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Application of Some Physical Seed Treatment Methods to Increase Germination of the Genus *Catalpa* Scop.

To increase the production volume of planting material for ornamental plants in the conditions of Central Kazakhstan, the selection of pre-sowing treatment methods for seed material becomes relevant. The use of safe and effective germination activators accelerates the biological processes of plant growth. The aim of the research was to study the impact of physical methods on the germination of *Catalpa speciosa* seeds as relatively safe methods of seed material activation. The seed treatment was carried out in three ways: the effect of laser irradiation, magnetic fields for 24, 72 hours, and twenty-four-hour aeration. A different response of seedlings to physical factors of influence was noted. The effect of the magnetic field allowed to increase germination by an average of 10 % compared to the control group. The impact of laser irradiation for 1–4 minutes on the growth of *Catalpa speciosa* seedlings was less significant. Aeration had a positive effect on the energy of seed germination. Thus, to increase the germination of seedlings during early sowings of *Catalpa speciosa* seeds, it is promising to use the influence of the magnetic field and aeration.

Keywords: laboratory germination, treatment methods, pre-sowing treatment, *Catalpa speciosa*, seeds.

Introduction

In urban environments, landscaping with decorative plant species plays a vital role. The continental climate of Central Kazakhstan, marked by arid conditions and scarce precipitation, poses challenges for vegetation. In this context, pre-sowing seed preparation becomes crucial for enhancing germination and sprouting rates. While various seed preparation methods for sowing are known, not all have been thoroughly researched or come with application guidelines. It is recognized that different growth stimulation methods are employed to boost seed germination. Such treatments include physical, chemical, and thermal methods, among others, which are instrumental in facilitating rapid seed germination [1].

Employing physical methods for pre-sowing seed treatment offers numerous benefits over traditional chemical methods, chiefly because it avoids contaminating soil and groundwater with chemicals. Treating seeds with a magnetic field enhances plant resilience to both biotic and abiotic stresses by stimulating the antioxidant defense mechanism [2-3]. When employing aeration (barbotage), a notably positive impact on uniform seed germination is observed, particularly beneficial in arid planting conditions [4]. An enhancement in the energy of seed germination is also observed [5].

The primary objective of this scientific research is to identify physical methods that guarantee high germination rates, enhanced vitality, and improved sprouting of seed material. To address this challenge, pre-sowing treatment of the seed material was employed.

Materials and Methods

The subjects of the research are the seeds of *Catalpa speciosa*. *C. speciosa* is a deciduous broadleaf tree that can reach up to 10 meters in height, known for its high decorative value, resistance to cold winter, and adaptability to various soil conditions [6].

Experiments were carried out to examine the influence of physical factors on the seed germination process of the species in question. Specifically, the research focused on how magnetic fields affect the germination rate of *C. speciosa* seeds. The seeds, contained within plastic tubes, were positioned in a setup fitted with magnets for durations of 24 and 72 hours (Fig. 1B). In this setup, the seed material was subjected to the influence of both single and double constant magnetic fields.

One of the experiments involved irradiating the seed material with a helium-neon laser at a wavelength of 632.8 nm with an intensity of 5 mW/cm² for durations of 30 seconds, 1, 2, and 4 minutes.

A B

Experiment variants: *A* — seed aeration; *B* — setup for seed treatment with a magnetic field

Figure 1. The methods of pre-sowing treating *Catalpa speciosa* seeds

An experiment was conducted using seed aeration. This method involves enriching the seeds with air in an aquatic environment. The seeds were aerated in special fabric bags placed in a measuring plastic cylinder with a volume of 1000 ml, equipped with a compressor (Fig. 1A). The seed aeration in fabric bags was carried out for 24 hours.

The seeds were sown after the pre-sowing treatment had been conducted. The germination of the seed material was carried out in Petri dishes, placed on two layers of filter paper that had been pre-moistened with distilled water under laboratory conditions. The experiments were conducted in a climatic chamber at a temperature of +24 °C with four repetitions. Seeds for the study were selected randomly, excluding only those that were damaged, discolored, or empty. Watering was carried out three times a week.

The analysis of germination parameters and the energy of seed germination were carried out in accordance with generally accepted methodological recommendations [7-8]. Observation of the growth and development phases of the seedlings was carried out over 14–18 days. Statistical analysis of the results was conducted according to the methodology of N.L. Udolskaya [9].

