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Features of generative reproduction in plants of the genus *Cercis* L.

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Abstract. The challenge of germinating *Cercis* L. seeds, caused by their physiological and physical dormancy, necessitates the improvement of generative propagation methods using growth stimulants. This study examined the influence of organo-mineral growth stimulants on the germination efficiency of experimental species seeds, as well as their subsequent impact on the morphometric parameters of seedlings. Field germination was determined by direct counting of germinated seeds, while laboratory germination was assessed according to the International Seed Testing Association (ISTA) methodology for evaluating seed quality. Statistical data processing was performed using MS Excel (one-way ANOVA and Standard Deviation). The study revealed a statistically significant effect of the tested preparations on seed germination efficiency. It was found that *Cercis siliquastrum* "Alba" seeds exhibited the highest germination rate when treated with Succinic acid at a concentration of 1 g/L. For *Cercis canadensis* L., the preparations "Megafol" (5.0 mL/L, germination rate 70-77%) and "Alga 600" (1.25 g/L, germination rate 50-70%) demonstrated a positive effect. Additionally, experimental data showed that seedlings derived from stimulant-treated seeds exhibited greater growth increments compared to the control group. Treatment with "Succinic acid" resulted in a 2.5-2.9-fold increase in *Cercis siliquastrum* "Alba" seedlings. Similarly, *Cercis canadensis* L. seedlings from seeds treated with

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"Succinic acid" showed nearly double the growth increment. Application of "Radifarm" (5.0 mL/L) increased the height of *Cercis canadensis* L. seedlings by approximately 1.6-fold

Keywords: seed propagation; Judas tree; seedlings; growth stimulants; germination

Introduction

The genus *Cercis* L. comprises ornamental woody plants distinguished by their vibrant flowering and distinctive leaf morphology, making them widely used in landscaping, garden design, and botanical cultivation. Despite their horticultural value, large-scale propagation of *Cercis* remains challenging due to the biological characteristics of its seeds. Specifically, the seeds exhibit deep physiological and physical dormancy, significantly complicating germination and limiting the widespread application of generative propagation in nursery conditions. Consequently, there is a need to refine stratification techniques and employ growth stimulants to enhance *Cercis* seed germination and reduce pre-sowing preparation time.

The simplest propagation method is generative. As noted by N. Nimavat & P. Parikh (2024), generative reproduction carries a risk of parental trait segregation. However, for plants that are difficult to propagate via cuttings, grafting serves as an alternative for preserving the ornamental traits of parent plants. This technological process requires rootstock planting material, which is typically obtained through generative propagation. Thus, improving generative propagation techniques and studying the influence of growth stimulants on seed germination efficiency and subsequent seedling quality remain pressing issues.

According to F.A. Chattha *et al.* (2025), seed germination is a complex process influenced by both endogenous and exogenous factors. Key determinants of successful germination include temperature, moisture, and oxygen. The endosperm acts as a nutrient reservoir, containing hormones that regulate germination. Phytohormones play a critical role in germination and early seedling development. For instance, auxins regulate embryo growth and development, with their concentration controlling differentiation into various plant organs. Gibberellins, another vital group of phytohormones, are used in seed treatment to induce amylase production, which promotes germination. Post-germination, increased sugar content elevates respiration rates, facilitating growth. Cytokinins regulate seedling development, particularly stem elongation and enzyme induction. These phytohormones are synthesised in the apical tissues of young roots. In contrast, abscisic acid acts as an inhibitor and interacts antagonistically with gibberellins. Additionally, exogenous chemicals are employed to modulate seed and plant growth, influencing not only development but also providing insights into seed physiology through compositional analysis.

R. Zhou *et al.* (2025) investigated the effects of gibberellic acid and cold stratification on the germination of the perennial medicinal plant Ferula gigantea via controlled experiments. They found that a 90-day cold stratification period yielded the highest germination rate (86.7%), recommending this pre-sowing treatment for the species. Garg (2024) studied the positive influence of beneficial microbes, including arbuscular mycorrhizal fungi, *Trichoderma* spp., rhizobia, and other bacteria, noting significant germination improvements in cereals, oilseeds, and vegetables.

During the generative propagation of *Zostera marina* L., researchers R. Pieraccini *et al.* (2025) investigated the effects of light and gibberellic acid on seed germination in the studied species. They examined the combined influence of light spectra (white, red, and absence of light), photoperiod, and gibberellic acid at concentrations of 0, 50, 500, and 1000 mg/L on germination rates. Their findings revealed that the absence of light or exposure to red light spectra, in combination with gibberellic acid, significantly increased the likelihood of seed germination. Additionally, it was noted that moderate (50 mg/L) and high (500 mg/L) concentrations of gibberellic acid also had a positive effect on reducing germination time. Based on their research, the authors concluded that seed treatment could mitigate dormancy periods induced by stress or handling and may represent a viable strategy for generative propagation in nursery settings.

The study by X. Wang *et al*. (2025) focused on the effects of freezing and stratification on the germination of pecan (*Carya illinoinensis*) seeds, which are widely used for rootstock cultivation. The authors emphasised that, despite the traditional emphasis on scions, rootstocks largely determine plant growth, phenology, and resilience. The primary challenges arise from the seeds deep dormancy and hard seed coat. It was found that stratification significantly improved germination rates (up to 48.5%) and reduced germination time (to 18 days), whereas freezing without stratification demonstrated markedly lower efficacy (germination rate of 15.7%, with germination occurring after 37 days). Conversely, the combination of freezing and stratification negatively affected the results. Seed provenance had no significant influence.

