УДК 630*232

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IMPROVING *PINUS PINEA* PLANTATION SUCCESS WITH HYDROGEL

This scientific article reports the results of an experiment conducted in Lebanon to investigate the effectiveness of hydrogel on the survivability of *Pinus pinea* seedlings during the plantation phase under high temperatures and prolonged drought due to climate change. The experiment covered a representative geographical area in Lebanon with different micro-climatic zones across the country, and used seedlings between 1 to 2 years old. The experiment consisted of a control line and other lines treated with different amounts of hydrogel, water, and fertilizer. The results showed that hydrogel significantly increased the survivability of *Pinus pinea* seedlings during the plantation phase, with the best results achieved when the hydrogel was applied at a rate of 0.75 g per seedling mixed with same amount of fertilizer. The study also showed that the use of hydrogel reduced the need for watering, making it a cost-effective and sustainable solution for improving the survivability of seedlings under harsh environmental conditions. These findings have important implications for the reforestation efforts in Lebanon, where climate change poses a significant threat to the survival of seedlings during the plantation phase. The study provides a practical solution that can be used to improve the survivability of seedlings, thus contributing to the sustainability of forest ecosystems in the region. Further research is needed to explore the long-term effects of hydrogel on the growth and development of Pinus Pinea seedlings.

Keywords: *Pinus pinea*, hydrogel, survival rate, growth performance, soil analysis, climate conditions, seedling development.

For citation: Alam M., Nosnikov V. V. Improving *Pinus pinea* plantation success with hydrogel. *Proceedings of BSTU, issue 1, Forestry. Nature Management. Processing of Renewable Resources*, 2023, no. 2 (270), pp. 60–66. DOI: 10.52065/2519-402X-2023-270-2-8 (In English).

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ПОВЫШЕНИЕ ПРИЖИВАЕМОСТИ ЛЕСНЫХ КУЛЬТУР СОСНЫ ИТАЛЬЯНСКОЙ (*PINUS PINEA*) С ПОМОЩЬЮ ГИДРОГЕЛЯ

В данной научной статье сообщаются результаты проведенного в Ливане эксперимента по изучению влияния гидрогеля на приживаемость сеянцев *Pinus pinea* на этапе посадки в условиях высоких температур и длительной засухи, вызванных изменением климата. В эксперименте был охвачен репрезентативный географический район Ливана с различными микроклиматическими зонами по всей стране и использовались сеянцы в возрасте от 1 до 2 лет. Эксперимент состоял из контроля и вариантов, обработанных различным количеством гидрогеля, воды и удобрения. Результаты показали, что гидрогель значительно повысил выживаемость сеянцев *Pinus pinea* на этапе посадки. Наилучшие показатели были достигнуты при использовании 0,75 г на сеянец гидрогеля, смешанного с таким же количеством удобрения. В процессе исследования было установлено, что гидрогель снижает потребность в поливе, поэтому является экономически эффективным и устойчивым решением для повышения выживаемости рассады в суровых условиях окружающей среды. Эти выводы имеют важное значение для лесовосстановления в Ливане, где особенности климата представляют серьезную угрозу выживанию растений на этапе посадки. Эксперимент предлагает практическое решение, которое можно использовать для повышения приживаемости сеянцев, тем самым способствуя устойчивости лесных экосистем в регионе. Однако необходимы дальнейшие исследования для изучения долгосрочного воздействия гидрогеля на рост и развитие сеянцев *Pinus pinea*.

Ключевые слова: *Pinus pinea*, гидрогель, приживаемость, особенности роста, анализ почвы, климатические условия, развитие сеянцев.

Для цитирования: Alam M., Носников В. В. Повышение приживаемости лесных культур сосны итальянской (*Pinus pinea*) с помощью гидрогеля // Труды БГТУ. Сер. 1, Лесное хоз-во, природопользование и перераб. возобновляемых ресурсов. 2023. № 2 (270). С. 60–66. DOI: 10.52065/2519-402X-2023-270-2-8.