Results and Discussion

The analysis of the research results on the impact of magnetic fields on the germination of *C. speciosa* seed material showed that seeds exposed to a double magnetic field for 24 hours, as well as a single field for 72 hours, demonstrated improved germination, reaching 100.0±0 %. The control group of seeds showed a germination rate of 85.0±5.77 %. The germination rates of seeds exposed to magnetic fields, on average, exceed the control values by 15 %. Seeds treated with a single magnetic field for 24 hours showed the lowest level of germination — 85.0±11.06 %, and the germination energy was 80.0±13.33 % (Table 1).

Table 1

The influence of magnetic fields on the viability of *Catalpa speciosa* seeds

Indicators	Control group	Single field		Double field	
		24 hours	72 hours	24 hours	72 hours
Germination, %	85.0±5.77	85.0±11.06	100.0±0*	100.0±0*	90.0±6,67
Germination energy, %	55.0±5.77	80.0±13.33*	95.0±5.77*	95.0±5.77*	80.0±9,43*
Note. * reliability of differences between the variants of the experiment at $P \leq 0.05$.					

As a result of analyzing the presented data, it was found that seeds exposed to a magnetic field retain their viability, and an increase in germination rates is observed compared to the control group.

After analyzing the germination dynamics of the seed material of the studied species, it was revealed that in the control group, seeds begin to germinate on the fourth day after sowing, with a germination rate of 10.0±6.67 %. Seeds exposed to a single magnetic field for 72 hours show germination on the fourth day. On the fifth day of germination, the beginning of seed sprouting is observed in all groups treated with a magnetic field. It is particularly noteworthy that seeds treated with both single and double magnetic fields for 24 hours demonstrate a high level of germination — 55.0±5.77 %. On the sixth day, seeds exposed to both single and

double magnetic fields for 72 hours exhibit a significant increase in simultaneous germination, reaching an average of 80 % germination. This rate is characteristic of the following experimental variants: a single magnetic field for 24 and 72 hours, as well as a double magnetic field for 24 hours. The germination rate of the seed material in the control group is 35.0±11.06 %. On the tenth day, the lowest level of germination is observed in seeds exposed to a single magnetic field for 24 hours — 85.0±11.06 % (Table 2).

Table 2

The germination dynamics of *Catalpa speciosa* seeds following exposure to a magnetic field

Days to germination	Germination, %				
	Control group	Single field		Double field	
		24 hours	72 hours	24 hours	72 hours
1	–	–	–	–	–
2	–	–	–	–	–
3	–	–	–	–	–
4	10.0±6.67	–	5.0±5.77	–	–
5	15.0±5.77	55.0±5.77	15.0±5.77	55.0±577	10.0±6.67
6	35.0±1106	80.0±1333	80.0±9.43	80.0±3.33	70.0±6.67
7	55.0±5.77	80.0±13.33	95.0±5.77	95.0±5.77	80.0±9.43
8	65.0±11.06	80.0±1333	95.0±5.77	95.0±5.77	90.0±6.67
9	80.0±9.43	85.0±11.06	100.0±0	95.0±5.77	90.0±6.67
10	85.0±5.77	85.0±11.06	100.0±0	100.0±0	90.0±667

Upon analyzing the impact of magnetic fields on the germination of *C. speciosa* seed material, it was found that the viability of the seeds exceeds the corresponding indicators of the control group. In terms of ontogenesis phases, a slight delay in germination of 1-2 days was observed. The methodology demonstrates an improvement in seed germination indicators, expressed in increased germination rates, which is explained by the positive effect on the processes of germination and seedling development.

Research on the impact of aeration on seed germination and energy was conducted. Aeration is the process of seeds absorbing water saturated with air (oxygen). Positive dynamics in the seed germination process were observed. After conducting aeration, seed germination reached a level of 90.0±6.67 %, exceeding the control values by 35 % (Table 3).

Table 3

Germination indicators of *Catalpa speciosa* seeds after aeration

Experimental condition	Germination, %	Germination energy, %
Control group	85.0±5.77	55.0±5.77
Aeration	90.0±6.67	90.0±6.67*
Note: * reliability of differences between the variants of the experiment at $P \leq 0.05$.		

