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Theoretical and experimental research on pre-sowing seed treatment

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Abstract. Grain is a biological object, with all specific responses to external actions, that reside in this category. To define principles that are needed for pre-sowing seed treatment, possible seed responses to external actions were examined. For this, the analysis of the seed's adaptive response was used as an approach. Main rules to organize seeds stimulus have been established. Use of an informational approach for analysis of bio-logical seed response on external action allowed to find utilizing rules for electrophysical stimulation during a pre-sowing treatment. The idea behind them is to use the following sequence of operations at the pre-sawing seeds treatment: determine the lowest external action energetic at which grains response; organize cyclical action of external factor on seeds; change of action amplitude in each cycle; change of external action type. Field experiments have been conducted for several years, during which were determined operational modes of aerated grain bin electrical equipment, when used for pre-sowing seed treatment.
Keywords: pre-sowing seed treatment; air-heat treatment; electroactivated air; ions; electrphysical action; germination; germinative energy; yield; adaptive reaction.

1. Introduction
Pre-sowing seed treatment is a very important technological operation that improves seed material quality, which provides protection from pests and boosts sowing seed quality. The present level of these technologies offers widespread use of electrophysical methods of seed treatment, which allow to increase crop yield at relatively low energy consumption during treatment. This promotes research on the subject, but the implementation of such equipment is not widespread yet. There are several reasons, and the main is that grain is a biological object with all specific responses to ex-ternal actions, that reside in this category. Manufacturer, who decides to use electrophysical stimulation for pre-sowing treatment, wants to be certain in several aspects: receive guaranteed declared result; absence of side effects; stability of results, that are not affected by climatic factors. Let`s consider some elements of the electrophysical treatment influence on seed characteristics that can help manufacturers to get answers.

2. Biological aspects of sowing seed quality change under the influence of different factors
Observation of pre-sowing seed treatment methods demonstrates that there is a general scheme of living organism response, and grains, in particular, on the external action. Response can be directed at

both the preservation of initial grains condition (resistance, resiliency) and adaptation to a new condition.

Plant cells response to different external actions, for example, to temperature, were similar to other organisms' responses (animals, humans) [1-4], therefore, further consideration of this issue will be based on data not only from plants study but also from the other subjects.

In some papers [5, 6], any action on plants considered as stress, that leads to adaptation and development of stability. Specific responses evolve gradually during plant stability development. Fist to arise are nonspecific stress responses, such as a change of membrane permeability, increase of cell cyttropism to dye, pH shift, reduction of membrane potential, which change cytoplasm structure. Under the influence of these quick responses arise intermediate responses (acute-phase proteins, photosynthesis and growth arrest).

Living organism's evolution study tells us that there are a limited number of standard single-type responses to a large variety of actions. Grain response is almost the same to all types of seed treatments (UHF, laser radiation, heat and so on). The difference in responses can depend on the penetration depth of action (acts differently on different parts of grains), hardness and exposure.

Stress is a response to a strong stimulus, however, clear separation of stimulus based on its strength hasn`t been done by anybody. Fundamental research on stress influence on the living organism had been conducted by Selye [7, 8].

Garkavi L.H. and coauthors have shown that a strength of action defines the type of an adaptation response. There are three types of such responses:

- response to a weak action is called training.
- response to a moderate action is called activation.
- strong or extreme action leads to Selye stress.

The first stage, after action onset, is a «going through orientation» of the biological object when it decides further behavior scheme. This stage is called «orientation». If acting factor strength continues to be weak, then the biological object stops taking it as a dangerous and doesn`t accept it. If this situation is transferred on a pre-sowing seed treatment process, then it explains why a weak level of different factors action doesn`t change sowing characteristics. Therefore, it is necessary to know «the lowest» limit of every action, that seeds will respond to. To ensure biological objects staying in the «training» mode, it is important to change the intensity of external action in a cyclical way. In this case, the next stage will start developing, so-called «recombination».

