Influence of seed treatment with a magnetic field on sowing qualities and performance of spring barley

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Abstract. The article proposes an analysis of long-term studies to identify the effectiveness of the gradient magnetic field (GMF) on the growth and yield properties of spring barley. The experiments were carried out in Ryazan region of the Russian Federation on dark gray forest soils. According to the results of the experiments, it was revealed that the use of GMF for seed treatment before sowing contributed to an increase in the intensity of growth processes. Treatment of barley seeds before sowing with a gradient magnetic field, compared with the control, contributed to better plant survival and an increase in density by 2.2 %. In the variant with the use of a magnetic field, a higher volume of the photosynthetic apparatus was noted in all stages of the crop development compared to the variant without pre-sowing treatment. It was higher by an average of 17.14 % in the tillering stage and by 6.98 % in the booting stage. In the variant with seed treatment, barley plants were distinguished by an increased degree of tillering. On average, the maximum productivity was in the variant with pre-sowing seed treatment with GMF, where the increase in yield to the control values was 4.6 dt/ha or 12.7 %.

1. Introduction
Barley has the highest and most sustainable performance among spring grain crops and occupies a high proportion in Ryazan regional structure of sown areas. Early ripening varieties of spring barley need 1,000-1,500 °C for a full cycle and development in the soil and climatic conditions of the region. For late-ripening varieties these requirements are 1,900-2,000 °C [1–4].

In plant growing practice, annual fluctuations in the yield of agricultural crops are observed. This is largely due to the low sowing quality of seeds, the impact of harmful organisms, the negative influence of climatic factors [5–9].

In the context of rising prices for energy, fertilizers and plant protection products, as well as in the desire of agricultural producers to obtain environmentally friendly crop products, it becomes necessary to search for alternative ways to increase the yield. An actual and promising direction for improving the sowing quality of seeds is their pre-treatment magnetic fields. The gradient magnetic field (GMF) is of great interest, which affects biological systems without additional material costs [10–15].

In accordance with this, the tasks were set to identify the effectiveness of the impact of GMF in pre-sowing seed treatment on the growth, development and performance of spring barley plants.

2. Materials and methods
In accordance with the tasks set, a cycle of laboratory studies was carried out and field experiments were laid to determine the influence of the factor under study on the sowing qualities of seeds, growth,
development and yield of spring barley.

The experimental work was carried out in 2018-2020 at the experimental agrotechnological station and the department of agronomy and agro-technologies of Ryazan State Agrotechnological University named after P.A. Kostychev (FSBEI HE RSATU).

The experimental design was as follows:

1. Control (seeds without treatment).
2. Treatment of seeds with a magnetic field strength of 50 oersted.
3. Treatment of seeds with a magnetic field strength of 50 oersted, with seed exposure for 5 days before sowing.
4. Treatment of seeds with a magnetic field strength of 50 oersted with seed exposure for 10 days before sowing.

The experimental plot had dark gray forest soil with the following agrochemical indicators: $\text{pH}_{\text{KCl}}$ 5.5-5.7; humus content was 2.05-3.4 %, mobile phosphorus was 180-255 mg/kg (high), potassium was 117-141 mg/kg (increased).

The sown area of the plot was 50 m$^2$; the accounting area was 40 m$^2$. The replication was fourfold.

The crop cultivation technology was generally accepted for the Non-Chernozem zone of Russia. Sowing was carried out in the optimal agrotechnical terms in the third decade of May. The level of mineral nutrition in the agrocoenosis was $N_90P_60K_60$, fertilization for pre-sowing cultivation.

The studies were carried out according to generally accepted methods and GOSTs. Statistical data processing was carried out by the method of analysis of variance with the help of computer.

3. Results and Discussion

During the years of the study, weather conditions were variable (Fig. 1). Strong fluctuations in temperature and uneven precipitation were noted in 2018 and 2020; however, in general, the weather conditions of the study period were favorable for field work and the development of grain crops.