Analyzing the germination process of the seeds of the species in question, it was found that germination begins on the fifth day. A significant level of simultaneous seed sprouting was observed after aeration (Table 4).

Table 4

The germination dynamics of *Catalpa speciosa* seed material following aeration

Days to germination	Aeration	Control group
1	–	–
2	–	–
3	–	–
4	–	10.0±6.67
5	55.0±5.77	15.0±5.77
6	70.0±6.67	35.0±1106
7	90.0±6.67	55.0±5.77
8	90.0±6.67	65.0±11.06
9	90.0±6.67	80.0±9.43
10	90.0±6.67	85.0±5.77

As a result of aeration, inhibitors are lost, and seed swelling is accelerated; this seed treatment method is effective in arid conditions [10]. To speed up the development phases of the seedling and seed germination, seed aeration is recommended.

During laboratory studies, the method of laser irradiation on seed germination and the dynamics of subsequent seedling development stages were analyzed. *C. speciosa* seeds were exposed to a He-Ne laser for a time interval ranging from 30 seconds to 4 minutes. The obtained germination results were compared with a control group of seedlings. Upon completion of the observation period for seed germination and seedling development, laser treatment demonstrated that the optimal exposure time to achieve maximum seed germination is 30 seconds. In this experimental variant, germination was 100 %, which exceeds control values by 15 %, and the energy of germination increased by 38.3 % (Table 5).

Table 5

The influence of laser irradiation on the germination indicators of *Catalpa speciosa*

Indicators	Control group	30 sec	1 min	2 min	4 min
Germination, %	85.0±5.77	100.0±0	80.0±0	80.0±0	73.3±8.16
Germination energy, %	55.0±5.77	93.3±8.16	80.0±0	80.0±0	66.67±16.33

As a result of comparing different experimental variants of laser irradiation, it was found that optimal germination indicators are observed with shorter durations of exposure. For instance, in the experiment with seed irradiation by laser for 1 and 2 minutes, germination was 80.0±0 %, whereas in the variant with 4 minutes of irradiation, the germination rate decreased to 73.3±8.16 %. After conducting a comparative analysis of the germination dynamics of *C. speciosa* seed material in different experimental variants, it was revealed that seed germination, subjected to laser treatment in all duration variants, begins on the sixth day (Table 6).

Table 6

The germination dynamics of *Catalpa speciosa* seed material following laser irradiation

Days to germination	Germination, %				
	Control group	30 sec	1 min	2 min	4 min
1	–	–	–	–	–
2	–	–	–	–	–
3	–	–	–	–	–
4	10.0±6.67	–	–	–	–
5	15.0±5.77	–	–	–	–
6	35.0±11.06	80.0±14.14	66.7±8.16	53.3±21.60	60.0±14.14
7	55.0±5.77	93.3±8.16	80.0±0	80.0±0	66.67±16.33
8	65.0±11.06	93.3±8.16	80.0±0	80.0±0	66.67±16.33
9	80.0±9.43	93.3±8.16	80.0±0	80.0±0	66.67±16.33
10	85.0±5.77	100.0±0	80.0±0	80.0±0	66.67±16.33

Thus, the irradiation of *C. speciosa* seeds with a He-Ne laser confirms the preservation of their viability, and the seedling successfully passes through all stages of development. The optimal duration of laser irradiation, at which the best germination rates are achieved, is 30 seconds. The irradiation method using a He-Ne laser proves to be effective with a short exposure time for the species under study.

After conducting a comparative analysis of physical methods of influence on the viability of *C. speciosa* seed material, it was determined that to achieve maximum germination rates, it is recommended to use the magnetic field method and aeration, as well as laser irradiation with a short duration of exposure (Fig. 2).

