	27.31	27.44
4	25.06	25.19	26.13	26.19	27.31	27.44
5	25.06	25.25	26.44	26.50	27.31	27.44
6	25.06	25.19	26.63	26.69	27.31	27.44
7	25.06	25.19	26.75	26.81	27.31	27.44
8	25.06	25.19	26.88	26.94	27.31	27.44
9	25.06	25.19	26.94	27.00	27.31	27.44
10	25.06	25.19	27.00	27.06	27.31	27.44
11	25.06	25.19	27.06	27.19	27.31	27.44
12			27.00	27.19		
13			27.06	27.25		
14			27.13	27.31		
15			27.19	27.36		
16			27.25	27.38		
17			27.31	27.44		
18			27.31	27.44		

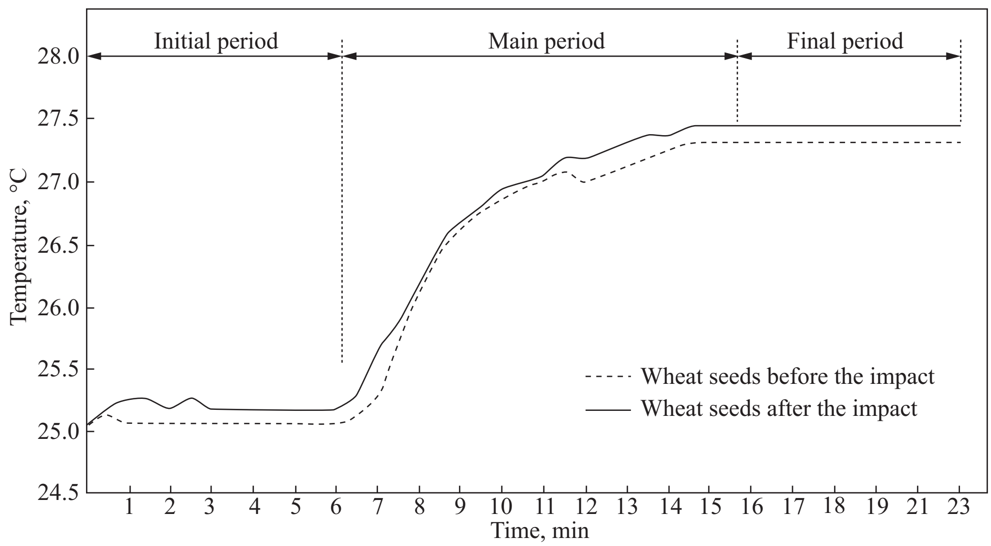

Fig. 3. Changes in the temperature of wheat seeds before and after the impact

face, m. We use 2, 3, 4 m for the experiment. *G* is acceleration of gravity, 9.81 m/s^2; *c* is heat capacity of seeds, $c = 1550$ J/kg deg.

From expression 2 we find Δt for different heights of fall (stressful situations)

$$\Delta t = \frac{g \cdot h}{s} = \frac{9.81 \cdot 2}{1550} = 0.0126\ ^{\circ}\mathrm{C},$$

$$\Delta t = \frac{g \cdot h}{s} = \frac{9.81 \cdot 3}{1550} = 0.0189\ ^{\circ}\mathrm{C},$$

$$\Delta t = \frac{g \cdot h}{s} = \frac{9.81 \cdot 4}{1550} = 0.0253\ ^{\circ}\mathrm{C}.$$

When the seeds are stressed, they are heated by 0.064 °C per 1 m,, on average, i.e. the seed mass comes out of dormancy. Temperature is one of the factors influencing the consequences of bioenergy capacity.

If we consider the seed material a ready-made natural granule or briquette, and choose the stress method for increasing the bioenergy capacity, using a calorimetric bomb is justified to measure the amount of heat released or absorbed in this process.

Calorimetry is a set of methods for measuring the amount of heat released or absorbed during various physical or chemical processes. Table 2 shows the records the thermometer readings in the periods for the stress mode of shock impact.

The integrated graph of changes in the temperature of wheat seeds before and after the impact is built according to the method described in [7] and shown in Fig. 3. The histogram of the temperature distribution in the main period is presented in Fig. 4.

Figures 3 and 4 show that the temperature jump of the main period after the impact is higher than the that before the impact, which has been confirmed by the results of determining the heat of combustion of analytical mass of wheat seeds in a calorimetric bomb (the determination of bioenergy capacity) (Table 3).

The analysis of the calorimetric results of Table 3 has shown that the bioenergy capacity of seeds before the impact is 10 842 kJ/kg, and that after the impact is 12 649 kJ/kg. At the same time, the bioenergy capacity after the impact is hi-

Table 3. **Determination of the Bioenergy Capacity**

Parameter		Wheat seed before the impact	Wheat seed after the impact
Q^{a}_{δ}, (heat of combustion (bioenergy capacity) of the analytical mass of grain)	cal/g kJ/kg	2593 10842	3025 12649

Source: created by the authors on the basis of [17].