![Figure 1. Air temperature (°C) and precipitation (mm), 2018-2020](image)

Laboratory studies showed that the germination energy and laboratory germination of the treated seeds were higher than in the control variant. Thus, when the seeds were magnetized, the germination energy increased to 76 %, and the laboratory germination to 91 %, which, respectively, was 5 % and 3 % higher than the values of these indicators in the experiment without seed treatment.

When the seeds were exposed before sowing for 5 and 10 days, there was a decrease in the stimulating effect of GMF, which was expressed in a decrease in the values of the studied parameters. At the same time, the longer the seeds lay before sowing after treatment, the more significant the decrease in the stimulating effect of magnetization occurred. So, the germination energy of seeds was 75 % and 73 %, respectively, when exposed for 5 and 10 days after treatment. The germination energy was also lower than in the variant without seed retention, 89 % and 88 %, respectively. It should be noted that seeds exposure after magnetization before sowing for 10 days completely neutralized the
magneto biological effect in relation to the laboratory germination rate. The revealed patterns were also manifested in determining the effect of magnetization of seeds and the timing of their exposure before sowing. Magnetization of barley seeds stimulated the formation of embryonic roots by an average of 1.4-1.6 times than in the variant without treatment. An increase in the length of the sprout and primary root system was observed by 23.1 % and 52.6 %, respectively.

When the seeds were exposed after treatment in a gradient magnetic field for 5 and 10 days, the stimulating effect in the formation of embryonic roots decreased to 1.3-1.1 times. The length of shoots and embryonic roots in these variants decreased in comparison with the variant where the seeds were not kept before sowing by 2.5 % and 7.3 %, by 5.7 % and 12.8 %.

In field studies, over the years of the experiment, the germination of sown seeds in the control was in the range of 79.8-83.2 %, while on crops with magnetized seeds there were 2.3-4.1 % more seedlings.

When the seeds were exposed before sowing for 5 days, there was an increase in field germination by 1.2-3.4 % compared to untreated seeds. An exposure for 10 days increased field germination only by 0.6-1.8 %.

In the process of observing the stages of ontogenesis of barley during its growing season, no significant differences were found. We note, however, a more intensive development of the assimilation apparatus in the variant with pre-sowing magnetization of seeds (Table 1).

Table 1. The influence of pre-sowing seed treatment on the formation of the assimilation apparatus of barley plants, average in 2018-2020

| Treatment type | Leaf area index |
|----------------|----------------|
|                | tillering stage | booting stage | milky stage |
| Control (no treatment) | 3.5 | 4.3 | 3.2 |
| Treatment with GMF | 4.1 | 4.6 | 3.4 |
| Treatment with GMF and keeping seeds for 5 days before sowing | 4.0 | 4.5 | 3.4 |
| Treatment with GMF and keeping seeds for 10 days before sowing | 3.7 | 4.4 | 3.3 |

The maximum leaf area index was observed in the phase of booting stage in all variants of the experiment. A higher volume of the photosynthetic apparatus was observed in the variant with the use of a magnetic field at all stages of barley development, in comparison with the indicators of the variant without pre-sowing treatment by an average of 17.14 % in the tillering stage and 6.98 % in the booting stage.

A less intense increase in the assimilation apparatus of plants was observed in the variants where the seeds were exposed from the moment of magnetization to sowing for 5 and 10 days. So, in the variant with 5-day exposure, the volume of leaf mass increased by an average of 14.28 % in the tillering stage and 4.65 % in the booting stage in comparison with the control. With an increase in the exposure period to 10 days, the stimulating effect decreased even more: to 5.71 % and 3.12 %, respectively.

When filling stage in conditions of a decrease in the area of the assimilation apparatus, the flag leaf plays a great role in the process of accumulation of plastic substances. Its size and durability determine the productive performance of the ear. The largest area of the flag leaf was observed in plants of the variant with seed treatment with GMF without aging. The differences between the variants by the years of research were 1.69-2.14 %.

The yield of barley together with the density of plants for harvesting are also greatly influenced by the coefficient of productive tillering and the weight of 1,000 grains (Table 2).