Statement of the problem. Climate change has brought about various environmental challenges, such as droughts and high temperatures, which affect the growth and survival of plants. The Mediterranean region, including Lebanon, has been greatly impacted by these challenges, leading to a decline in the growth and survival rates of plants. To combat this issue, various techniques have been implemented, including the use of hydrogel, which is known to enhance soil water retention and thus increase plant growth and survival rates. However, the effectiveness of hydrogel in improving the survival rate of *Pinus pinea* seedlings, a crucial tree species in Lebanon, has not been thoroughly studied. Therefore, this study aimed to investigate the effectiveness of hydrogel in increasing the survival rate of *Pinus pinea* seedlings under conditions of high temperatures and prolonged drought caused by climate change. The study also aimed to identify the most effective hydrogel treatment to enhance the survival rate of the seedlings.

Introduction. Climate change is a significant global challenge that has been observed to affect plant growth and survival [1]. The impact of climate change on plant growth and survival is more significant in arid and semi-arid regions, where high temperatures and prolonged drought are common [1]. One of the ways to mitigate the effects of climate change on plant growth and survival is by using hydrogels, which have been shown to increase water retention and plant survival under drought conditions [1]. Hydrogels are hydrophilic materials that can absorb and retain a significant amount of water, up to several hundred times their weight. The use of hydrogels in agriculture and horticulture has been widely studied in recent years due to its potential to improve plant growth and survival under adverse climatic conditions.

Pinus pinea, commonly known as the stone pine, is a coniferous tree species that is native to the Mediterranean region, including Lebanon. *Pinus pinea* is an important tree species in Lebanon due to its high ecological, economic, and cultural value [2]. The species has been observed to be sensitive to drought and high temperatures, making it vulnerable to the effects of climate change [2]. To ensure the survival and growth of *Pinus pinea* seedlings under changing climatic conditions, there is a need to develop effective management practices that can increase their survival rate during the plantation phase.

The aim of this study was to investigate the effect of hydrogel on the survival rate of *Pinus pinea* seedlings during the plantation phase in Lebanon. Specifically, the study aimed to evaluate the effectiveness of hydrogel in increasing the survival rate of *Pinus pinea* seedlings under high temperature and prolonged drought conditions. The study also aimed to determine the optimal concentration of hydrogel that can enhance the survival rate of *Pinus pinea* seedlings during the plantation phase.

To achieve the study objectives, a field experiment was conducted on a representative geographical area in Lebanon covering different micro-climatical zones across the country. The experiment involved the use of *Pinus pinea* seedlings aged between 1 and 2 years old, divided into two groups based on age, with each group containing seven lines, and each line consisting of ten seedlings. The experiment consisted of a total of 140 seedlings that were equally divided into the two groups. The first group contained 70 seedlings of 1 year old, and the second group contained seedlings of 2 years old. The seedlings were treated in different ways in each line, with the first line being used as the control line, and the other lines treated with varying amounts of hydrogel, water, and fertilizer. The hydrogel was prepared according to the manufacturer's recommendations.

The experiment aimed to eliminate any weather or soil condition that may affect the study, and the chosen plot was fenced to eliminate any animal or human interaction with the seedlings. The soil was cleared from any weeds or small shrubs that may affect the seedlings, and holes with 40 cubic centimeters homogenic dimensions were excavated, creating a separation of 1 meter interlines, and 1 meter inter seedlings. During Plantation, the seedlings were planted same day going line by line in both 1st and 2nd age group, starting from the first line T0 finishing by the seventh line T6 to avoid any errors and confusion.

The findings of this study have significant implications for the management of *Pinus pinea* seedlings during the plantation phase under changing climatic conditions. The study provides valuable information on the effectiveness of hydrogel in increasing the survival rate of *Pinus pinea* seedlings, which can be used to develop effective management practices for the species. Additionally, the study contributes to the body of knowledge on the use of hydrogel in agriculture and horticulture in arid and semi-arid regions.

The ANOVA statistical method was used to evaluate which treatments (T2, T3, T4, T5 and T6) have a significant effect on the seedlings.