M. Szymajda & R. Maciorowski (2025) investigated the impact of different treatment methods on the germination and growth of cherry seedlings under greenhouse conditions. The tested treatments included varying durations of cold stratification (+5°C) and several approaches to removing germination inhibitors present in the endocarp, seed coat, endosperm, and cotyledons of the embryos. Their results indicated that the highest germination rates were achieved by removing the seed coat attached to the endosperm and exposing the embryos to +20°C after 90 days of stratification. Germination rates reached 80-90%, with germination time ranging between 10-15 days. The authors also noted that under conventional stratification methods (seeds in endocarps at +5°C), a significant proportion of seeds failed to germinate even after 150 days. Using this method, seedlings 20-25 cm tall were obtained within five months, while the final germination rate for the control group varied between 16.4% and 54.4%. Seedlings derived from seeds stratified for 90 days exhibited better growth than those subjected to shorter stratification periods.

The objective of this study was to determine the effects of organo-mineral growth stimulants on the germination of experimental *Cercis* L. species and to analyse subsequent changes in the morphometric characteristics of the resulting seedlings.

Materials and Methods

Germination tests were conducted by sowing seeds of *Cercis canadensis* L. and *Cercis siliquastrum* "Alba" in multi-cell trays (60×40 cm, cell size 4.5×4.5×7.0 cm). Seeds of *Cercis canadensis* L. "F" and *Cercis siliquastrum* "Alba" were collected from trees growing in the O.O. Fomin Botanical Garden and from a plant located on V. Petriv Str. (*Cercis canadensis* L. "K"). The seeds subsequently underwent cold stratification at +4°C for four months. Pre-sowing treatment included scarification of the seed coat using hot water: seeds were soaked in boiling water (t = 100°C) and left to cool for 24 hours. Afterward, the seeds were soaked in solutions of the tested preparations at varying concentrations (according to the experimental design) for 24 hours. The tested substances included "Megafol", "Radifarm", "Alga 600", and succinic acid. The seeds were then sown in individual cells of the trays at a depth of 1-1.5 cm, with one seed per cell. Lowland peat was used as the substrate. The trays were placed in a greenhouse. The study was conducted between 2022 and 2024. Irrigation was performed as needed based on substrate dryness, supplemented by automated watering three times daily (5-minute intervals at 8:00, 12:00, and 16:00) via fine mist nozzles (flow rate: 2 L/h). Germination rates were assessed 30 days after sowing. Seedling height was measured on day 40 and after growth completion (five months post-sowing).

Laboratory germination capacity of the seeds was determined in accordance with the International Rules for Seed Testing 2025 by the International Seed Testing Association (ISTA) at the State Enterprise "State Centre of Agricultural Products Certification and Examination". Seeds from different harvest years (2021 and 2023) and subjected to different stratification methods were used for the experiment. The 2021 seeds were stored under controlled cold conditions, whereas the 2023 seeds were collected directly from trees immediately before sowing, thus undergoing natural stratification. Due to the absence of the studied genus and species in the aforementioned Rules, it was decided to conduct the research using the methodology for determining the sowing qualities of *Robinia pseudoacacia* L. seeds, as this species requires similar pre-sowing preparation procedures and has a hard seed coat. According to the methodology, the seeds were germinated on filter paper under alternating temperatures: 20°C for 16 hours and 30°C for 8 hours. Seed evaluation was recommended to be conducted first on day 7 (germination energy) and finally on day 14 (germination capacity). To determine the influence of the germination method on laboratory germination capacity, seeds were placed for germination between layers of filter paper. Seeds used for germination included those from the 2021 harvest, which had undergone cold stratification (for 4 months at +4°C) in 2021-2022 and were subsequently stored at room temperature, as well as seeds from the 2023 harvest, collected directly from trees immediately before the experiment (March 2024) and not subjected to artificial stratification. Germination was carried out in a laboratory incubator with cooling (ST700 BASIC, manufactured by PolEko Aparatura, Poland) under a variable temperature regime in accordance with the methodology, as well as under a variable photoperiod – 8 hours with light and 16 hours without light. Seed evaluation was conducted following the methodology; however, the final evaluation period was extended to day 30 due to low germination energy. The study was conducted in compliance with the Convention on Biological Diversity (1992).

Results and Discussion

Seed germination capacity was evaluated on day 30, and morphometric measurements were taken on day 40 after sowing. The summarised data on germination capacity are presented in Table 1.

Table 1. *Efficacy of the influence of tested preparation concentrations on the germination rate of the studied plant species*

Preparation	Concentration, ml/l	Germination rate, %		
		C. canadensis L. (O.O. Fomin Botanical Garden)	*C. canadensis* L. (V. Petriv Str.)	*C. siliquastrum* "Alba"
Radifarm	2.5	60.0 ± 3.4	66.7 ± 2.8	80.0 ± 4.7
	5.0	56.7 ± 2.8	46.7 ± 3.6	66.7 ± 2.9
	10.0	36.7 ± 5.1	50 ± 4.3	63.3 ± 3.2
Megafol	2.5	63.3 ± 3.2	60 ± 3.7	56.7 ± 4.1
	5.0	70 ± 4.1	76.7 ± 4.6	70.0 ± 5.3
	10.0	56.7 ± 5.3	50 ± 5.2	56.7 ± 5.1
Alga 600 (g/l)	1.25	70 ± 3.6	50.0 ± 4.2	60.0 ± 2.9
	2.5	56.7 ± 3.1	56.7 ± 3.5	56.7 ± 3.8
	5.0	36.7 ± 3.8	46.7 ± 2.9	46.7 ± 3.4

Table 1. *Continued*

Preparation	Concentration, ml/l	Germination rate, %		
		C. canadensis **L. (O.O. Fomin Botanical Garden)**	***C. canadensis*** **L. (V. Petriv Str.)**	***C. siliquastrum*** **"Alba"**
Succinic acid	0.5	66.7 ± 3.2	73.3 ± 3.6	80.0 ± 4.0
	1	73.3 ± 3.3	73.3 ± 4.3	83.3 ± 3.3
	2	66.7 ± 3.1	63.3 ± 3.6	63.3 ± 4.1
Control		70.0 ± 7.6	80.0 ± 6.8	93.3 ± 2.3

