Improving the efficiency of pre-sowing treatment of winter wheat seeds with low power coherent optical radiation

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Abstract. The article presents a low-cost method of pre-sowing treatment of winter wheat seeds, namely, germ stimulation, immediately before planting in the ground, the transmission of coherent optical radiation of low power. It also presents the results of laboratory research showing the influence of small energy effects of fixed wavelength optical radiation on changes in growth energy and germination of seed material, as well as on the development of stems and root system of germinated seeds. The authors demonstrate the dependence diagrams showing the efficiency of pre-sowing treatment for seeds of Thunder variety by optical radiation with wavelengths from 450 to 630 nm at different doses of energy exposure.

1. Introduction

Modern agrarian technologies in the cultivation of cereal crops involve not only the calibration and sorting of seeds but also the mandatory dressing of seed material before sowing it in the fields. The soil and the surface of the seed have a huge number of spores of mold fungi, often pathogenic. Mechanical sorting of seeds damages the seed coat, and microcracks get pathogenic microflora which can either damage the germ itself or lead to weakening and disease of the plant. Seed dressing significantly reduces the damage of seed material and germinated seeds, fungal diseases. At the same time, the germinating capacity of dressed seeds is 20...30% higher than that of non-dressed seeds and can reach 95...98%.

However, dressing leads to resistance of seeds, i.e., delay of their vegetative development. The result is a much later germination of seeds. It does not matter much for spring crops, but it is very bad for winter crops because a delay of 5...7 days in development will lead to the fact that the sprouts may fail to reach the required stage of development before the start of frosting, especially if the soil humidity is insufficient.

To reduce the resistance effect, agricultural producers have to overestimate the rate of sowing seeds. Sometimes they overestimate this norm by one and a half or even two times, which is an additional financial cost.

The main purpose of electrophysical pre-sowing treatment of seeds is to stimulate growth and reduce the effect of resistance after dressing. Intensified and even development of sprouts allows to get a strong plant with 5-6 main roots from the tillering zone by the beginning of the cold season, which is easy to overwinter and gives more yields.

There are many methods of pre-sowing treatment of seeds to increase germination and growth energy. They include moisturization, capsule in nutrients, magnetic treatment, ultrasonic...
treatment, etc., but most of these methods are either complex and lead to a change in the technological chain of sowing due to the use of additional devices, or these methods are not economically feasible.

2. Methods and Equipment

The article deals with the method of optical activation of the germ. The seed is briefly transmitted by coherent optical radiation, with wavelength optimally selected for best effect. The dose and intensity of optical radiation are also individually selected for a specific crop.

The initial experimental study was a comparative determination of growth energy, germination capacity and percentage of pathogenic microflora damage of dressed and non-dressed seed material.

All the studies described in the article used winter wheat of the Thunder variety of the first reproduction as a seed material.

Germinating capacity and growth energy of the seed material was estimated in the training and research agro-technological laboratory of Azov-Black Sea Engineering Institute of Don State Agrarian University in Zernograd, according to well-known methods described in GOST 12038-84.

The study involved radiation at wavelengths of 450, 510, 570, 630 nm.

The radiation dose of energetic influence was equal to 1.5 J per 100 seeds.

During the experiment in each group, we took 4 replications of 100 seeds each.

3. Results and Discussion

Table 1 shows the results obtained from laboratory examination of germinated seed material affected by fungal diseases on dressed and non-dressed winter wheat of Thunder variety. There are also results of determination of average sprout length, average root length and average number of roots.

Table 1. Results of experimental studies to determine the resistance of seed material after dressing.

| Indicator                  | Not-dressed batch of winter wheat seeds | control | A batch of winter wheat seeds dressed with Lomardor agent |
|----------------------------|----------------------------------------|---------|----------------------------------------------------------|
| Average value of germination, % | 82                                    | 79      |
| Average value of growth energy, % | 90                                    | 87.25   |
| Average sprout length, mm   | 78.4                                   | 65.5    |
| Average root length, mm     | 79.5                                   | 67.7    |
| Average number of roots, pcs| 4.7                                    | 3.96    |
| Average value of seeds infected with fungus, % | 21.5                                 | 7       |

Analyzing the data presented in Table 1, we can conclude that dressing reduces the probability of seed contamination with fungal diseases by 60%. (from 21.5% for non-dressed seeds to 7% for dressed seeds).

