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Germination and phytosanitary state of flax and wheat seeds after electron beam irradiation

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Abstract. Radiation technologies are widely used in agriculture to accelerate the sprouting of plants, increase crop yields, improve product quality, and destroy pathogenic microflora. This article assesses the effect of treatment with accelerated electrons in various doses on the germination of wheat and flax seeds, as well as on their phytosanitary state. It was established that the most efficient dose for flax variety Severny is 10 Gy, since this dose not only showed the most considerable increase in the germination rate by 38% but also decreased the number of fungi in seeds by 15 % and reduced the average diameter of the remaining colonies by 30% or more. For spring wheat variety Novosibirskaya 29, however, the doses which would be able to significantly reduce the number and the diameter of colonies without causing the inhibition of seed germination were not found.

1. Introduction

The application of radiation technologies for increasing crop yields and quality, inhibiting pathogenic microflora present in seed material as well as inhibiting root crop sprouting has a great potential in agrobiotechnology being an environmentally friendly and high-performance solution to compare with methods which use chemical compounds [1-2].

Irradiation allows to eliminate bacteria, fungi and viruses preventing the spread of most common diseases, such as brown leaf rust, powdery mildew, Septoria in wheat, and fusarium, anthracnose and rust in flax [3-4].

Some research focus on low-dose irradiation to stimulate sprouting of plants and to decrease the risk of being infected by phytopathogens from the soil [5-6]. Considering a vast difference in soil typology across Russia it is necessary to study the impact of radiation doses on regional crop varieties both in laboratory conditions and in the field to differentiate between the influence of irradiation on the plant with and without any external factors [7-8].

The team of scientists consisting of experts from Physics Department of Moscow State University and the Siberian Federal Scientific Center of the Russian Academy of Sciences is conducting a research to improve the efficiency of radiation treatment of agricultural products in order to improve the quality of the crop and plant resistance to fungal diseases, in particular, rhizoctiniosis, phomosis and fusarium [9-14].

The purpose of the study described in this paper is to determine the effect of 1 MeV accelerated electrons on the germination and phytosanitary state of flax and wheat seeds naturally contaminated with phytopathogenic fungi.

2. Materials and methods

The objects of this study were the seeds of flax oilseed variety Severny and spring wheat variety Novosibirskaya 29 with naturally occurring infections caused by phytopathogens from the genera Fusarium and Alternaria.

Variety Severny is a highly productive and early ripe flax variety and is intended for oil and fiber production. The vegetation period of plants is 80-104 days. It has a high resistance to Fusarium (90-95%), shedding and lodging.

Variety Novosibirskaya is a mid-early wheat variety with a high yield. The vegetation period of plants is 70-78 days. Plants on an infectious background are weakly affected by dusty smut, powdery mildew and medium affected by brown rust. It has a high resistance to lodging

The samples were irradiated using the continuous electron accelerator UELR-1-25-T001 with a maximum energy of 1 MeV (SINP MSU, Moscow, Russia). The seeds were packed in 30 pieces in hermetically sealed bags and evenly distributed in one monolayer on a duralumin plate and exposed to under an electron beam (figure 1). The experiment was repeated three times for both types of seeds for all doses.

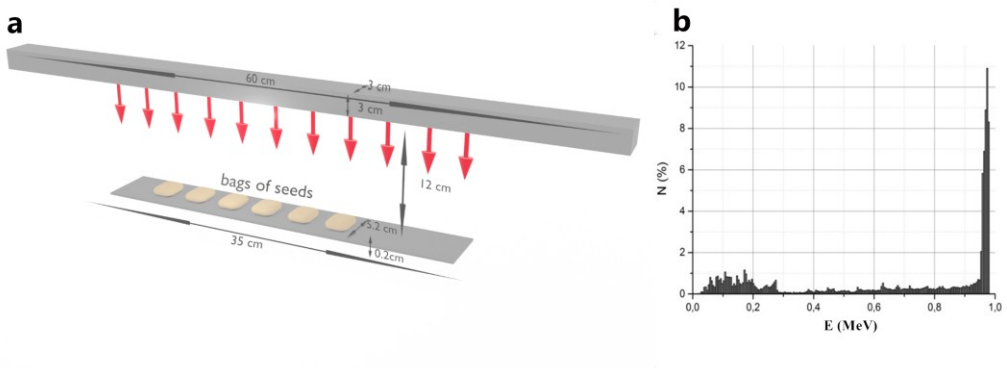

Figure 1. Irradiation of packages with seeds (a) and the spectrum of the electron accelerator UELR-1-25-T001 (b).