Source: developed by the authors

The data presented in Table 1 demonstrate that the seed germination rate of the studied plant species varies depending on both the concentrations of the tested substances and the species. Specifically, the seeds of *Cercis siliquastrum* "Alba" exhibited a higher germination rate compared to those of *Cercis canadensis* L., which were collected from two different locations in Kyiv. It was hypothesised that this difference in germination rate may reflect a species-specific trait of *C. siliquastrum* "Alba". Statistical analysis confirmed that the preparation concentrations had a statistically significant effect on the seed germination rate of the studied species. The results of the data analysis are presented in Table 2.

Table 2. *One-way ANOVA*

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	4400.824	12	366.7353	6.16992	0.0000534	2.147926

Note: *df* – number of degrees of freedom; *MS* – variances; *F* – calculated value of the Fischer criterion; *P-value* – calculated value of the minimum substantiality; *Fcrit* – critical value of the Fischer criterion
Source: developed by the authors

"Radifarm" showed the greatest efficacy at a concentration of 2.5 ml/l, whereas "Megafol" was most effective at 5.0 ml/l. Succinic acid demonstrated optimal influence at the manufacturer-recommended concentration of 1 g/l (Figs. 1, 2).

The data obtained during the study revealed that the germination rate of *C. canadensis* L. seeds ranged from 36.7% (treated with "Radifarm" and "Alga 600" at a concentration of 5.0 g/L) to 73.3% (succinic acid at 1 g/L). The least variability in germination results (66.7-73.3%) was observed with the "Succinic Acid" preparation. The germination variability of *Cercis canadensis* L. seeds collected from plants growing on V. Petriv Street ranged from 46.7% ("Radifarm" and "Alga 600" at concentrations of 2.5 g/L and 5.0 g/L, respectively) to 80% (Control). The smallest fluctuation in seed germination between preparation concentrations was noted for "Succinic Acid" (63.3-73.3%) and "Alga 600" (46.7-56.7%).

It was established that succinic acid at a concentration of 1 g/L is optimal for enhancing the germination of *Cercis* L. seeds. However, it should be noted that a high germination rate (80%) was observed in *C. siliquastrum* "Alba" seeds treated with "Radifarm" at 2.5 ml/l. At the same time, high germination rates in *C. canadensis* L. were achieved with "Megafol" at 5.0 ml/l and "Alga 600" at 1.25 g/L. The control sample of *Cercis siliquastrum* "Alba" seeds exhibited a germination rate of 93.3%, the highest recorded.

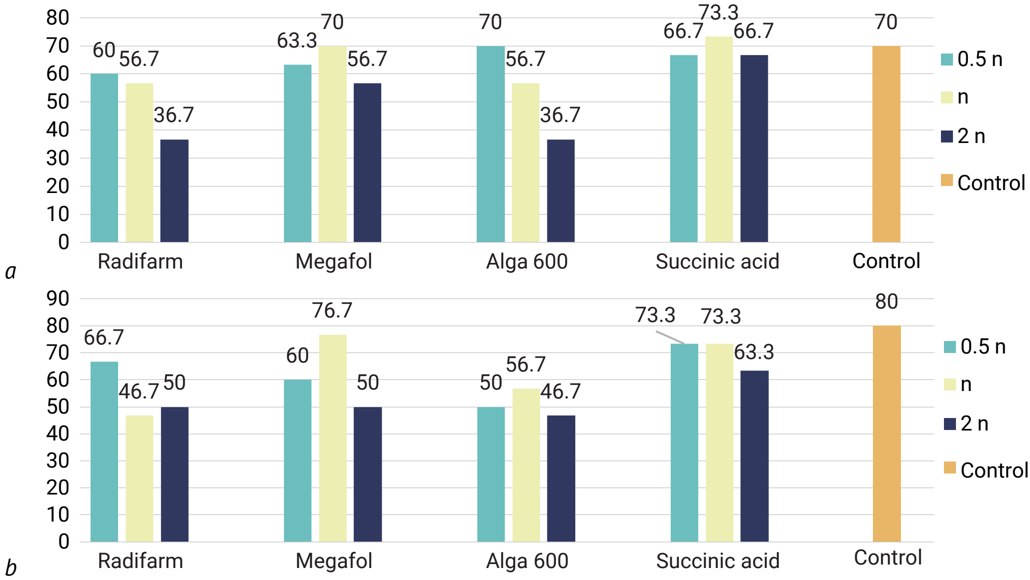

Figure 1. *Efficacy of organo-mineral biostimulant concentrations on the generative propagation of Cercis canadensis L.*

Note: a – seeds from a tree growing in the O.O. Fomin Botanical Garden ("F"); b – seeds from a tree growing in Kyiv, V. Petriv Str. ("K"); n = manufacturer-recommended concentration
Source: developed by the authors

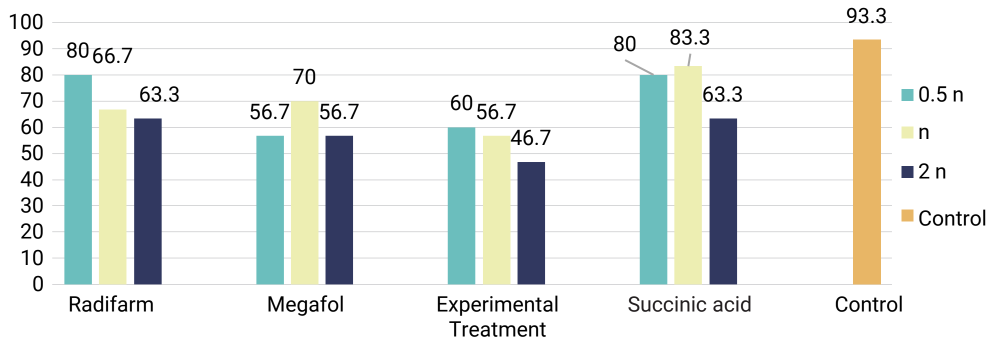

Figure 2. *Effect of tested preparation concentrations on the field germination of C. siliquastrum "Alba"*