The systematic repetition of weak but gradually increasing stimulus, after some time leads to a defending system enhancement, for this reason, the organism becomes resistant to damaging actions not only because of an inhibition development but also due to defending system activation increase. It is notable, that whatever action was used for «training», resistance increase happens not only to this action but also to the others [10]. Referring to the pre-sowing seed treatment by air-heat processing [11-13], it is reasonable to make an assumption, that positive effect at such pro-longed way of treatment shows up precisely because temperature and relative air humidity are changing during the day. Moreover, changes are happening, for the most part, gradually. There-fore, weak stimulus repetition becomes systematic. The systematic repetition of the moderate strength stimulus, over a period of time, leads to the development of «long-lasting activation».

The facts mentioned above allow assuming that if air-heat treatment of seeds will be carried out in a similar mode, then there is a possibility to get the stable maximum effect. The question is that how the level of seed resistance is connected to its sowing characteristics, what type and what lev-el of external action should be, to ensure seeds «move up» to the «long-lasting activation» level of response. Garkavi L.H. [10] on this problem explains that the level of external action is a relative value. The reference point should start from the action strength when the response of the biological object on the given type of action is evident [10]. Therefore, during the setting of the pre-sowing seed treatment measure of acting factor is not so much important as the increment of its measure in relation to the initial condition. However, there are natural boundary conditions exist, that cannot be omitted, otherwise, the effect might be negative. For example, it is known, that grains shouldn`t be heated above the temperature of 55-60°C. When this is not the case, their sowing quality degrade.

Referring to the factor`s level, which ensures grains transition to the required response, paper [10] says that «… during the experiment, to move from one response to the other (adjacent), it is enough to change acting factor value on 20%». In this regard, main adaptation responses – «training», «mild activation», «extreme activation», and stress – can be triggered in a narrow dose range (strength) of acting factor.

Based on the example of grains temperature change during its aeration treatment, let`s examine the condition of the grain layer.

Let`s define the initial grain temperature at 20°C. Heating of the grain to the temperature of 22-24°C transfers it to the training mode. To the mild activation – 26.4-28.8°C. Extreme activation mode requires a grain temperature at 31.7-34.6°C. Initial temperature decrease will change the temperature of the transition thresholds.

Based on the above, it can be concluded, that seeds resistance increase (and as a consequence, sowing quality) requires the following conditions [14, 15]:

- for adaptation responses occurrence on a level of functional changes but not on a structural lev-el, acting factor should be gradually increasing, longstanding, alternating (cyclical);
- to receive an activation response, it is necessary to start with a physical stimulus of a certain value, then it should be decreased or stopped. Next step is an increase of stimulus strength on 10-20% in relation to the initial value;
- the initial value of a stimulus should be minimal to ensure adaptation responses occurrence at the lower floors of responsiveness. This ensures the highest responsiveness level;
- maximum effect from the physical stimulus can be achieved by a combination of nonspecific responses with specific.

Authors have attempted to describe grain's behavior, as a biological object, under the external influence on it by using the informational approach [16]. Usefulness of grains response was taken as a criterion of stimulus effectiveness. Used by the authors principle of maximum information have shown that usefulness of seeds response to the external action will be maximum at a changeover of different acting factors or at cycles «action - rest». Usefulness of response gets higher when the energetic level of external action goes down. Longstanding low energetic action and short term high energetic action gives different final usefulness of grains response and different pre-sowing treatment results. This will be reflected in specific grain's responses to the external action, which can be observed at different stages of plant development, spike formation, grain filling. In order not to create an extreme inhibition response in grain, it is preferable that the energy level of external action was as low as possible, but still, be accepted by the grains.

The use of the maximum information principle helped to formulate electro-technologies implementation approaches for technological processes development, which are directed at sowing seeds quality improvement and yield structure adjustment. [17]:

- determination of the lowest level of electrophysical value, that ensures seeds response;
- cyclical change of the action amplitude;
- changeover of the external action.

3. Experimental determination of the air-heat processing modes of pre-sowing seed treatment

Experiment on pre-sowing seed treatment by the air-heat processing has been conducted, to confirm presented theoretical statements. Determination of an optimal treatment mode requires a clear understanding of being examined factors range change on the existing facilities during the standard technological process. Aeration has been taken as an example of such a process.

