Evaluation of the effect of pre-sowing electron irradiation of barley seeds on plant development and disease incidence

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Abstract. The effect of electron irradiation of barley seeds of the Vladimir variety on the development of plants, disease incidence and productivity in controlled greenhouse conditions has been studied. It was found that the effectiveness of the effect of seed treatment with low-energy electronic radiation in the dose range of 30–150 kGy on the morphometric parameters of barley largely depends on the accelerating voltage – 130 kV (mode 1) and 160 kV (mode 2). It was noted that irradiation suppressed the formation of chlorophyll a and b and carotenoids in barley leaves at all doses and irradiation regimes and, at the tendency level, reduced the infestation of Bipolaris sorokiniana plants in the tillering and heading phases. It was shown that irradiation of seeds caused an increase in the total tillering of plants (mode 2), but at the same time reduced the productive tillering. Electron irradiation caused an increase in the mass of 1000 grains and did not affect the yield of grain and straw.

1. Introduction
The use of innovative technologies in agriculture is aimed at further increasing production in order to address the country's food security, as well as expand export opportunities. One of the promising directions for solving this problem is the use of radiation technologies. The use of various types of radiation for pre-sowing stimulation of agricultural seeds has been known for a long time. However, the development of this method continues at the present time with the aim of working out effective modes of application of irradiation.

The use of low-energy electron radiation for pre-sowing irradiation of seeds of various crops in laboratory experiments has shown that this technique is promising for increasing the sowing qualities of seeds and reducing the incidence of diseases [1-3].

When using electron irradiation of seeds for further growing plants before harvest under the conditions of a growing experiment, it was not clear to what extent the positive effects noted on seedlings would remain on adult plants during the growing season.

The aim of the study was to investigate the effect of electron irradiation of barley seeds on the development of plants, their disease incidence and productivity.

2. Materials and Methods
The research was carried out on spring barley (*Hordeum vulgare* L.) variety Vladimir. The irradiation of the grain was carried out on a Duet wide-aperture electron accelerator with a grid plasma cathode and the extraction of a formed beam of a large cross section into the surrounding atmosphere [4]. The radiation dose rate absorbed by the surface was about 3000 Gy/pulse, the accelerating voltage was 130 kV (mode 1) and 160 kV (mode 2). In this case, the depth of dose absorption did not exceed 300 μm.

After irradiation, the seeds were sown in vessels with sod-podzolic soil and grown until harvest. The experiments were repeated 3 times. The morphometric and biochemical parameters of the development of vegetative plants, the structure of the yield and the susceptibility of barley to root rot (*Bipolaris sorokiniana*) were studied according to generally accepted methods.

3. Results
The study of the biological effectiveness of pre-sowing electron irradiation of barley seeds showed that low-energy electron radiation influenced the morphometric and biochemical parameters of plant development.

Analysis of the development of plants in the tillering phase revealed the absence of a significant effect of irradiation on all biometric parameters at irradiation mode 1 and inhibition of barley development at mode 2 in terms of the following indicators: "plant height" by 20-26% (doses of 90-150 kGy and "leaf area", "wet and dry biomass" by 35% at a dose of 150 kGy (figure 1).

![Figure 1. Development of spring barley in the tillering phase (1 – mode, 2 – mode 2).](image)

When assessing the development of plants for the same parameters in the heading phase, a significant increase of 41-71% in dry biomass and a decrease in leaf surface area by 25-44% were noted, regardless of the dose and irradiation regime (figure 2).

Determination of the photosynthetic activity of barley in the tillering phase showed that electron irradiation inhibits the formation of chlorophyll a and b (decrease by 9-25%) and carotenoids in leaves at all doses and modes of irradiation (figure 3). A decrease in the photosynthetic activity of barley was the reason that led to the suppression of the development of barley in the tillering phase in terms of the main morphometric parameters (figure 1).