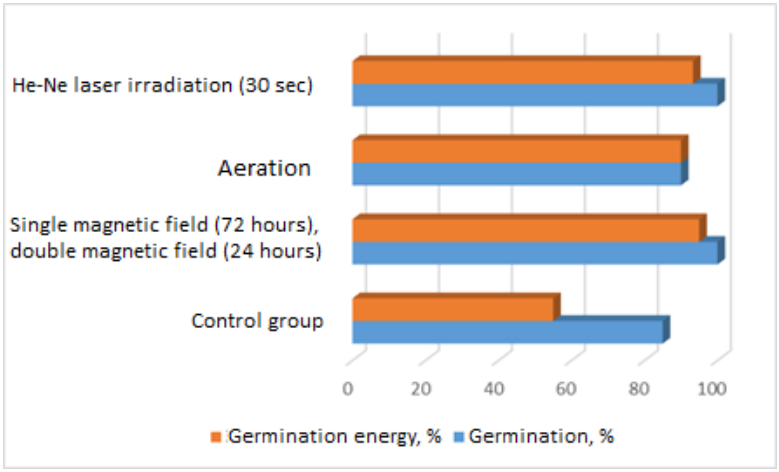

Figure 2. Germination and energy of seed germination of *Catalpa speciosa* seed material treated with physical methods

In analyzing the optimal germination indicators of the seeds of the studied species subjected to various variations of physical factors, it was found that maximum germination is observed in the experimental variant with a double magnetic field for 24 hours, as well as with a single field for 72 hours. Seeds in these variants exhibited higher germination rates. In the control group and in the experiment with seed irradiation by a He-Ne laser, seed germination was noted on the fourth day, while in the experiment with the influence of a double magnetic field, germination occurred on the fifth day (Fig. 3).

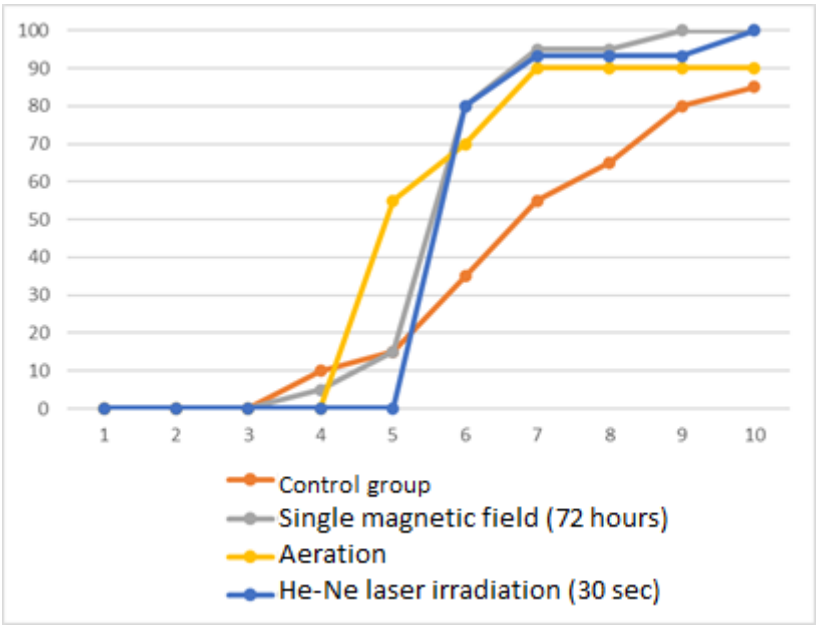

Figure 3. Dynamics of seed germination in different experimental variants of *Catalpa speciosa*

Conclusions

In a number of scientific publications, positive results of physical methods of influence on the germination of seed material and the development of seedlings have been noted.

During the conducted studies, an increase in germination rates was observed in experimental variants with aeration and the influence of magnetic fields. On average, the germination level increased by 5 % compared to control values. Prolonged irradiation of seeds with a He-Ne laser beam (1–4 min) had a negative impact on seed germination. Germination rates in these cases were below control values, however, a positive result was noted with laser irradiation for 30 seconds (15 % higher than control values). Thus, the influence of magnetic fields, the aeration method, and irradiation of seeds with a He-Ne laser beam for 30 seconds can

be recommended for practical application. However, the mechanism of perception of magnetic fields and laser beams by plants and their reactions to them remains insufficiently studied. Additional research is required to expand knowledge on the molecular mechanisms responsible for accelerating seed germination and increasing seedling viability.