Note: n = manufacturer-recommended concentration
Source: developed by the authors

The most common practice for using growth regulators involves vegetative propagation using plant cuttings. However, as asserted by J.D. Bewley & M. Black (1985), these substances can also be employed to break seed dormancy. The researchers provide a list of compounds capable of mitigating or eliminating such issues, including respiratory inhibitors, oxidisers, nitrates, nitrites, and phytohormones themselves. Gibberellins promote the induction of cell wall hydrolases, thereby weakening and damaging the endosperm. Abscisic acid (ABA), acting as an antagonist to gibberellic acid, inhibits the induction of cell wall hydrolases, reducing endosperm weakening and damage. As stated by K. Müller *et al.* (2006), gibberellic acid enhances, while abscisic acid suppresses, embryonic growth potential. The work of H. Fernandez *et al*. (1997) demonstrates significant variations in gibberellins during dormancy release in beech (*Fagus sylvatica* L.) seeds and the capacity of non-dormant seeds to undergo metabolic transformations.

Although the germination percentage of control samples was equal to or slightly higher than that of seeds subjected to pre-sowing treatment, qualitative indicators such as seedling height were significantly lower in the control group (Table 3).

Table 3. *Morphometric parameters of Cercis L. (x ± SDev, n = 30)*

Preparation	Concentration, ml/l (g/l)	Seedling height, cm					
		16.05.2022			16.10.2022		
		C. canadensis L. "F"	*C. canadensis* L. "K"	*C. siliquastrum* "Alba"	*C. canadensis* L. "F"	*C. canadensis* L. "K"	*C. siliquastrum* "Alba"
Radifarm	2.5	4.6 ± 1.8	6.2 ± 1.2	2.6 ± 0.3	11.5 ± 3.9	9.2 ± 3.5	7.5 ± 2.9
	5.0	4.7 ± 1.8	5.9 ± 1.0	2.5 ± 0.5	12.5 ± 4.3	10.0 ± 3.2	5.9 ± 2.7
	10.0	5.8 ± 1.4	5.7 ± 1.5	2.3 ± 0.3	10.8 ± 4.7	9.6 ± 3.7	4.8±1.2
Megafol	2.5	4.6 ± 1.9	6.2 ± 1.2	2.3 ± 0.3	8.1 ± 1.5	13.6 ± 3.1	8.0 ± 1.6
	5.0	4.7 ± 1.8	5.9 ± 1.0	2.5 ± 0.5	7.8 ± 2.3	9.5 ± 2.9	7.3 ± 1.7
	10.0	5.8 ± 1.4	5.7 ± 1.5	2.3 ± 0.3	8.3 ± 1.7	10.2 ± 3.4	6.0 ± 1.9
Alga 600	1.25	4.3 ± 1.4	4.8 ± 1.7	2.8 ± 0.6	9.9 ± 3.2	11.4 ± 2.2	9.3 ± 3.3
	2.5	4.3 ± 1.4	5.7 ± 1.4	2.6 ± 0.6	10.0 ± 2.6	12.5 ± 3.1	8.1±2.7
	5.0	4.6 ± 1.7	5.8 ± 1.1	3.0 ± 0.7	10.6 ± 2.9	11.1 ± 3.9	8.8 ± 2.5
Succinic acid	0.5	4.1 ± 1.8	5.1 ± 1.7	2.5±0.4	12.6±3.7	12.0±3.3	9.8±2.9
	1.0	4.2±1.8	5.0±1.8	2.5±0.4	12.5±4.0	10.8±3.1	9.4±2.7
	2.0	4.1±1.5	5.6±2.3	2.7±0.5	10.5±3.8	13.4±2.8	9.3±3.3
Control		4.2±1.3	4.9±1.4	2.1±0.5	8.1±2.4	8.3±1.7	4.5±2.0

Source: developed by the authors

Seedling height of the studied species on the 40th day after sowing ranged from 2.1 cm (control sample of *Cercis siliquastrum* "Alba") to 6.2 cm (*Cercis canadensis* L. "K" treated with "Radifarm" at 2.5 ml/l). Seedling height measurements were conducted after growth cessation, five months after the initial assessment. At the end of the growth period, seedling height varied between 4.5 cm (control, *Cercis siliquastrum* "Alba") and 13.4 cm (*Cercis canadensis* L. "K" treated with succinic acid at 2 g/L). The growth increment data are presented in Table 4.