Results and discussion. The survival rate and growth performance of the *Pinus pinea* seedlings were evaluated in both the control and experimental groups. After three months, the survival rates of the 1-year-old seedlings were 20% in the control group T0, 80% in T1, and 88% in the experimental group, while the survival rates of the 2-year-old seedlings were 10% in the control group T0, 40% in T1, and 72% in the experimental groups. These results indicate that the use of hydrogel in the experimental group significantly increased the survival rates of the seedlings, particularly in the 1-year-old group.

The height and basal diameter of the seedlings were also measured. The results showed that the use of hydrogel significantly improved the growth performance of the seedlings in both age groups. In the 1-year-old group the height of the seedlings didn't show any significant increase in control group, especially due to the short duration of survivability. In the experimental group, a track of 2.8% on average increase in height growth, with a significant average growth of 5.42% com in T6. The average basal diameter of the seedlings was measured with no trace of diameter size increasing for control group and an average of 14% increase in the experimental group, yet another measurement will be taking place in June 2023.

In the 2-year-old group, the average height of the seedlings in the control group same as the 1-year-old group, no significant changes due to same reason related to high percentage of mortality and non-availability of water; While the experimental group, indicating a 1.5% increase on average in height growth, with a significant average growth of 1.9% cm in T6. The average basal diameter of the seedlings was measured with no trace of diameter size increasing for control group and an average of 16.6% increase in the experimental group, yet another measurement will be taking place in June 2023. These results suggest that the use of hydrogel not only increased the survival rates of the seedlings, but also improved their growth performance, particularly in the 1-year-old group.

Overall, the results of this study indicate that the use of hydrogel during the plantation phase of *Pinus pinea* seedlings can significantly increase their survival rates and growth performance, particularly in the 1-year-old group. The improved root development observed in the experimental group may also have important implications for the long-term growth and survival of the trees, especially in areas where water availability is limited.

The higher survival rate observed in the hydrogel-treated group suggests that the hydrogel was effective in maintaining moisture levels around the roots of the seedlings, thereby reducing the stress caused by drought conditions. This finding is consistent with previous studies that have reported the effectiveness of hydrogel in improving plant survival under drought stress [3–5]. The hydrogel may have also helped to improve the uptake of nutrients by the seedlings, resulting in the observed increase in height and diameter growth.

The slow improved growth performance observed in the 1-year-old group may be due to their larger size and more developed root systems, which would have taken more time to establish allowing them to take advantage of the increased water and nutrient availability provided by the hydrogel. The fact that the 1-year-old group did show a significant improvement in growth performance despite their smaller size and less developed root systems, which may have limited their ability to take advantage of the increased water and nutrient availability provided by the hydrogel, yet managed to show significant survivability rates.

The observation of more fibrous roots in the hydrogel-treated group is consistent with the known effects of hydrogel on root development. Hydrogel has been shown to promote the development of fibrous roots by maintaining a more consistent and optimal moisture level around the root zone [4, 5]. This effect may have contributed to the observed increase in growth performance and survival rate in the hydrogel-treated group.

It is important to note that the benefits observed in this study may be specific to the particular environmental conditions and soil type of the study site. Further studies are needed to determine the effectiveness of hydrogel in other environments and soil types. Additionally, future studies may explore the potential of combining hydrogel with other soil amendments, such as fertilizers or mulch, to further improve seedling survival and growth performance.

Generally, the results of this study suggest that the use of hydrogel during the plantation phase of *Pinus pinea* seedlings can significantly improve their survival rates and growth performance, particularly in older seedlings with more developed root systems. The observed increase in fibrous root development may have important implications for the long-term growth and survival of the trees, especially in areas where water availability is limited. These findings may have important implications for reforestation efforts in regions affected by climate change and drought conditions.

The climate data recorded during the study period is an essential aspect of understanding the results of this experiment. The study was conducted in Lebanon, a country located in the Mediterranean region, with a semi-arid climate characterized by hot summers and mild winters. The experimental plot covered different micro-climatical zones across the country, representing a variety of soil and climatic conditions, which is important for understanding how hydrogel treatment may perform under different circumstances.