The preliminary experiment has been conducted at the first stage, the objective of which was the determination of what seed treatment mode gives the best effect. Preliminary experiment results have shown that the best seed treatment mode is the cyclical mode: «heating» – «cooling» – «heating». The best results have been obtained at airspeed which is going through grain layer Va = 0.3 m/s, air temperature Ta = 29 - 30°C, time of half-cycle treatment tp = 0.4 hr. Holding time – 2 days. Half-cycle treatment time is the time during which the heating or cooling phase happens once. Obtained results have confirmed theoretical statements for the selection of the best modes for pre-sowing treatment.

However, these results were obtained during seeds treatment on the laboratory experimental equipment, where the layer of treated seeds was 0.15 m and 0.45 m. When the treated grain layer is thin, then it can be considered that the temperature of air and grain is uniform throughout the entire layer. In the existing aerated grain bins, air should penetrate the grain layer of 1.2-1.5 m.

During treatment by the aeration of grain layer with thickness of 1,2 m, airspeed slows from 0.7 m/s at the entrance to 0.1-0.2 m/s at the exit from the grain layer. Air temperature and temperature of grain heating are also changing throughout the layer. Therefore, to speak about adequate accuracy of the effectiveness of one or another treatment mode, it is necessary to obtain the dependence of sowing seed qualities on operational modes of existing aerated grain bins electrical equipment, expressed in air temperature and speed. Multifactorial experiment allowed to obtain such dependence. The experiment has been conducted for three factors: grain temperature increment DQ_c in %, airspeed V_a in m/s, time of half-cycle treatment t_p in hr. Corresponding regression equations have been obtained.

For germinative energy:

$$EG = -27.5736 + 0.693\Delta\Theta_c + 62.256V_a + 20.736t_p + 0.0864\Delta\Theta_c V_a + 0.0392\Delta\Theta_c t_p - 4.08V_a t_p - 0.007\Delta{\Theta_c}^2 - 69.44{V_a}^2 - 9.8{t_p}^2. \quad (1)$$

For germination:

$$G = -23.905 + 0.598\Delta\Theta_c + 50.488V_a + 19.405t_p + 0.082\Delta\Theta_c V_a + 0.035\Delta\Theta_c t_p - 3.9V_a t_p - 0.0067\Delta{\Theta_c}^2 - 56.32{V_a}^2 - 9.8{t_p}^2 \quad (2)$$

Based on the multifactorial experiment results and their processing, family of curves of two-dimensional section of response surface were obtained. Contour plots were constructed for the equation (2) $G = f(\mathrm{DQ_c}, t_p)$, Figure 1 and $G = f(\mathrm{DQ_c}, V_a)$, Figure 2.

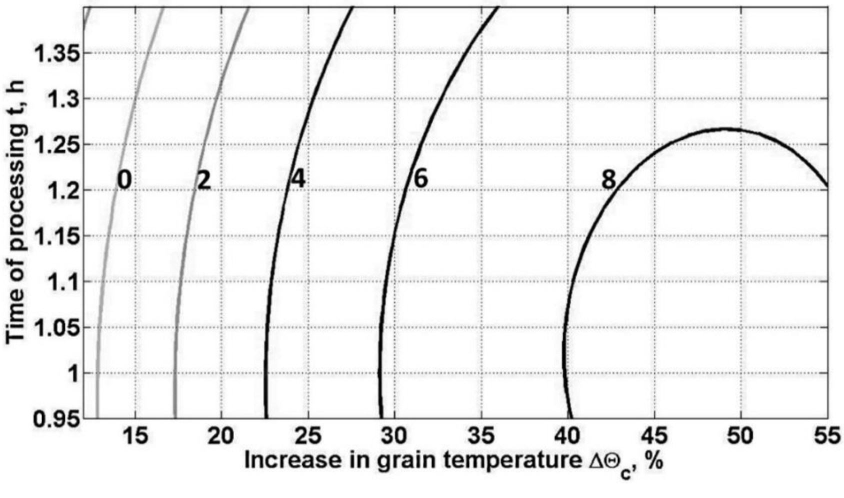

Figure 1. Contour plot of the dependence $G = f\left(\mathrm{DQ_c}, t_p\right)$.

