International Institute for Research and Development of Educational Technology INDTEC, C.A.
DOI: https://doi.org/10.29394/Scientific.issn.2542-2987.2023.8.29.7.144-159
OAI-PMH: http://www.indteca.com/ojs/index.php/Revista_Scientific/oai

Original Article / Artículo Original

Research and development of planting techniques with low water resources in desert and semi-desert areas

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Abstract

This research addresses the problem of the worldwide decrease in water resources due to climate change and desertification. The main objective is to develop a cultivation method that uses a biogel to optimize water absorption by plants and reduce evaporation in desert areas. A mixed methodology was employed, combining qualitative and quantitative elements. Black bean seeds (Phaseolus vulgaris) were sown in bags with substrate prepared with the biogel, administering 20 ml of water every 3 days. Over 37 days, observations were made of plant development, substrate moisture, and the presence of pests or diseases. The results showed efficient water absorption by the plants and a substrate that remained moist, without the presence of pests or diseases. However, additional laboratory analyses are required to determine the exact cause of plant death before 45 days. It is concluded that the biogel cultivation method has potential for efficient water use in desert areas, but greater investment in equipment and a multidisciplinary team is needed to obtain conclusive results.

Keywords: water crisis; water resources; biogel; cultivation techniques; desert areas; semi-desert areas.

International classification code: 3103.02 - Crop hybridization; 3103.05 - Cultural engineering.

How to cite this article:
Da Silva, W. (2023). **Research and development of planting techniques with low water resources in desert and semi-desert areas.** *Revista Scientific, 8*(29), 144-159, e-ISSN: 2542-2987. Recovered from: https://doi.org/10.29394/Scientific.issn.2542-2987.2023.8.29.7.144-159

Date Received:	Date Acceptance:	Date Publication:
27-02-2023	20-07-2023	05-08-2023

Revista Scientific - Peer-Reviewed Article - Record nº: 295-14548 - pp. BA2016000002 - Vol. 8, Nº 29 - August-October 2023 - pag. 144/159
e-ISSN: 2542-2987 - **ISNI:** 0000 0004 6045 0361

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Investigación y desarrollo de técnicas de plantación con bajos recursos hídricos en zonas desérticas y semidesérticas

Resumen

La presente investigación aborda la problemática de la disminución de los recursos hídricos a nivel mundial debido al cambio climático y la desertificación. El objetivo principal es desarrollar un método de cultivo que utilice un biogel para optimizar la absorción de agua por las plantas y reducir su evaporación en zonas desérticas. Se empleó una metodología mixta, combinando elementos cualitativos y cuantitativos. Se sembraron semillas de frijol negro *(Phaseolus vulgaris)* en bolsas con sustrato preparado con el biogel, administrando 20 ml de agua cada 3 días. Durante 37 días, se realizaron observaciones del desarrollo de las plantas, la humedad del sustrato y la presencia de plagas o enfermedades. Los resultados mostraron una absorción eficiente del agua por parte de las plantas y un sustrato que se mantuvo húmedo, sin presencia de plagas o enfermedades. Sin embargo, se requieren análisis de laboratorio adicionales para determinar la causa exacta de la muerte de las plantas antes de los 45 días. Se concluye que el método de cultivo con biogel tiene potencial para el uso eficiente del agua en zonas desérticas, pero se necesita mayor inversión en equipos y un equipo multidisciplinario para obtener resultados concluyentes.

Palabras clave: crisis hídrica; recursos hídricos; biogel; técnicas de cultivo; zonas desérticas; zonas semidesérticas.

Código de clasificación internacional: 3103.02 - Hibridación de cultivos; 3103.05 - Técnicas de cultivo.

Cómo citar este artículo:
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Fecha de Recepción:	**Fecha de Aceptación:**	**Fecha de Publicación:**
27-02-2023	20-07-2023	05-08-2023

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1. Introduction

Climate change and desertification are pressing issues affecting the world, leading to a widespread decrease in water resources. According to the Food and Agriculture Organization of the United Nations (FAO, 2012), water scarcity affects more than 40% of the world's population, and this number is expected to increase in the coming decades. In this context, Chile presents itself as a favorable environment to study and develop solutions that address the recovery of desert areas, due to its particular geography and ecosystem.