References

1 Coperland L.O. Principles of Seed Science and Technology / L.O. Coperland, M.B. McDonald. — Spriger US, 2013. — 409 p.

2 Araujo S.D.S. Physical methods for seed invigoration: advantages and challenges in seed technology / S.D.S. Araujo, S. Paparella, D. Dondi, et al. // Frontiers in Plant Science. — 2016. — Vol. 7. — Article ID 646. https://doi.org/10.3389/fpls.2016.00646

3 Bhardwaj J. Biochemical and biophysical changes associated with magnetopriming in germinating cucumber seeds / J. Bhardwaj, A. Anand, S. Nagarajan // Plant Physiology and Biochemistry. — 2012. — Vol. 57. — P. 67–73. https://doi.org/10.1016/j.plaphy.2012.05.008

4 Пастухова А.М. Влияние барботирования на всхожесть семян сосны обыкновенной / А.М. Пастухова, А. Хертек // Плодоводство, семеноводство, интродукция древесных растений: материалы XXIII Междунар. науч. конф. — Красноярск, 2020. — С. 85–87.

5 Пастухова А.М. Изучение влияния искусственного освещения и барботирования на рост сосны обыкновенной и лиственницы сибирской / А.М. Пастухова, А.Е. Войткевич // Междунар. науч.-исслед. журн. — 2022. — № 12 (126). — С. 1–6. https://doi.org/10.23670/IRJ.2022.126.55

6 Мурзабулатова Ф.К. Опыт интродукции видов рода *Catalpa* Scop. в Ботаническом саду г. Уфы / Ф.К. Мурзабулатова, Н.В. Полякова // Изв. Самар. науч. центра РАН. — 2015. — Т. 17, № 4. — С. 245–247.

7 Зорина М.С. Определение семенной продуктивности и качества семян интродуцентов / М.С. Зорина, С.П. Кабанов // Методики интродукционных испытаний в Казахстане. — Алма-Ата: Наука, 1986. — С. 75–85.

8 Мальцева М.В. Пособие по определению посевных качеств семян лекарственных растений / М.В. Мальцева. — М., 1950. — 56 с.

9 Удольская Н.Л. Методика биометрических расчетов / Н.Л. Удольская. — Алма-Ата: Наука, 1976. — 45 с.

10 Методы предпосевной обработки семян овощных культур (рекомендации). — М.: Рос. гос. аграр. ун-т, 2000. — С. 14–15.

А.К. Айтымов

Catalpa Scop. тұқымының өнуін арттыру үшін тұқымдарды өңдеудің кейбір физикалық әдістерін қолдану

Орталық Қазақстан жағдайында әсемдік өсімдіктердің көшет материалын өндіру көлемін ұлғайту үшін тұқым материалын себу алдындағы өңдеу әдістерін таңдау өзекті. Қауіпсіз және тиімді өну белсендіргіштерін пайдалану өсімдіктердің биологиялық өсу процестерін жеделдетеді. Зерттеудің мақсаты — көшет материалын белсендірудің салыстырмалы түрде қауіпсіз әдістері ретінде *Catalpa speciosa* тұқымының өнуіне физикалық әдістердің әсерін зерттеу. Тұқымдарды өңдеу үш жолмен жүргізілді, атап айтсақ: 24, 72 сағат ішіндегі магнит өрістері мен лазерлік сәулеленудің әсері, тәулік бойы аэрация. Физикалық әсер ету факторларына өскіндердің әртүрлі реакциясы байқалды. Магниттік өрістің әрекеті бақылау тобымен салыстырғанда өнуді орта есеппен 10%-ға арттыруға мүмкіндік берді. 1-4 минут ішінде лазерлік сәулеленудің *Catalpa speciosa* көшеттерінің өсуіне әсері онша маңызды болмады. Аэрация тұқымның өну энергиясына оң әсер етті. Осылайша, *Catalpa speciosa* тұқымын ерте себу кезінде көшеттердің өнгіштігін арттыру үшін магнит өрісі мен аэрацияның әсерін пайдалану перспективалы болып табылады.

Кілт сөздер: зертханалық өну, өңдеу әдістері, егу алдындағы өңдеу, *Catalpa speciosa*, тұқымдар.

А.К. Айтымов

Применение некоторых физических методов обработки семян для повышения всхожести рода *Catalpa* Scop.