Table 4. *Dynamics of changes in the mean shoot increment of seedlings from the genus Cercis L.*

Preparation	Concentration, ml/l (g/l)	Seedling increments					
		Absolute (Δh), cm			Relative, %		
		C. canadensis L. "F"	*C. canadensis* L. "K"	*C. siliquastrum* "Alba"	*C. canadensis* L. "F"	*C. canadensis* L. "K"	*C. siliquastrum* "Alba"
Radifarm	2.5	6.9	3	4.9	150	48	188
	5.0	7.8	4.1	3.4	166	69	136

***Table 4.** Continued*

Preparation	Concentration, ml/l (g/l)	Seedling increments					
		Absolute (Δh), cm			Relative, %		
		C. canadensis L. "F"	*C. canadensis* L. "K"	*C. siliquastrum* "Alba"	*C. canadensis* L. "F"	*C. canadensis* L. "K"	*C. siliquastrum* "Alba"
Radifarm	10.0	5.0	3.9	2.5	86	68	109
Megafol	2.5	3.5	7.4	5.7	76	119	248
	5.0	3.1	3.6	4.8	66	61	192
	10.0	2.5	4.5	3.7	43	79	161
Alga 600	1.25	5.6	6.6	6.5	130	138	232
	2.5	5.7	6.8	5.5	133	119	212
	5.0	6.0	5.3	5.8	130	91	193
Succinic acid	0.5	8.5	6.2	7.3	207	122	292
	1.0	8.3	5.8	6.9	198	116	276
	2.0	6.4	7.8	6.6	156	139	244
Control		3.9	3.4	2.4	93	69	114

Source: developed by the authors

The data presented in Table 4 allow for a comparison of changes in seedling height between the initial measurement and the end of the growth period. Over five months, seedling increments ranged from 2.4 cm (control sample, *Cercis siliquastrum* "Alba") to 8.5 cm (succinic acid, 0.5 g/L, *Cercis canadensis* L. "F"). However, given that seedlings had varying initial heights, those with identical absolute increments may exhibit differing relative values. Calculating the relative increment provides insight into the change in seedling height relative to their initial value. Figure 6 illustrates the dynamics of seedling height. The best-performing seedlings were those of *Cercis siliquastrum* "Alba", with the smallest height increase observed in samples treated with "Radifarm" at 10 ml/l (109%), and the largest in those treated with succinic acid at 0.5 g/L (292%). The relative height change in the control sample was 114%, representing the second-lowest increment for this cultivar (Fig. 3).

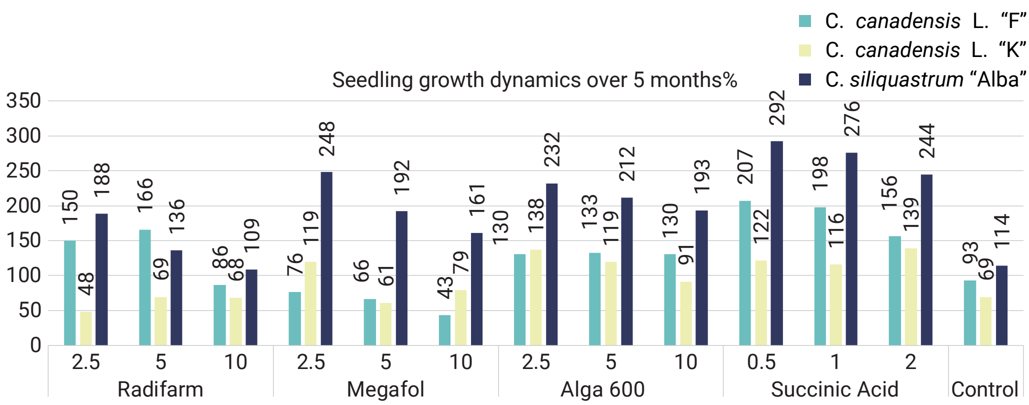

***Figure 3.** The effect of tested preparation concentrations on the dynamics of height changes in seedlings of the studied plant taxa*

Source: developed by the authors

Among *Cercis canadensis* L. "F" seedlings, the variability in height change ranged from 43% (for the preparation "Megafol" at a concentration of 10 ml/l) to 207% (for succinic acid at a concentration of 0.5 g/L). The dynamics of height increment in *Cercis canadensis* L. "K" seedlings varied from 48% (for "Radifarm", 2.5 ml/l) to 139% (for succinic acid, 2 g/L). In summary, it can be concluded that both the preparations and their concentrations significantly influence growth and development.

During the experiments, it was established that regular irrigation adversely affects the growth and development of seedlings of the studied genus. In particular, triple irrigation with fine-dispersed nozzles, with each irrigation lasting 5 minutes and a water flow rate of 2 l/h, leads to waterlogging of the root system and suppression of seedling development, eventually resulting in their complete mortality (Fig. 4).

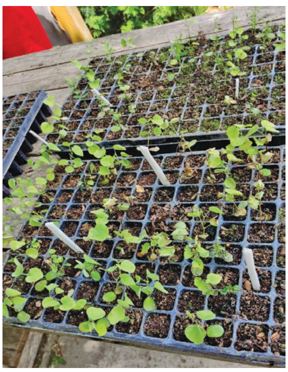

Figure 4. *The process of root system waterlogging and seedling mortality*
Source: authors' photo

During the experiment, a decision was made to extend the seed evaluation period from 14 to 30 days. This was justified, firstly, by the absence of the studied genus in the ISTA methodology; therefore, it was decided to conduct the research in accordance with the germination testing method for *Robinia pseudoacacia* L. Secondly, the germination rate on the 14th day exhibited high variability: from 4% for *Cercis siliquastrum* "Alba" (2023 harvest) to 94% for *Cercis canadensis* L. (2021 harvest). Seed germination was also influenced by the sprouting method, as seeds germinated according to the filter paper method (fP) demonstrated higher germination rates compared to those germinated between filter paper layers (bF). Germination rates ranged from 68% (bF) to 94% (fP) for *Cercis canadensis* L. and from 26% (bF) to 76% (fP) for *Cercis siliquastrum* "Alba". Additionally, during seed germination, the release of secondary metabolites on the filter paper was observed (Fig. 5). The results of laboratory germination are presented in Table 5.