The dose absorbed by the samples was estimated using the algorithm described in [15], taking into account the time of exposure, beam current, and charge absorbed by the plate during each irradiation session, seen in table 1.

Table 1. Irradiation parameters obtained during the experiment.

No.	Time of exposure, s	Beam current, μA	Charge on the plate, nC	Absorbed dose, Gy
1	34 ± 1	0.01	250	5
2	55 ± 1	0.01	500	10
3	108 ± 1	0.01	1000	20
4	50 ± 1	0.03	1500	30
5	102 ± 1	0.03	2000	40
6	50 ± 1	0.04	2500	50
7	75 ± 1	0.1	5000	100
8	189 ± 1	0.1	10000	200
9	212 ± 1	0.1	15000	300

Flax seeds were irradiated with the doses of 0, 5, 10, 30, 50 and 100 Gy, wheat seeds were treated with the doses of 0, 5, 10, 20, 30, 40, 50, 100, 200 and 300 Gy. The dose rate varied in the range from 0.2 to 1.3 Gy/sec.

After the irradiation, the seeds were delivered to the SFSC RAS.

Wheat and flax seeds were planted in Petri dishes containing a nutritional medium PDA (potato dextrose agar), where they sprouted.

The germination constant was established as the ratio between the number of seeds that sprouted and the total number of seeds on the 3rd and 7th day after being planted. The number of sprouted and dead seeds, as well as the quantity and the diameter of phytopathogenic fungal colonies, were counted on the 7th day after crops were sown.

3. Results and Discussion

Irradiating flax and wheat seeds led to the non-linear dependencies between germination on the irradiation dose (figure 2 a-d). The control germination constant established on the 3rd and 7th day was (77 ± 14)% and (70 ± 25)% for flax seeds, and (93 ± 14)% and (97 ± 14)% for wheat seeds.

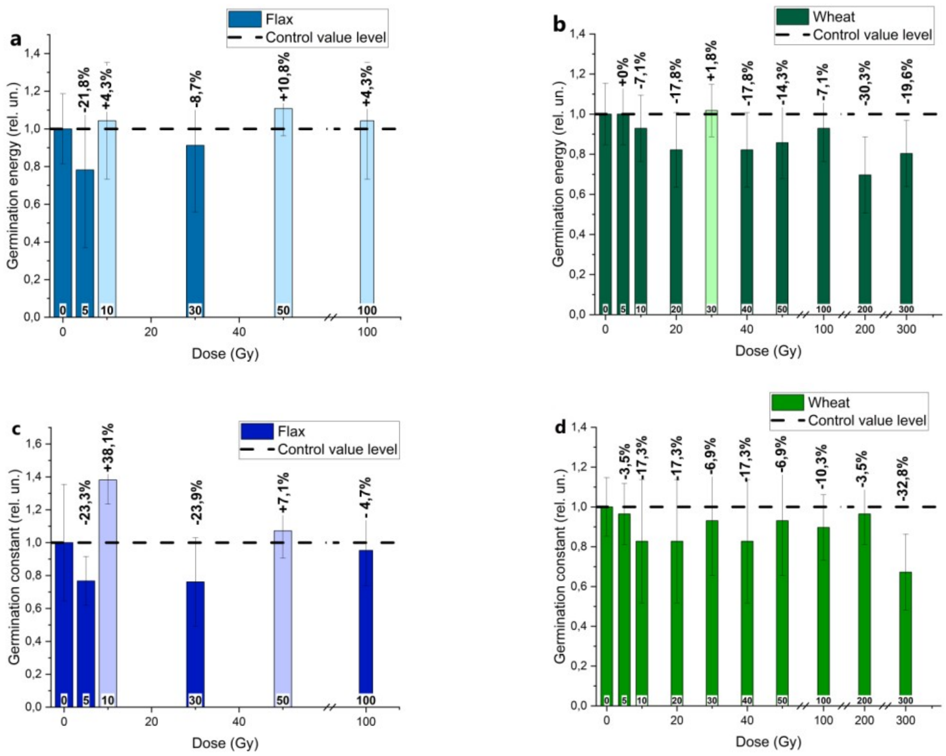

Figure 2. Dependencies of the germination constant for flax (a,c) and wheat (b,d) on the 3rd day and the 7th day on the radiation dose.