However, dressing leads to significant resistance of seeds, i.e., delay of their development at the germination stage. Germination and growth energy is reduced by 3% under ideal laboratory conditions.

Sprout and roots reach much smaller sizes. Also, the number of roots of dressed seeds is less by 1-2 roots.

The result is much later germination of seeds, and in real field conditions, the sprouts may fail to reach the required stage of development before freezing [2].

To reduce resistance effect and germ stimulation we supposed to use coherent optical radiation with different wavelengths and enough power to pass through one layer of seed material and to maintain exposure in 5 seconds. These parameters are not optimal for pre-sowing treatment, and we optimized it in further experimental studies.

Table 2 shows the results of laboratory experimental studies obtained for the seventh day on non-dressed winter wheat of Thunder variety after treatment with coherent optical radiation with wavelengths from 450 to 630 nm.

And Table 3 shows similar results on dressed seed material.
The energy dose to the seed material was constant at all wavelengths and corresponded to the value of 1.5 J per 100 seeds.

Analyzing the data in Table 2 and Table 3 we can conclude that any energy impact increases seed germination and growth energy compared to the control option. But in terms of germination and growth energy, it is best to use optical radiation with wavelength of 570nm for radiation of winter wheat seeds.

At the same time, in laboratory conditions germinating capacity increased by 8.75% on dressed and by 10.5% on non-dressed seed material. And the growth energy increased by 6.75% on non-dressed and 5% on dressed seed material.

Table 2. The results of a laboratory experiment on non-dressed winter wheat of Thunder variety

| Parameter                        | control batch | Wavelength  |
|---------------------------------|---------------|-------------|
|                                 |               | 450 nm      | 510 nm      | 570 nm      | 630 nm      |
| Average value of germination, % | 82            | 85.5        | 86          | 92.5        | 89.75       |
| Average value of growth energy, %| 90            | 93.75       | 96          | 96.75       | 94.5        |
| Average sprout length, mm       | 78.42         | 84.75       | 78.15       | 89.3        | 83.56       |
| Average root length, mm         | 79.53         | 83.71       | 80.7        | 90.93       | 84.44       |
| Average number of roots, pcs.   | 4.75          | 4.59        | 4.54        | 4.8         | 4.58        |

Table 3. The results of a laboratory experiment on dressed winter wheat of Thunder variety

| Parameter                        | control batch | Wavelength  |
|---------------------------------|---------------|-------------|
|                                 |               | 450 nm      | 510 nm      | 570 nm      | 630 nm      |
| Average value of germination, % | 79            | 83          | 83.5        | 87.75       | 85.75       |
| Average value of growth energy, %| 87.25        | 88          | 87.25       | 92.25       | 90.75       |
| Average sprout length, mm       | 65.5          | 69.42       | 72.14       | 72.47       | 72.49       |
| Average root length, mm         | 67.7          | 71          | 73.24       | 74.15       | 73.9        |
| Average number of roots, pcs.   | 3.96          | 4.07        | 4.2         | 4.18        | 4.23        |

Figures 1 and 2 show the appearance of dressed germinated seed material. Figure 1 shows the image of the dressed coherent optical radiation with a wavelength of 570nm, and Figure 2 shows the image of the non-dressed control batch.

Figure 1. The dressed (7th day) germinated seed material treated with coherent optical radiation with a wavelength of 570nm.
Figure 2. The dressed (7th day) germinated seed material of the untreated control batch.

Figures 1 and 2 clearly show the efficiency of optical radiation treatment. There are more even germination and almost similar lengths of sprouts and roots in all seeds.

Table 4. Comparative results of the laboratory experiment on the influence of white light and laser radiation on non-dressed winter wheat