Figure 5. *Isolation of secondary metabolites from C. canadensis L. (2023)*
Source: authors' photo

Table 5. *The effect of pre-sowing treatment and germination methods on the germination capacity of Cercis L.*

Harvest year (germination method)	Species, cultivar	Germination energy (7 days), %	Germination capacity (14 days), %	Germination capacity (30 days), %
2021 (on paper)	*C. canadensis* L. "F"	66 ± 6.2	94 ± 3.1	94 ± 3.1
	C. *canadensis* L. "K"	42 ± 5.5	68 ± 4.2	74 ± 4.5
	C. *siliquastrum* "Alba"	0	12 ± 2.5	76 ± 3.6
2023 (on paper)	C. *canadensis* L. "K"	0	8 ± 2.9	20 ± 3.4
	C. *siliquastrum* "Alba"	0	4 ± 1.8	24 ± 4.1

Table 5. *Continued*

Harvest year (germination method)	Species, cultivar	Germination energy (7 days), %	Germination capacity (14 days), %	Germination capacity (30 days), %
2021 (between paper layers)	*C. canadensis* L. "F"	20 ± 2.4	58 ± 3.8	72 ± 3.3
	C. *canadensis* L. "K"	8 ± 2.1	42 ± 3.3	68 ± 3.8
	C. *siliquastrum* "Alba"	0	6 ± 2.2	26 ± 2.5

Source: developed by the authors

The conducted experiment established that seed germination efficiency is significantly influenced by pre-sowing treatment, specifically cold stratification. The effect of cold stratification duration was investigated by Greek researchers E. Pipinis *et al*. (2011). Their study aimed to determine how the germination rate of *Cercis siliquastrum* L. seeds varied under different exposure times to sulfuric acid scarification and cold stratification periods. The experimental design was as follows: seeds were treated with concentrated sulfuric acid (95-97%) for 20, 40, and 60 minutes. After scarification, the seeds underwent cold stratification at 2-4°C in moist river sand for 1, 2, 3, and 4 months. The results demonstrated that seeds subjected to neither scarification nor stratification failed to germinate. The highest germination rates (88-98%) were observed in seeds scarified for 20-60 minutes and cold-stratified for 3 months. As noted by E. Pipinis *et al*. (2011), seed germination increased to 95-97% under cold stratification conditions. Their experiments showed that germination rates rose from 31% (1-month stratification) to 94% (3-month stratification). However, extending the stratification period beyond 3 months led to a decline in germination efficiency, dropping to 81% after 4 months (Table 6).

Table 6. *Basic physical and chemical parameters of raw materials (n = 4)*

H_2SO_4 scarification (min)	Stratification (2-4°C) (months)	Germination, %
20	2	31.0 ± 5.03
	3	94.0 ± 5.16
	4	81.0 ± 6.0
40	2	38.0 ± 4.0
	3	88.0 ± 5.66
	4	68.0 ± 5.66
60	2	65.0 ± 6.0
	3	98.0 ± 2.31
	4	59.0 ± 5.03

Source: developed by the authors based on E. Pipinis *et al*. (2011)

Research on the generative propagation of plants from the genus *Cercis* L. has been conducted by a number of foreign scientists. The influence of various groups of phytohormones on the germination of *Cercis siliquastrum* L. seeds was studied by M. Grbić *et al*. (2014), a group of researchers from Serbia. The essence of their research lay in examining the effect of gibberellic acid in combination with cold stratification of seeds, as well as the ability of gibberellic acid to break seed dormancy and enhance overall germination rates.

As a result of their studies, P. Profumo *et al*. (1979) and O. Babyn *et al*. (2024) asserted that gibberellic acid has a significant impact on the germination of *Cercis siliquastrum* L. seeds.

However, they did not recommend simultaneously combining gibberellic acid treatment with cold stratification, explaining that gibberellic acid at 4°C does not exhibit its physiologically active properties. The findings of E. Pipinis *et al.* (2011) align with the data of J.L. Frett & M.A. Dirr (1979). According to the latter, unscarified seeds did not absorb moisture or germinate due to the presence of a hard seed coat (Orozco-Almanza *et al.*, 2003). The restrictive effect of a hard seed coat on germination has also been studied in several species of the Leguminosae family (Demel, 1996).

Additionally, scarified but non-stratified seeds also failed to germinate, indicating the presence of endogenous dormancy in the seeds. As noted by R. Martinuzzi *et al.* (1985), endogenous seed dormancy may be linked to the presence of ferulic acid in the endosperm, which limits oxygen availability to the embryo. G.H. Gebre & N.S. Karam (2004) recommended an optimal cold stratification period of 16 weeks for mechanically scarified seeds. According to the study by E. Pipinis *et al.* (2011), the duration of cold stratification could be reduced to three months if preceded by acid scarification. The authors suggested that this reduction might be due to differences in seed scarification methods, as also mentioned by L.S. Rosner *et al.* (2003), or to variations in the degree of endogenous dormancy in seeds of the same species under different habitat conditions (Anderson & Milberg, 1998). It is also worth noting that J.L. Tipton (1992) observed in their research that seeds of *Cercis canadensis* var. mexicana also failed to germinate without scarification and cold stratification.

M. Zencirkıran *et al.* (2010) reported a positive effect of three different seed scarification methods: mechanical, acid immersion, or hot water treatment. In their study, the authors used seed soaking in concentrated H_2SO_4 for 30 minutes, followed by cold stratification for 8 weeks at 1-5°C. Under these conditions, they achieved approximately 85% seed germination. As noted by N.Y. Liu *et al.* (1981), acid treatment of seeds yields slightly better and more stable results.

Among domestic researchers, L.A. Koldar (2003) also studied seed propagation of plants from the genus *Cercis* L. In her work, she described the influence of seedling pricking-out timing on morphometric parameters and the survival rate of *Cercis* L. seedlings. The author noted that seeds of the studied genus exhibit "hard-seededness", which negatively affects germination vigour. For this reason, she conducted pricking-out in three stages: 05.06, 15.06, and 25.06.2003. Her research data indicate a direct correlation between pricking-out timing and seedling morphometric parameters, such as seedling height, stem thickness at the root collar, and crown diameter.