The data from the records of barley root rot infestation indicate that irradiation promoted, at the level of a tendency, a decrease in the disease infestation of plants in the tillering phase at doses of 60-120 kGy (mode 1) and a dose of 30 kGy (mode 2), in the heading phase at doses of 60 and 120 kGy (mode 1) and at doses of 60, 120 and 150 kGy (mode 2). In the phase of full ripeness, the effect of irradiation on the infestation of barley by root rot was almost completely leveled out in comparison with the non-irradiated control (figure 4).
Electron irradiation of seeds caused an increase in the total tillering of plants (especially in mode 2), but at the same time reduced the productive tillering, except for a dose of 120 kGy (mode 1) and a
dose of 60 kGy (mode 2), where the growth of productive stems was noted. The weight of grain and straw per one plant did not differ from the control, but the weight of 1000 grains increased in almost all variants with irradiation by an average of 10-15% (figure 5).

![Figure 5. Influence of pre-sowing electron irradiation on the productivity of barley.](image)

4. Discussion
The works [5, 6] describe the successful use of X-rays to accelerate seed germination. A stimulating effect of pre-sowing gamma-irradiation of seeds on the yield of grain and vegetable crops (by 5-20%) and an improvement in product quality was noted. It is emphasized that the use of pre-sowing irradiation of seeds more significantly increases the yield when growing crops in a high agricultural background.

It has been established that the best results are achieved with irradiation of low-quality seeds, as well as under weather conditions unfavorable for growing crops [7, 8].

In this work, irradiated seeds of spring barley were grown in soil, where, during packing, mineral fertilizers were introduced into the vessels in an amount optimal for the normal growth and development of plants. However, the seeds used for irradiation were of good quality and corresponded to the elite class, and the cultivation of barley plants was carried out in a greenhouse, under controlled conditions for temperature, light, air and soil humidity. It is possible that this, along with the magnitude of the dose and the accelerating voltage, could have an effect on the efficiency of pre-sowing low-energy electron irradiation of spring barley seeds.

A slight change in the electron energy (from 130 to 160 keV) leads, all other things being equal, to a noticeable change in the properties and growth parameters of barley. This is probably due to the fact that irradiation of seeds in mode 2 has a greater penetrating ability than in mode 1, which causes activation of redox processes in irradiated seeds.

5. Conclusion
Thus, experimental studies in a vegetation experiment established that the presowing treatment of barley seeds of the Vladimir variety with low-energy electron radiation in the dose range of 30-150 kGy at an accelerating voltage of 130 kV (mode 1) did not affect the morphometric parameters of plant development in the tillering phase and caused a pre-tolerable increase in by 41-71% of dry biomass at all radiation doses in the heading phase. At an accelerating voltage of 160 kV (mode 2), the inhibition of plant development in the tillering phase was noted in terms of: “plant height” by 20-26% (doses of 90-150 kGy) and “leaf area”, “wet and dry biomass” by 35% at a dose of 150 kGy and a stimulating effect on dry biomass of plants in the heading phase.

Electron irradiation reduced the formation of chlorophyll a and b and carotenoids in barley leaves by 9–25% at all doses and modes of irradiation.
Irradiation of seeds promoted, at the level of a tendency, a decrease in the infestation of plants by *Bipolaris sorokiniana* in the tillering phase at doses of 60-120 kGy (mode 1) and a dose of 30 kGy (mode 2), in the heading phase – at doses of 60 and 120 kGy (mode 1) and at doses 60, 120 and 150 kGy (mode 2). In the phase of full ripeness, the effect of irradiation on the infestation of barley by root rot was almost completely leveled out in comparison with the option without irradiation.

Electron irradiation of seeds caused an increase in the total tillering of plants (especially in mode 2), but at the same time reduced the productive tillering, except for a dose of 120 kGy (mode 1) and a dose of 60 kGy (mode 2), where the growth of productive stems was noted. Irradiation did not affect the yield of grain and straw per plant, but it contributed to an increase in the mass of 1000 grains in almost all variants with irradiation by an average of 10–15%.

The positive effects of irradiation on plant development noted under the action of electron radiation on barley seeds, require further research in order to clarify the dose range and irradiation regimes.

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