Для увеличения объемов производства посадочного материала декоративных растений в условиях Центрального Казахстана актуальным становится выбор методов предпосевной обработки семенного

материала. Использование безопасных и эффективных активаторов прорастания ускоряет биологические процессы роста растений. Целью исследований было изучение влияния физических методов на прорастание семян *Catalpa speciosa* как относительно безопасных способов активации семенного материала. Обработка семян проводилась тремя способами: воздействие лазерного облучения, магнитных полей в течение 24, 72 ч и круглосуточная аэрация. Отмечена различная реакция проростков на физические факторы воздействия. Действие магнитного поля позволило увеличить всхожесть в среднем на 10 % по сравнению с контрольной группой. Влияние лазерного облучения в течение 1–4 мин на рост проростков *Catalpa speciosa* было менее значительным. Аэрация положительно влияла на энергию прорастания семян. Таким образом, для повышения всхожести проростков при ранних посевах семян *Catalpa speciosa* перспективно использовать воздействие магнитного поля и аэрации.

Ключевые слова: лабораторная всхожесть, методы обработки, предпосевная обработка, *Catalpa speciosa*, семена.

References

1 Coperland, L.O. & McDonald, M.B. (2013). *Principles of Seed Science and Technology*. Spriger US.

2 Araujo, S.D.S., Paparella, S., Dondi, D. et al. (2016). Physical methods for seed invigoration: advantages and challenges in seed technology. *Frontiers in Plant Science, 7;* 646. https://doi.org/10.3389/fpls.2016.00646

3 Bhardwaj, J., Anand, A., & Nagarajan, S. (2012). Biochemical and biophysical changes associated with magnetopriming in germinating cucumber seeds. *Plant Physiology and Biochemistry, 57*; 67–73. https://doi.org/10.1016/j.plaphy.2012.05.008

4 Pastukhova, A.M., & Khertek, A. (2020). Vliianie barbotirovaniia na vskhozhest semian sosny obyknovennoi [The Effect of Aeration on the Germination of Scots Pine Seeds]. *Plodovodstvo, semenovodstvo, introduktsiia drevesnykh rastenii: Materialy XXIII Mezhdunarodnoi nauchnoi konferentsii — Ruit growing, seed production, introduction of woody plants: Proceedings of the XXIII International Scientific Conference.* Krasnoyarsk, 85–87 [in Russian].

5 Pastukhova, A.M., & Voitkevich, A.E. (2022). Izuchenie vliianiia iskusstvennogo osveshcheniia i barbotirovaniia na rost sosny obyknovennoi i listvennitsy sibirskoi [Study of the Influence of Artificial Lighting and Aeration on the Growth of Scots Pine and Siberian Larch Seedlings]. *Mezhdunarodnyi nauchno-issledovatelskii zhurnal — International Research Journal, 12* (126); 1–6 https://doi.org/10.23670/IRJ.2022.126.55 [in Russian].

6 Murzabulatova, F.K., & Poliakova, N.V. (2015). Opyt introduktsii vidov roda *Catalpa* Scop. v Botanicheskom sadu g. Ufy [Experience in the Introduction of *Catalpa* Scop. Species in the Botanical Garden of Ufa]. *Izvestiia Samarskogo nauchnogo tsentra Rossiiskoi akademii nauk — Proceedings of the Samara Scientific Center of the Russian Academy of Sciences, 17*(4); 245–247 [in Russian].

7 Zorina, M.S., & Kabanov, S.P. (1986). Opredelenie semennoi produktivnosti i kachestva semian introdutsentov [Determination of Seed Productivity and Quality of Introducents]. *Metodiki introduktsionnykh ispytanii v Kazakhstane — Methods of Introduction Research in Kazakhstan*. Almaty: Nauka, 75–85 [in Russian].

8 Maltseva, M.V. (1950). *Posobie po opredeleniiu posevnykh kachestv semian lekarstvennykh rastenii [A Guide to Determining the Sowing Qualities of Medicinal Plant Seeds]*. Moscow [in Russian].

9 Udolskaya, N.L. (1976). *Metodika biometricheskikh raschetov [Methodology of Biometric Calculations]*. Almaty: Nauka [in Russian].

10 (2000). *Metody predposevnoi obrabotki semian ovoshchnykh kultur (rekomendatsii) [Methods of Pre-sowing Preparation of Vegetable Crop Seeds (recommendations)]*. Moscow: Rossiiskii gosudarstvennyi agrarnyi universitet, 14–15 [in Russian].

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