Thus, the research results demonstrate that the germination efficiency of *Cercis* L. seeds depends not only on the degree of physical and physiological embryo dormancy but also on germination conditions and pre-sowing seed treatment. By ensuring optimal germination conditions and pre-sowing preparation, high-quality planting material of Cercis L. plants obtained through generative propagation can be achieved.

Conclusions

Based on the research results, a positive effect of cold stratification for 4 months at +4°C, followed by seed scarification with boiling water ($t = 100$°C), has been established. Seeds subjected to artificial stratification under the above scheme maintained high laboratory germination rates (70-90%) compared to seeds undergoing natural stratification (20-30%).

Experimental studies confirmed that the tested growth stimulants influence seed germination and subsequent seedling development compared to the control sample. The optimal concentrations of growth stimulants were as follows: "Radifarm" – 2.5 ml/l; "Megafol" – 5.0 ml/l; "Succinic acid" – 1 g/L; Alga 600 – 1.25 g/L. Notably, the control sample exhibited higher germination rates, but the subsequent morphometric parameters of seedlings treated with growth stimulants were superior to those of the control. It was observed that "Succinic Acid" at all tested concentrations and Megafol at 2.5 ml/l had the best effect on the morphometric parameters of *Cercis siliquastrum* "Alba" seedlings. Seedlings increased in height by 2.44 to 2.92 times compared to initial measurements. "Radifarm" at 5.0 ml/l and "Succinic Acid" at 0.5 g/L positively influenced the development of *Cercis canadensis* L. "F" seedlings.

It was established that substrate waterlogging negatively affects the development of *Cercis* L. plants. With triple watering (2 L/h for 5 min), seedling root systems became waterlogged, leading to complete loss of planting material. During laboratory germination tests, it was found that germination efficiency depends on the seed germination method. Higher germination rates were achieved when germinating *Cercis* L. seeds on filter paper, following the methodology for determining *Robinia pseudoacacia* L. germination. Further research will focus on studying the influence of biochemical processes and growth stimulants on morphometric parameters and the growth intensity of planting material.

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Conflict of Interest

None.

References

[1] Anderson, L., & Milberg, P. (1998). Variation in seed dormancy among mother plants, populations and years of seed collection. *Seed Science Research*, 8, 29-38. doi: 10.1017/S0960258500003883.

[2] Babyn, O., Pinchuk, A., Derii, A., Boyko, O., & Likhanov, A. (2024). Influence of urban environment factors on morphometric parameters and accumulation of secondary metabolites in *Cercis canadensis* L. and *Cercis siliquastrum* "Alba". *Ukrainian Journal of Forest and Wood Science*, 15(1), 8-24. doi: 10.31548/forest/1.2024.08.

[3] Bewley, J.D., & Black, M. (1985). *Seed: Physiology of development and germination*. Heidelberg: Springer Science+Business Media.

[4] Chattha, F.A., Kousar, S., Naeem, F., & Ahmad, S. (2025). Connotation of plant growth regulators on seed germination. *Journal of Experimental Agriculture International*, 47(1), 343-356. doi: 10.9734/jeai/2025/v47i13236.

[5] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text

[6] Demel, T. (1996). Germination ecology of twelve indigenous and eight exotic multipurpose leguminous species from Ethiopia. *Forest Ecology and Management*, 80, 209-223. doi: 10.1016/0378-1127(95)03616-4.

[7] Fernandez, H., Doumas, P., & Bonnet-Masimbert, M. (1997). Quantification of GA_1, GA_3, GA_4, GA_7, GA_8, GA_9, GA_{19} and GA_{20}; and GA_{20} metabolism in dormant and nondormant beechnuts. *Plant Growth Regulation*, 22(1), 29-35. doi: 10.1023/A:1005814926549.

[8] Frett, J.L., & Dirr, M.A. (1979). Scarification and stratification requirements for seed of *Cercis canadensis* L. (redbud), *Cladrastis lutea* (Michx. f.) C. Koch (yellowwood), and *Gymnocladus dioicus* (L.) C. Koch (Kentucky coffee tree). *Plant Propagator*, 25(2), 4-6.

[9] Garg, F.C. (2024). Role of microorganisms in seed germination. In *New perspectives on seed germination*. IntechOpen. doi: 10.5772/intechopen.1006270.

[10] Gebre, G.H., & Karam, N.S. (2004). Germination of *Cercis siliquastrum* seeds in response to gibberellic acid and stratification. *Seed Science and Technology*, 32(1), 255-260. doi: 10.15258/sst.2004.32.1.29.

[11] Grbić, M., Skočajić, D., Đukić, M., Đunisijević-Bojović, D., Obratov-Petković, D., & Bjedov, I. (2014). Breaking of Judas tree seed dormancy by plant hormone treatments. *Glasnik Šumarskog Fakulteta*, 109, 73-84. doi: 10.2298/GSF1409073G.

[12] International Seed Testing Association. (2025). *International rules for seed testing*. Bassersdorf: International Seed Testing Association. doi: 10.15258/istarules.2025.F.

[13] Koldar, L.A. (2003). Features of ornamental planting material formation of Cercis species by transplanting. *Introduction of Plants*, 1-2, 113-116.

[14] Liu, N.Y., Khatamian, H., & Freta, T.A. (1981). Seed coat structure of three woody legume species after chemical and physical treatments to increase seed germination. *Journal of the American Society for Horticultural Science*, 106(5), 691-694. doi: 10.21273/JASHS.106.5.691.