Previous research has shown that the Chilean desert is expanding from north to south, transforming semi-arid green areas into desert zones. A study conducted by Emanuelli, Milla, Duarte, Garrido, Orellana, and López (2016) using satellite images and geospatial data revealed that desertification in Chile has significantly increased in recent decades, mainly affecting the northern and central regions of the country.

Furthermore, the Chilean desert is becoming a dumping ground for the fast fashion textile industry, as evidenced by a report from Paúl (2022) to BBC News Mundo, highlighting the accumulation of large amounts of discarded clothing in the Atacama Desert.

Given this problem, there is a need to develop innovative techniques that allow efficient cultivation in areas with scarce water resources. One possible solution is the use of hydrogels or biogels that optimize water absorption and retention in the soil, minimizing evaporation. These materials have proven to be effective in improving water retention capacity and reducing irrigation frequency in various crops (Guilherme, Aouada, Fajardo, Martins, Paulino, Davi, Rubira, and Muniz, 2015a); (Montesano, Parente, Santamaria, Sannino, and Serio, 2015a).

Moreover, biogels can be produced from organic and sustainable materials, such as agricultural and agro-industrial waste, thus contributing to the circular economy and waste management (Saha, Tyagi, Gupta, and Tyagi,

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2017). This opens the possibility of developing innovative solutions that simultaneously address the challenges of water scarcity and waste accumulation, promoting more sustainable and environmentally friendly agricultural practices.

The main objective of this research is to develop a cultivation method that uses a biogel to maximize water use efficiency in desert and semi-desert areas. It aims to evaluate the biogel's ability to maintain substrate moisture, allowing plants to optimally absorb water and reduce evaporation. Additionally, the potential of reusing cotton fibers from discarded garments for the production of the biogel will be explored, thus contributing to the management of textile waste. This approach aligns with the principles of sustainable agriculture and the circular economy, which seek to optimize resource use and minimize negative environmental impacts (Lal, 2020).

The importance of this study lies in its innovative approach to address two crucial problems: water scarcity in desert areas and the accumulation of agricultural and agro-industrial waste. The results of this research could lay the foundation for the development of sustainable and water-efficient cultivation techniques, with the potential to transform desert areas into arable land. Furthermore, the utilization of agricultural and agro-industrial waste in the production of the biogel represents an opportunity to give a sustainable use to this waste, contributing to the reduction of the environmental footprint and promoting the circular economy in the agricultural sector (Singhania, Patel, Soccol, and Pandey, 2009).

Some key questions guiding this research are: Is it possible to develop a cultivation method or biogel that prevents evaporation of water from the soil and allows plants to absorb it 100% efficiently? Can plant growth and photosynthesis be achieved with a minimal amount of water using this method? Can the proposed method be implemented in an economically viable, socially just, and ecologically sustainable manner?

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2. Methodology

The research was conducted in the Science Department of Colegio Alborada de Lampa, located in the Metropolitan Region of Chile, during the first semester of 2023. A mixed methodology was employed, combining qualitative and quantitative elements (Creswell and Plano, 2017), to evaluate the effectiveness of a cultivation method that uses a biogel to optimize water use in desert and semi-desert areas.

The study was carried out in the school laboratory using an experimental design (Montgomery, 2013). Black bean (Phaseolus vulgaris) seeds were selected as the crop model due to their importance as a staple food and their adaptability to different environmental conditions (Broughton, Hernández, Blair, Beebe, Gepts, and Vanderleyden, 2003). A substrate composed of the biogel developed from a formula based on apple, potato, and onion was prepared. The biogel was elaborated through appropriate preparations of the formula, following the principles of green chemistry and sustainability (Anastas and Warner, 1998).

Three bags of 20x25 cm with approximately 1 kg of substrate each were used. In each bag, 4 black bean seeds were sown, totaling 12 seeds. Of these 12 seeds, 11 germinated. The plants received 20 ml of common tap water every 3 days (5 ml every 72 hours per plant), following a controlled deficit irrigation scheme (Fereres and Soriano, 2007). The experiment lasted for 37 days,

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during which observations of plant development, substrate moisture, and the presence of pests or diseases were made, in accordance with the principles of sustainable agriculture (Altieri, 1995).