Irradiating flax seeds with the doses of 10, 50, and 100 Gy increased the seed germination on the third day after sowing by 4.3%, 10.8% and 4.3% respectively, compared to the control values (shown in a lighter shade of blue in figure 2a). Doses of 5 and 30 Gy have an overwhelming effect of 21.8% and 8.7% on the growth of flax seeds, respectively (shown in a darker shade of blue in figure 2a). Further examination of flax seeds on day 7 revealed that, at the doses of 10 Gy and 50 Gy, the germination constant values were also greater than the control values by 38% and 7%, respectively (shown in a lighter shade of dark blue in figure 2c), and that, at a dose of 100 Gy, the germination fell by about 5% in comparison to the control samples (shown in a darker shade of dark blue in figure 2a).

The study of wheat seeds revealed that none of the radiation doses significantly increased the germination constant neither on the 3rd day or on the 7th day after planting. As a result, germination constant was reduced by the doses of 20, 40, 50, 200, and 300 Gy in comparison to the control samples by more than 17%. In other cases, the values were at the same level as the control values. On the 3rd day after irradiation with the dose of 30 Gy, there was a marginal increase in the germination constant of wheat seeds (shown in a lighter shade of green in Figure 2b); however, when examined on the 7th day, this indicator was found to be nearly 17% lower than the control one.

Thus, the irradiation of flax seeds with the doses of 10 Gy and 50 Gy increased the germination rate slightly, by 38% and 7% respectively, while none of the doses applied to wheat seeds showed any increase in germination. In contrast, a significant inhibitory impact was seen at doses of 5 Gy and 30 Gy in flax seeds and at 20 Gy, 40 Gy, 200 Gy, and 300 Gy in wheat seeds.

The phytosanitary state of control and irradiated samples of wheat and flax seeds revealed that the fungus on wheat seeds predominantly belonged to the genus Alternaria sp., and on flax seeds, to the genus Fusarium sp. In the control samples of flax seeds, (2.0 ± 0.6) colonies of phytopathogenic fungi were found, with the average diameter (25.3 ± 1.4) mm. In the control samples of wheat seeds (8.5 ± 0.9) colonies with the average diameter (19.8 ± 1.2) mm were detected. The number of fungi and the diameter of colonies for both types of seeds showed no linear dependency on the irradiation dose (figure 3a-d).

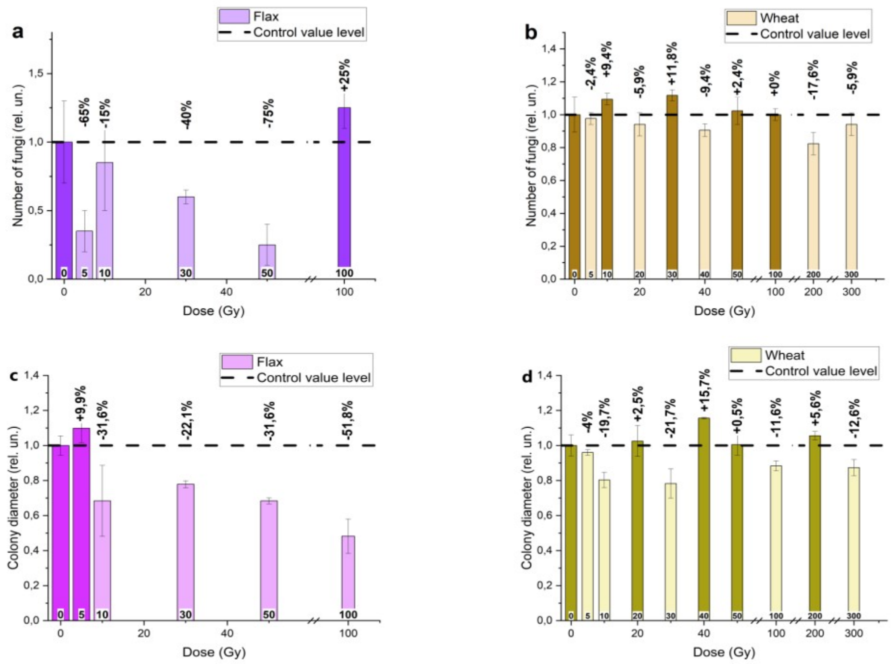

Figure 3. Dependencies of the number of fungi in flax (a) and wheat (b) seeds, and the diameter of their colonies on the radiation dose (c,d).