[15] Martinuzzi, R., Gastaldo, P., Profumo, P., & Riggio Bevilacqua, L. (1985). Bound ferulic acid in the endosperm of *Cercis siliquastrum* L. *Plant Science*, 38(1), 41-46. doi: 10.1016/0168-9452(85)90077-9.

[16] Müller, K., Tintelnot, S., & Leubner-Metzger, G. (2006). Endosperm-limited *Brassicaceae* seed germination: Abscisic acid inhibits embryo-induced endosperm weakening of *Lepidium sativum* (cress) and endosperm rupture of cress and *Arabidopsis thaliana*. *Plant and Cell Physiology*, 47(6), 864-877. doi: 10.1093/pcp/pcj059.

[17] Nimavat, N., & Parikh, P. (2024). Innovations in Date palm (*Phoenix dactylifera* L.) micropropagation: detailed review of in vitro culture methods and plant growth regulator applications. *Plant Cell, Tissue and Organ Culture*, 159, article number 6. doi: 10.1007/s11240-024-02866-7.

[18] Orozco-Almanza, M.S., Leon-Garcia, L.P., Grether, R., & Garcia-Moya, E. (2003). Germination of four species of the genus *Mimosa* (*Leguminosae*) in a semi-arid zone of Central Mexico. *Journal of Arid Environments*, 55, 75-92. doi: 10.1016/S0140-1963(02)00265-3.

[19] Pieraccini, R., Whatley, L., Koedam, N., Vanreusel, A., Dolch, T., Dierick, J., & Van der Stocken, T. (2025). Gibberellic acid and light effects on seed germination in the seagrass *Zostera marina*. *Physiologia Plantarum*, 177(2), article number e70137. doi: 10.1111/ppl.70137.

[20] Pipinis, E., Milios, E., Smiris, P., & Gioumousidis, C. (2011). Effect of acid scarification and cold moist stratification on the germination of *Cercis siliquastrum* L. seeds. *Turkish Journal of Agriculture and Forestry*, 35(3), 259-264. doi: 10.3906/tar-1003-848.

[21] Profumo, P., Gastaldo, P., & Martinuzzi, R. (1979). On the inhibiting action of the endosperm on the seed germination of *Cercis siliquastrum*. *Experientia*, 35(11), 1452-1453. doi: 10.1007/BF01962777.

[22] Rosner, L.S., Harrington, J.T., Dreesen, D.R., & Murray, L. (2003). Sulfuric acid scarification of wax currant seeds from New Mexico. *Native Plants Journal*, 4, 65-71. doi: 10.3368/npj.4.1.65.

[23] Szymajda, M., & Maciorowski, R. (2025). Seed preparation methods for increasing the germination of sour cherry (*Prunus cerasus* L.). *Forests,* 16(3), article number 516. doi: 10.3390/f16030516.

[24] Tipton, J. L. (1992). Requirements for seed germination of Mexican redbud, evergreen sumac, and mealy sage. *HortScience,* 27, 313-316.

[25] Wang, X., Kubenka, K., Hilton, A., Chatwin, W., Cox, T., & Shu, S. (2025). The effects of freezing and stratification on pecan (*Carya illinoinensis*) seed germination and seedling growth. *Technology in Horticulture,* 5, article number e002. doi: 10.48130/tihort-0024-0030.

[26] Zencirkıran, M., Tümsavaş, Z., & Ünal, H. (2010). The effects of different acid treatment and stratification duration on germination of *Cercis siliquastrum* L. seeds. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca,* 38(1), 159-163.

[27] Zhou, R., Boboev, M., Kurbonova, P., Li, W.J., & Lu, T. (2025). Seed germination of the medicinal plant *Ferula gigantea*. *Seed Science and Technology,* 53(1), 17-21. doi: 10.15258/sst.2025.53.1.03.

Особливості генеративного розмноження рослин роду *Cercis* L.

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Анотація. Проблема складного пророщування насіння *Cercis* L., зумовлена його фізіологічним і фізичним станом спокою, потребує удосконалення методів генеративного розмноження з використанням стимуляторів росту. В даній статті розглядався вплив органо-мінеральних стимуляторів росту на ефективність проростання насіння дослідних видів, а також подальший вплив на морфометричні показники сіянців. Ґрунтова схожість визначалась шляхом прямого підрахунку схожого насіння, а лабораторна схожість визначалась згідно методики визначення посівних якостей насіння International Seed Testing Association (ISTA). Статистична обробка даних проводилась за допомогою MS Excel (однофакторний дисперсійний аналіз ANOVA та Standard Deviation) У результаті проведених досліджень виявлено статистично значущий вплив апробованих препаратів на ефективність проростання насіння. Встановлено, що найкращий вплив на схожість насіння *Cercis siliquastrum* 'Alba' має «Бурштинова кислота» в концентрації 1 г/л. Позитивний вплив на проростання насіння *Cercis canadensis* L. мали препарати «Megafol» в концентрації 5,0 мл/л (схожість варіювалась в межах 70-77 %), а також «Альга 600» в концентрації 1,25 г/л (схожість варіювалась в межах 50-70 %). Окрім цього дослідним шляхом встановлено, що сіянці, насіння яких було оброблено стимуляторами росту мали вищі показники приростів, ніж контрольний зразок. При обробці насіння препаратом «Бурштинова кислота» сіянці *Cercis siliquastrum* 'Alba' збільшились в 2,5-2,9 рази. Динаміка приростів сіянців *Cercis canadensis* L., насіння яких оброблене препаратом «Бурштинова кислота» збільшились майже вдвічі. Вплив препарату «Radifarm» в концентрації 5,0 мл/л на динаміку сіянців *Cercis canadensis* L. проявився у збільшенні висоти в майже в 1,6 рази

Ключові слова: насіннєве розмноження; іудине дерево; сіянці; стимулятори росту; схожість