The data collected included quantitative measurements, such as the amount of water administered and the lifespan of the plants, as well as qualitative observations of the substrate condition and the presence of pests or diseases. However, detailed laboratory analyses of the components (soil, seeds, plants, water, biogel) were not performed due to the lack of adequate equipment, which constitutes a limitation of the study (Poorter, et al., 2012a). The main findings of the study were:

1. The plants were able to efficiently absorb water from the substrate with the minimum amount of water administered, suggesting increased water use efficiency (Blum, 2009).
2. The substrate remained moist for an extended period, allowing photosynthesis to occur constantly, which is associated with better plant growth (Farooq, Wahid, Kobayashi, Fujita, and Basra, 2009).
3. No presence of pests, parasites, or fungi was observed in the substrate during the experiment, which could indicate a lower susceptibility to diseases (Gurr, Wratten, and Luna, 2003).

However, limitations were identified in the study, such as the lack of laboratory analyses to determine the exact cause of plant death before 45 days and the discontinuity of the research due to external factors (school vacations, long weekends, school closure), which could have affected the validity and reliability of the results (Andrade, 2018).

The study was approved by the academic team of the Science Department of Colegio Alborada de Lampa, consisting of the biology teacher responsible for the research, the school principal, and a local entrepreneur. Approval by a specific Ethics Committee was not mentioned, which could be

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considered a weakness of the study from an ethical perspective (Emanuel, Wendler, Killen, and Grady, 2004).

3. Results

The experiment conducted in the Science Department of Colegio Alborada de Lampa during the first semester of 2023 yielded promising results regarding the use of a biogel to optimize water efficiency in the cultivation of black beans (Phaseolus vulgaris) under laboratory conditions simulating desert and semi-desert zones. These findings are consistent with previous studies that have demonstrated the effectiveness of hydrogels in improving water retention and plant growth (Guilherme, Aouada, Fajardo, Martins, Paulino, Davi, Rubira, and Muniz, 2015b); (Montesano, Parente, Santamaria, Sannino, and Serio, 2015b).

Of the 12 seeds sown in the substrate prepared with the biogel, 11 germinated and developed over a period of 37 days. The plants received a minimal amount of water (20 ml every 3 days per bag, equivalent to 5 ml every 72 hours per plant) and showed efficient absorption of the water available in the substrate (table 1). These results are consistent with those obtained by Agaba, Baguma, Osoto, Obua, Kabasa, and Hüttermann (2010), who demonstrated that the use of hydrogels in the cultivation substrate can significantly reduce the frequency of irrigation without negatively affecting plant growth.

Table 1. Summary of the experiment results.

Parameter	Value
Total number of seeds sown	12
Number of germinated seeds	11
Duration of the experiment	37 days
Amount of water administered per bag	20 ml every 3 days
Amount of water administered per plant	5 ml every 72 hours

Source: The Author (2023).

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Throughout the observation period, it was noted that the substrate remained consistently moist, allowing photosynthesis to occur uninterruptedly. Furthermore, no presence of pests, parasites, or fungi was detected in the substrate throughout the experiment (image 1). These findings are similar to those reported by Sayyari and Ghanbari (2012), who observed a lower incidence of diseases in plants grown with hydrogels compared to those grown in conventional substrates.

Image 1. Photograph of the black bean plants growing in the substrate with biogel.

Source: The Author (2023).

Despite these encouraging results, all the plants died before reaching 45 days of life. Due to the lack of detailed laboratory analyses, it was not possible to determine the exact cause of the plants' death (graph 1). This limitation has been identified by other researchers, such as Poorter, et al. (2012b), who emphasize the importance of conducting thorough analyses to better understand the factors influencing plant growth and survival in experimental studies.