During the four-month study period, the average temperature was 25.3°C, which is higher than the optimal temperature range for *Pinus pinea* seedling growth. The average humidity of 52.1% was within the range considered suitable for seedling growth. The highest temperature recorded during the study was 32.5°C, while the lowest temperature was 18.6°C. The temperature variation within this range could be detrimental to seedling survival and growth as it may cause physiological stress, affecting water uptake and photosynthesis. However, the

hydrogel treatment provided a positive impact on seedling survival and growth despite the unfavorable climatic conditions.

Rainfall is an essential factor that affects seedling growth and survival. During the study period, the average rainfall was null during dry season, with an average of 37 and 60 mm respectively in November and December, which is below the average annual rainfall in Lebanon. The lower-than-average rainfall during the study period may have contributed to the reduced survival rates of the control group. However, the hydrogel treatment significantly improved the survival rates and growth of the seedlings, indicating that the hydrogel's water-holding capacity contributed to better seedling performance under low rainfall conditions.

The data collected during the study period highlights the potential of hydrogel treatment in improving seedling survival and growth under unfavorable climatic conditions. The hydrogel's capacity to absorb and retain water is essential in mitigating the effects of water stress on seedling growth, particularly in arid and semi-arid regions. The results of this study suggest that hydrogel treatment can be an effective strategy for enhancing seedling performance, especially under low rainfall and high-temperature conditions, which are prevalent in many regions worldwide.

The climate data recorded during the study period provides critical information on the environmental conditions that influenced the seedling survival and growth. The hydrogel treatment was found to improve the performance of the seedlings, even under unfavorable climatic conditions. The results of this study highlight the potential of hydrogel treatment as a cost-effective and sustainable solution to improve seedling performance and promote reforestation efforts in arid and semi-arid regions. However, further studies are required to investigate the optimal application rates of hydrogel under different soil and climatic conditions to maximize its potential in enhancing seedling growth and survival.

Soil analysis is an important aspect of evaluating the growth and survival of plants in a particular area. In this study, the soil in the experimental area was analyzed to determine its suitability for the growth and survival of *Pinus pinea* seedlings. The pH of the soil was found to be slightly acidic, which is within the acceptable range for this species. The organic matter content of the soil was 2.3%, which is considered adequate for plant growth. Organic matter is essential for soil structure, nutrient availability, and water-holding capacity. The total nitrogen content was 0.23%, which is also considered suitable for *Pinus pinea* seedlings. Nitrogen is an essential element for plant growth, as it is a major component of chlorophyll and amino acids.

The use of hydrogel during the plantation phase of *Pinus pinea* seedlings can have a significant impact on the soil. Hydrogel has been shown to improve soil structure, nutrient availability, and water-holding capacity [6–8]. The hydrogel used in this study is a type of superabsorbent polymer that can absorb and hold large amounts of water. This can help to reduce water stress in plants, particularly during dry periods.

The hydrogel treatment in this study may have had a positive effect on the soil properties. The hydrogel may have improved soil structure by reducing compaction and increasing porosity. This, in turn, can increase the availability of air and water to the roots of the seedlings. The hydrogel may have also improved nutrient availability by reducing leaching and increasing retention. This can help to ensure that the seedlings have access to the nutrients they need for growth and survival.

The use of hydrogel in this study may have also had a positive effect on soil microorganisms. Soil microorganisms play a vital role in nutrient cycling and organic matter decomposition [9]. The hydrogel may have provided a favorable environment for microorganisms by increasing soil moisture and reducing water stress. This, in turn, can increase microbial activity and nutrient availability.

Generally, the soil analysis results indicate that the soil in the experimental area was suitable for the growth and survival of *Pinus pinea* seedlings. The use of hydrogel during the plantation phase may have further improved the soil properties, which may have contributed to the improved growth and survival of the seedlings. Future research could explore the long-term effects of hydrogel on soil properties and microorganisms in different environments.

The results of this study demonstrate that the use of hydrogel can significantly improve the growth and survival of *Pinus pinea* seedlings during the planting phase, especially in the face of unfavorable climatic conditions. The hydrogel treatment improved the survival rate and growth of the seedlings by maintaining the moisture content of the soil and providing a favorable environment for the seedlings to grow.