The most significant difference in the number of phytopathogenic fungi in flax seeds was found only between the control values and those corresponding to irradiation at doses of 5 Gy and 50 Gy, where the number of fungi was less than 35%. Fungi mostly developed when seeds were irradiated at the dose of 100 Gy, and the number of fungal colonies amounted to (2.5 ± 0.3), which exceeded the control values by 25% (shown in a darker shade of purple in Figure 3a). The only dose that increased the colony diameter was 5 Gy (shown in a lighter shade of pink in figure 3c). All other doses showed the 23-52% reduction in colony diameter as compared to control values. The smallest radius of colonies was recorded at 100 Gy and amounted to (12.2 ± 2.9) mm.

There was no significant effect of radiation dose on the number of fungal colonies in wheat seeds, except for the dose of 200 Gy, where this indicator was 17.6 % lower than the control value. The most considerable fungal growth was amounted to (9.5 ± 0.29) pcs and was caused by the dose of 30 Gy. A statistical difference in the radial growth of mycelium in wheat seeds was observed after irradiation with the dose of 40 Gy (shown in a darker shade of khaki in figure 3d). The radiation doses of 10, 30, 100, and 300 Gy caused a considerable reduction in the growth of the mycelium by 12–22%. The largest radial growth of a fungal colony was (22.9 ± 0.1) mm at a dose of 40 Gy, while the minimum was (15.5 ± 3.1) mm at 30 Gy.

Based on a combination of factors including germination, suppression of the number of fungi of the genera Fusarium and Alternaria and the diameter of their colonies, the most efficient dose of 1 MeV electron radiation is 10 Gy for flax variety Severny, which corresponds to the experimental data provided in the article [16], where it is shown that gamma radiation at doses of 8–10 Gy increases the flax seed production by 15-20%. For spring wheat variety Novosibirskaya 29, however, the doses which were found to significantly reduce the number and the diameter of colonies failed to inhibit the germination of seeds. A series of research conducted by [17-18] revealed that the inhibition of the growth of fungi, such as genera Fusarium sp, Helminthosporium sp, Alternaria sp. in wheat variety Iren, was caused by pulsed X-ray and low-energy electron irradiation with the doses above 1.5 kGy, while seed germination significantly decreased compared with the control values. Thus, it can be assumed that 1 MeV electron irradiation is more effective for pre-planting treatment of wheat seeds in terms of pathogen inhibition since the reduction of the number and the diameter of colonies is observed after the irradiation with the doses up to 300 Gy, which are considerably lower than the doses obtained during the X-ray irradiation and low-energy electron irradiation with 250 keV.

4. Conclusion

It was found that 1 MeV electron irradiation of flax and wheat seeds with the doses ranging from 5 to 300 Gy has a nonlinear effect on the germination and the suppression of phytopathogens in seeds. It is clear that the doses which would be the most efficient for increasing the germination rate and suppressing phytopathogens are sensitive to specific properties of regional flax and wheat varieties, so they should be selected on an individual basis.

It was established that the most efficient dose for flax variety Severny is 10 Gy, since this dose not only showed the most considerable increase in the germination rate by 38% but also decreased the number of fungi in seeds by 15 % and reduced the average diameter of the remaining colonies by 30% or more.

For spring wheat variety Novosibirskaya 29, however, the doses which would be able to significantly reduce the number and the diameter of colonies without causing the inhibition of seed germination were not found. That being said, the 1 MeV electron irradiation with the doses up to 300 Gy proved to be efficient for improving the phytosanitary state of seeds since this dose reduced the number and the diameter of fungi by more than 17% and 20% respectively.

Acknowledgments
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