Analysis of the contour plots shows that the smallest half-cycle of pre-sowing treatment, that was used in the experiment (0.95 hr.), allows to ensure the biggest seed germination increment (8%). However, this requires the temperature of the grain heating increment up to 40%. This mode can be realized at initial grain temperature not higher than 21°C and atmospheric air not lower than 25°C. The reason for this is that electric air heater capacity in the existing aerated grain bins pro-vides air heating on 7-8°C only. Lower initial grain temperatures (12-18°C) allow much easier im-plementation of such modes in the existing equipment. The best half-cycle time is 1,05 hr., at which grain temperature in-crement can be lowered to 39%.

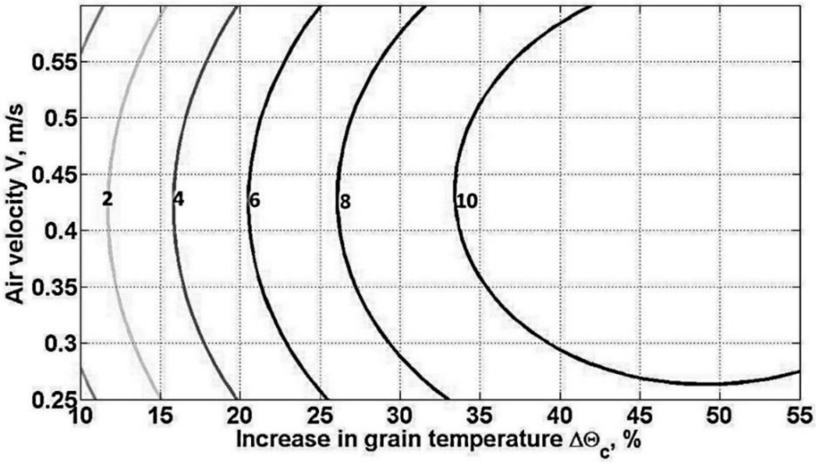

Figure 2. Contour plot of the dependence $G = f(\mathrm{DQ}_c, V_a)$.

Analysis of the contour plot in Figure 2 allows to suggest that if the airspeed in the intergrain space stays at 0,42 m/s than to achieve maximum value of the germination, it is enough to limit grain heating temperature increment to 33%.

The use of grain bins with aeration for pre-sowing seed treatment requires consideration of their design specifics (airspeed change throughout the layer and air heater capacity), which impose con-straints on the pre-sowing treatment modes. However, obtained dependences (1) and (2) reflect pa-rameter relationship for the other facilities also, which can use discussed treatment modes. Grain dry-ers, for example. The maximum grain heating temperature, in this case, is the main restriction. It shouldn`t exceed 45°C.

4. Conclusion

Use of adaptive approach to analysis of the biological seed response to external action during pre-sowing treatment allowed to establish that seeds resistance increase (and as a consequence, sow-ing qualities) requires action to be gradually increasing, longstanding, alternating (cyclical). At the same time, the stimulus should be cyclical with amplitude change.

The initial value of a stimulus should be minimal to ensure adaptation responses occurrence at the lower floors of responsiveness. In this case, the level of responsiveness will be the biggest. The maxi-mum effect from the physical stimulus can be achieved by a combination of nonspecific responses with specific.

The use of the maximum information principle helped to formulate methods of electrophysical stimulus implementation for technological processes development, which are directed at sowing seeds quality improvement and yield structure adjustment. To control this process, it is necessary to observe the following algorithm: determine the lowest level of electrophysical value, which leads to the seed response to external action; stimulus should be cyclical with amplitude change; external action type changeover should be implemented during seed treatment.

The result of the experiments confirmed theoretical researches and determined modes of the air-heat pre-sowing seed treatment on aerated grain bins. It was established that to obtain maxi-mum seed germination increment, it is necessary to aerate grains with air at speed of 0,45 m/s, the temperature which ensures grain temperature increment 33-40%, with half-cycle treatment time of 0,95-1,1 hr.

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