Seed treatment before sowing with a gradient magnetic field contributed to better plant survival and an increase in density by 2.2 %, compared with the control. Plants in the variant with seed treatment also differed in an increased degree of tillering. The coefficient of productive tillering was 1.58, which
was 11.3 % higher than in the control. The weight of 1,000 grains exceeded the values of the variant without treatment by 1.24 g or 3 %.

A decrease in these indicators was observed in variants with seed exposure for 5 and 10 days from the moment of pre-sowing treatment to sowing, compared to the variant where the seeds were sown directly after magnetization. The degree of tillering decreased by 7.6 % and 9.5 %, respectively. There was also a decrease in the weight of 1,000 grains to values of 42.82 and 42.31 g. That was 0.4 % and 1.6 % less than in the variant without seed exposure.

**Table 2.** Elements of barley performance depending on variants for pre-sowing seed treatment, average for 2018-2020

| Treatment type                        | Number of plants to be harvested, pcs/m² | Productive tillering coefficient | Weight of 1,000 grains, g | Ear performance, pigeons |
|---------------------------------------|------------------------------------------|-----------------------------------|---------------------------|--------------------------|
| Control (no treatment)                | 335.7                                    | 1.42                              | 41.76                     | 0.80                     | 19.16                     |
| Treatment with GMF                   | 342.5                                    | 1.58                              | 43.00                     | 0.81                     | 18.84                     |
| Treatment with GMF and keeping seeds for 5 days before sowing | 338.4                                    | 1.46                              | 42.82                     | 0.81                     | 18.92                     |
| Treatment with GMF and keeping seeds for 10 days before sowing | 336.1                                    | 1.43                              | 42.31                     | 0.80                     | 18.91                     |

Yields during the study period were subject to year-to-year fluctuations (Table 3).

**Table 3.** The influence of pre-sowing seed treatment on barley yield, dt/ha

| Treatment type                        | 2018  | 2019  | 2020  | Average | Increase in yield, % |
|---------------------------------------|-------|-------|-------|---------|----------------------|
| Control (no treatment)                | 31.3  | 36.7  | 40.2  | 36.1    | -                     | 100.0                     |
| Treatment with GMF                   | 34.2  | 43.0  | 44.9  | 40.7    | 4.6                  | 112.7                     |
| Treatment with GMF and keeping seeds for 5 days before sowing | 33.6  | 40.3  | 41.4  | 38.4    | 2.3                  | 106.4                     |
| Treatment with GMF and keeping seeds for 10 days before sowing | 31.5  | 38.2  | 40.5  | 36.7    | 0.6                  | 101.7                     |
| LSD<sub>0.05</sub>                   | 2.05  | 3.15  | 1.74  | 2.13    |                       |                           |

During the entire research period, the maximum yield was formed in the variant with pre-sowing GMF treatment of seeds without any exposure before sowing. On average, the increase in yield to the control values was 4.6 dt/ha or 12.7 % compared to the control.

When the seeds were exposed for 5 and 10 days, a decrease in barley performance to 38.4 and 36.7 dt/ha was observed, which amounted to an increase of 6.4 % and 1.7 %, respectively.

Indicators of the quality of barley grain are shown in Figure 3.

It was found that for all variants of treatment there was an increase in protein content by 0.1-1.24 %, crude fat – by 0.01-0.4 % and ash – by 0.01-0.08 %, while the best results were obtained in the variant without exposing the seeds after treatment.
Figure 2. Biochemical composition of spring barley grain depending on the variant of pre-sowing treatment

4. Conclusion
Thus, the use of GMF had a stimulating effect on the intensity of seed germination. Treatment of barley seeds before sowing with a gradient magnetic field in comparison with the control contributed to better plant survival and an increase in density by 2.2%. Plants in the variant with seed treatment were distinguished by an increased degree of tillering. On average, the maximum productivity was observed in the variant with pre-sowing GMF treatment of seeds, where the increase in yield to the control values was 4.6 dt/ha or 12.7%. It was also found that the greatest stimulating effect from the use of GMF in the pre-sowing treatment of seeds was observed if the sowing was carried out immediately after the treatment of seeds.

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