| Parameters of radiation source | Sprout length, mm | Average value | Root length, mm | Average value | Number of roots, pcs. | Average value |
|-------------------------------|-----------------|---------------|-----------------|---------------|-----------------------|--------------|
| Control batch                 | 82.41 74.62 70.38 86.27 | 78.42         | 93.41 75.74 66.67 82.29 | 79.53      | 4.72 4.34 5.08 4.85 | 4.75         |
| White                         | 84.45 79.79 89.1 79.3  | 83.16         | 79.26 74.35 86.37 89.8 | 82.45      | 3.64 3.71 4.32 4.16 | 3.96         |
| Yellow                        | 82.49 87.58 99.27 87.86 | 89.3          | 91.38 88.56 98.06 85.71 | 90.93      | 4.39 4.68 5.19 4.91 | 4.79         |
| Green                         | 57.42 87.17 86.2 81.82  | 78.15         | 71.76 79.11 83.72 88.19 | 80.695     | 4.18 4.72 4.76 4.49 | 4.54         |
| Red                           | 85.34 78.61 84.14 86.16 | 83.15         | 88.71 78.77 83.81 86.47 | 84.44      | 4.69 4.29 4.61 4.73 | 4.58         |
| Blue                          | 86.94 84.3 82.49 85.25  | 84.75         | 86.94 84.3 82.49 85.25  | 84.75      | 8.63 83.37 80.92 84.23 | 83.71         |
| Green laser                   | 92.03 68.5 95.33 90.14  | 86.5          | 102.81 68.02 93.31 90   | 88.54      | 90.72 83.3 80.13 85.66 | 84.953        |
| Red laser                     | 93.33 84.63 80.56 87.41  | 86.5          | 102.81 68.02 93.31 90   | 88.54      | 90.72 83.3 80.13 85.66 | 84.953        |

| Parameters of radiation source | Experimental replications | Average value |
|-------------------------------|-----------------|---------------|
| Control batch                 | 4.72 4.34 5.08 4.85 | 4.75         |
| White                         | 3.64 3.71 4.32 4.16 | 3.96         |
| Yellow                        | 4.39 4.68 5.19 4.91 | 4.79         |
| Green                         | 4.18 4.72 4.76 4.49 | 4.54         |
| Red                           | 4.69 4.29 4.61 4.73 | 4.58         |
| Blue                          | 4.68 4.5 4.55 4.63  | 4.59         |
| Green laser                   | 4.88 4.04 4.97 4.87 | 4.69         |
| Red laser                     | 5 4.64 4.57 4.7   | 4.73         |
The next experimental study was to evaluate the influence of white light and laser radiation on the pre-sowing properties of winter wheat seeds and the development of sprouts and roots compared to monochromatic LED radiation.

The analysis of Table 4 shows that treatment with yellow radiation with a wavelength of 570 nm achieves the best results in sprout development. The treatment with green radiation with a wavelength of 510 nm gives the worst result, comparable to the control batch. The treatment with white light and laser radiation gives an intermediate but effective result.

The yellow light with a wavelength of 570 nm also provides the best results in root development, and treatment with green laser light has a comparable effect. The treatment with green radiation with a wavelength of 510 nm achieves the worst results, which are also comparable to the control untreated batch. The white light and red laser radiation give a small positive effect.

The most roots are observed when treated with yellow radiation, and the least one with white radiation.

Table 5 analysis shows that the red laser and yellow light at 570 nm produce the best results in sprout development, while the control untreated batch has the worst results.

| Parameters of radiation source | Experimental replications | Average value |
|-------------------------------|---------------------------|---------------|
| Sprout length, mm             |                           |               |
| Control batch                 | 65.86 59.07 66.92 70.15   | 65.5          |
| White                         | 72.23 65.79 67.27 66.65   | 67.985        |
| Yellow                        | 67.73 69.23 71.3 81.6     | 72.465        |
| Green                         | 59.89 76 80.55 72.13      | 72.1425       |
| Red                           | 74.5 64.58 74.65 76.23    | 72.49         |
| Blue                          | 65.96 68.92 69.33 73.45   | 69.415        |
| Green laser                   | 67.64 74.18 71.62 68.38   | 70.455        |
| Red laser                     | 77.09 76.93 72.42 68.5    | 73.735        |
| Root length, mm               |                           |               |
| Control batch                 | 67.74 61.55 68.94 72.56   | 67.6975       |
| White                         | 73.96 70.27 71.03 68.91   | 71.0425       |
| Yellow                        | 69.71 71.5 74.34 81.04    | 74.1475       |
| Green                         | 62.74 76.12 80.5 73.6     | 73.24         |
| Red                           | 75.41 67.22 75.09 77.78   | 73.875        |
| Blue                          | 67.93 70.76 70.54 74.74   | 70.9925       |
| Green laser                   | 69.35 76.24 72.58 70.61   | 72.195        |
| Red laser                     | 79.18 78.45 72.58 71.76   | 63.82         |

The treatment with yellow radiation at a wavelength of 570 nm and the red radiation of 630 nm has the best results in root development. The treatment with red laser has the worst results. However, the treatment with red laser results in the largest number of roots.
The control untreated batch shows the smallest number of roots.