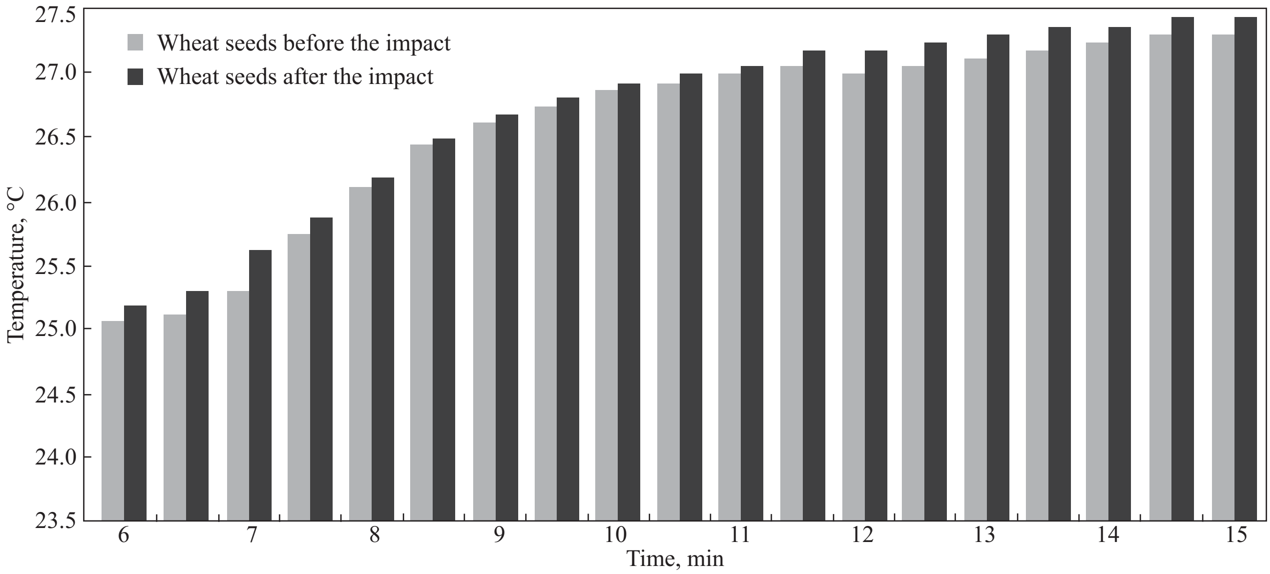

Fig. 4. Histogram of the temperature distribution in the main period

gher by 1807 kJ/kg or by 14.3% than that before the impact. The further research will aim at determining the bioenergy capacity of other crops, the duration of this method, and the development of process technology for the stress method.

Conclusions

1. New methods, the one for pre-sowing stimulation of wheat seeds, namely the stress method of impact by hitting the seed mass at a rigid surface, and the other for measuring the results of this effect, namely determining the bioenergy capacity of wheat seeds on a calorimetric bomb, have been proposed.

2. On the basis of experiments on stress treatment by hitting the seed mass at a rigid surface and the method of calorimetry, the dynamics of thermal processes related to the stress impact have been studied. It has been shown that the bioenergy capacity of wheat seeds before and after the impact is 10 842 kJ/kg and 12 649 kJ/kg, respectively. So, the difference is 1 807 kJ/kg. This indicates that as a result of the stress treatment by hitting the seed mass at a rigid surface, the bioenergy capacity of wheat seeds increases by 14.3%, for the experiment in which the seeds are dropped from a height of 3 meters to a fixed surface. No external damage of the seeds has been reported.

3. An increase in the bioenergy capacity of wheat seeds by 14.3% after the stress impact indicates that the method works and it may be recommended as a pre-sowing stimulation of seeds.

4. Increasing bioenergy capacity after the stress impact allows improving part of substandard seeds into conditioned ones.

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ДОСЛІДЖЕННЯ СТРЕСОВОГО СПОСОБУ
ПЕРЕДПОСІВНОГО СТИМУЛЮВАННЯ ЗЕРНОВОЇ МАСИ
І ВИЗНАЧЕННЯ ЇЇ БІОЕНЕРГЕТИЧНОГО ПОТЕНЦІАЛУ
КАЛОРИМЕТРИЧНИМ СПОСОБОМ

Вступ. На сьогодні розроблено значну кількість різноманітних установок і методів для передпосівної стимуляції посівного матеріалу з метою підвищення врожайності і максимального використання його потенційних біологічних можливостей.

Проблематика. Разом з тим традиційні методи передпосівної стимуляції зернової маси з подальшим визначенням схожості потребують широкого набору обладнання та витратних матеріалів, тривалих термінів дослідження. Перспективним є пошук нових методів передпосівної обробки та розробка нових способів визначення біоенергетичного потенціалу посівного матеріалу.

Мета. Дослідження стресового способу передпосівного стимулювання зернової маси і визначення її біоенергетичного потенціалу калориметричним способом.

Матеріали й методи. Для визначення біоенергетичного потенціалу насіннєвого матеріалу було взято дві партії насіння пшениці сорту Миронівська—808 вологістю 14 %, одну з яких піддавали стресовому способу впливу у вигляді удару об тверду поверхню. Біоенергетичний потенціал зерна визначали за допомогою калориметричної установки В-08 М згідно ДСТУ ISO 1928:2006.

Результати. Показано, що біоенергетичний потенціал до та після удару становить відповідно 10842 кДж/кг і 12649 кДж/кг, різниця між ними складає 1807 кДж/кг. Це вказує на те, що в результаті стресового впливу у вигляді удару зернової маси його біоенергетичний потенціал збільшується на 14,3 %. При цьому при падінні насіннєвої маси з висоти 3 м на нерухому поверхню зовнішніх пошкоджень зерна не виявлено.

Висновки. Підвищення біоенергетичного потенціалу зерна після удару на 14—15 % вказує на те, що стресовий спосіб передпосівної стимуляції відбувся, позитивний ефект зафіксовано. Використання методів калориметрії можна рекомендувати як спосіб контролю якості стресового способу передпосівної стимуляції насіннєвого матеріалу.

Ключові слова: калориметрична бомба, теплота згоряння, стресовий вплив, удар, насіння пшениці, біоенергетичний потенціал.