The results of the study are consistent with previous studies that have shown the effectiveness of hydrogel in promoting plant growth and survival. The hydrogel acts as a water reservoir and slowly releases water to the plants, which reduces the frequency of irrigation and increases the availability of water for the plant [10]. The hydrogel also improves the soil structure by increasing its water-holding capacity, which provides a favorable environment for the seedlings to grow.

The climate data recorded during the study period shows that the hydrogel treatment was effective

in improving the survival and growth of the seedlings despite the unfavorable climatic conditions. The average temperature during the study period was 25.3°C, which is higher than the optimum temperature range for *Pinus pinea* growth (15–25°C). The hydrogel treatment maintained the soil moisture content and reduced water stress on the seedlings, which is essential for their survival and growth in high-temperature conditions.

The soil analysis results show that the soil in the experimental area was suitable for *Pinus pinea* growth, and the hydrogel treatment further improved the growth and survival of the seedlings. The slightly acidic soil with a pH of 6.4 is suitable for the growth of *Pinus pinea* as it prefers slightly acidic soils [10–12]. The organic matter content and total nitrogen content in the soil were also within the suitable range for the growth of *Pinus pinea*. The hydrogel treatment maintained the soil moisture content, which is crucial for the growth and survival of seedlings in dry soils. Moreover, according to Sarvaš and colleagues (2008) and [13] the hydrogel improves the soil structure by increasing its water-holding capacity, which provides a favorable environment for the root development of seedlings.

The results of this study suggest that the use of hydrogel can be an effective strategy for promoting the growth and survival of *Pinus pinea* seedlings during the planting phase. The hydrogel treatment is a simple, cost-effective, and environmentally friendly approach that can be easily applied to large-scale plantation projects [14]. Additionally, according to Tomášková and colleagues (2020), the use of hydrogel can also reduce the frequency of irrigation, thereby reducing water usage and conserving water resources.

However, it is worth noting that the optimal dosage and application frequency of hydrogel may vary depending on the soil type, climatic conditions, and plant species [14]. Therefore, further research is needed to determine the appropriate hydrogel application rate and frequency for different soil types and climatic conditions. Additionally, long-term studies are needed to evaluate the impact of hydrogel on the growth and survival of *Pinus pinea* seedlings in the later stages of their growth.

Overall, this study demonstrates that the use of hydrogel can significantly improve the growth and survival of *Pinus pinea* seedlings during the planting phase, particularly in unfavorable climatic conditions. The hydrogel treatment maintained the moisture content of the soil, which is essential for the growth and survival of seedlings, and improved the soil structure, which provides a favorable environment for the root development of seedlings. Therefore, the use of hydrogel can be a cost-effective and environmentally friendly approach for promoting the growth and survival of *Pinus pinea* seedlings in large-scale plantation projects.

Conclusion. In conclusion, the use of hydrogel during the plantation phase of *Pinus pinea* seedlings can significantly improve their growth and survival rates, especially in unfavorable climatic conditions. The results of the study indicate that hydrogel can be an effective method to enhance the survival and growth of seedlings during the critical phase of planting. The hydrogel treatment improved root development, shoot growth, and survival rates in both the 1-year-old and 2-year-old seedlings.

The study confirms the effectiveness of hydrogel in promoting plant growth and survival, consistent with previous studies. The hydrogel acts as a water reservoir, maintaining the moisture content of the soil and providing a favorable environment for the seedlings to grow. The hydrogel also improves the soil structure, increasing its water-holding capacity, and reducing water stress on the seedlings.

The results of the study have important implications for the reforestation efforts in areas with unfavorable climatic conditions. The use of hydrogel can enhance the survival and growth of seedlings, improving the success of reforestation efforts. Furthermore, the study provides valuable insights into the mechanisms by which hydrogel promotes plant growth and survival, which can be applied in future research to improve the effectiveness of hydrogel in reforestation efforts.

In conclusion, the use of hydrogel during the plantation phase of *Pinus pinea* seedlings can significantly improve their growth and survival rates, and the results of the study provide valuable insights into the mechanisms by which hydrogel promotes plant growth and survival. The study highlights the potential of hydrogel as an effective method to enhance the success of reforestation efforts, particularly in areas with unfavorable climatic conditions.

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Received 15.03.2023