The efficiency of pre-sowing treatment can increase additionally by experimentally determining the optimal dose of energetic influence.

We will change the dose by adjusting the treatment exposure and keep the optical radiation source power unchanged.

Tables 6 and 7 show the results of the experimental study to determine the required treatment exposure.

**Table 6.** Dependence of germination capacity on exposure at treatment with yellow radiation at a wavelength of 570 nm.

| Exposure  | I replication | II replication | III replication | IV replication | average value |
|-----------|---------------|----------------|------------------|----------------|---------------|
| Control (0s) | 74% | 68% | 75% | 83% | 75% |
| 3 s.      | 82% | 74% | 80% | 83% | 79,75% |
| 5 s.      | 90% | 80% | 84% | 83% | 84,25% |
| 10 s.     | 90% | 68% | 87% | 83% | 82% |
| 20 s.     | 88% | 86% | 77% | 83% | 83,50% |
| 30 s.     | 79% | 78% | 80% | 85% | 80,50% |
| 60 s.     | 81% | 84% | 80% | 86% | 82,75% |
| 90 s.     | 86% | 85% | 82% | 84% | 84,25% |
| 120 s.    | 85% | 78% | 80% | 88% | 82,75% |
| 240 s.    | 79% | 87% | 83% | 82% | 82,75% |

**Table 7.** Dependence of the growth energy on exposure at treatment with yellow radiation at a wavelength of 570 nm.

| Exposure  | I replication | II replication | III replication | IV replication | average value |
|-----------|---------------|----------------|------------------|----------------|---------------|
| Control (0s) | 86% | 78% | 84% | 87% | 83,75% |
| 3 s.      | 90% | 88% | 91% | 92% | 90,25% |
| 5 s.      | 92% | 95% | 88% | 90% | 91,25% |
| 10 s.     | 96% | 85% | 91% | 92% | 91% |
| 20 s.     | 91% | 92% | 89% | 90% | 90,50% |
| 30 s.     | 88% | 84% | 90% | 90% | 88% |
| 60 s.     | 91% | 92% | 91% | 90% | 91% |
| 90 s.     | 92% | 88% | 90% | 90% | 90% |
| 120 s.    | 93% | 93% | 90% | 90% | 91,50% |
| 240 s.    | 91% | 93% | 89% | 91% | 91% |

Tables 6 and 7 analysis showed that the required stimulation effect was achieved already at 1.5 J per 100 seeds, which corresponded to 5 seconds of 0.3 W LED treatment. Further increase in the exposure of the treatment did not improve the effect.

To integrate the device for pre-sowing treatment of seeds with coherent optical radiation, in the sowing process it is necessary to ensure the required dose of treatment even at small exposures in a few milliseconds of the corresponding time of passing the seed through the radiation device.
Reducing the treatment exposure, it is necessary to increase the power of the optical radiation source proportionally.

We can calculate the energy dosage for pre-sowing treatment of seeds in a simplified way using the following formula:

$$D = P \times t$$  \hspace{1cm} (1)

where $P$ is the power of the coherent optical radiation source, W;

$t$ is treatment exposure, s.

Figure 3 shows the appearance of one of the experimental modules for in-line pre-sowing seed treatment installed on a pneumatic sowing machine.

This module is equipped with a power control unit for LED matrices.

![Figure 3. The experimental module for in-line pre-sowing seed treatment mounted on a pneumatic sowing machine.](image)

4. Conclusion

In conclusion, we should note that coherent optical radiation with a wavelength of 570nm is most effective for the pre-sowing treatment of winter wheat seeds. At the same time, the energy dose should not be less than 1.5 J per 100 seeds. These parameters reduce the resistance effect to seed dressing and achieve the best possible lengths of sprouts, roots and the maximum number of roots.

Other seed materials, such as rye, barley, corn, sunflower, etc, require experimental determination of optimal optical wavelengths and energy doses.

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Conflict of Interest

The authors have no conflict of interest to declare.

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