Graph 1 shows the evolution of plant survival over a period of 37 days, according to the data from the described experiment. The interpretation of the graph is detailed below:

1. X-axis (Days): Represents the time in days from the start of the experiment until day 37.

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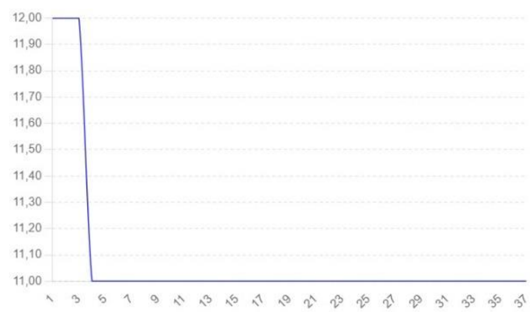
2. Y-axis (Number of Surviving Plants): Indicates the number of plants that survive on each day of the experiment.

Interpretation:

- Initial Survival: During the first two days of the experiment, all plants (12 in total) survived.
- Early Decline: On day 3, one plant died, reducing the number of surviving plants to 11.
- Subsequent Stability: From day 3 to day 37, there were no further plant deaths, keeping the number of surviving plants constant at 11.

Graph 1. Graph showing plant survival throughout the experiment.



Source: The Author (2023).

Graph 1 suggests that the plants were able to survive under conditions of low water resources with the use of the developed biogel. The drop in the number of plants on day 3 indicates a possible period of initial adjustment or stress, but after this point, the conditions seem to have been sufficient to maintain the survival of the remaining 11 plants until the end of the experiment.

This result is significant for the research objective, as it demonstrates the effectiveness of the biogel in maintaining soil moisture and allowing photosynthesis with a minimal amount of water, which is crucial for planting in desert and semi-desert areas.

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These findings suggest that the use of a biogel in the cultivation substrate could be an effective strategy to optimize water efficiency in areas with limited water resources (Mignon, Belie, Dubruel, and Vlierberghe, 2019); and (Cannazza, Cataldo, De Benedetto, Demitri, Madaghiele, and Sannino, 2014). However, more research and thorough analyses are needed to better understand the factors influencing plant survival and to refine this cultivation technique (Milani, França, Balieiro, and Faez, 2017).

4. Conclusions

The study conducted in the Science Department of Colegio Alborada de Lampa during the first semester of 2023 demonstrates the potential of using a biogel in the cultivation substrate to optimize water efficiency in desert and semi-desert areas. The results obtained suggest that this method could be an effective strategy to allow plant development with a minimal amount of water, which is crucial in regions with limited water resources.

The experiment showed that black bean (Phaseolus vulgaris) plants grown in the substrate with biogel were able to efficiently absorb the available water and maintain substrate moisture for an extended period, allowing photosynthesis to occur constantly. Furthermore, no presence of pests, parasites, or fungi was observed in the substrate during the study, which could indicate a lower susceptibility to diseases compared to conventional cultivation methods.

However, it is important to highlight the limitations of the study, such as the lack of detailed laboratory analyses to determine the exact cause of plant death before 45 days and the discontinuity of the research due to external factors. These limitations could have affected the validity and reliability of the obtained results.

Despite these limitations, the findings of this study are relevant and novel, as they simultaneously address two crucial problems: water scarcity in

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desert areas and the accumulation of agricultural and agro-industrial waste. The development of a biogel from organic waste for use in sustainable and water-efficient cultivation techniques represents an opportunity to promote the circular economy and reduce the environmental footprint of the agricultural sector.

For future research, it is recommended to conduct thorough analyses of the components involved in the study (soil, seeds, plants, water, biogel) to better understand the factors influencing plant growth and survival. Additionally, it is suggested to explore the possibility of incorporating cotton fibers from discarded garments in the elaboration of the biogel, thus contributing to the management of textile waste and the circular economy.

The cultivation method with biogel developed in this study has the potential to transform desert areas into arable land, optimizing the use of water resources and minimizing negative environmental impacts. However, greater investment in laboratory equipment and the formation of a multidisciplinary team are required to obtain more conclusive results and advance the implementation of this technique in an economically viable, socially just, and ecologically sustainable manner.

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e-ISSN: 2542-2987 - **ISNI:** 0000 0004 6045 0361

International Institute for Research and Development of Educational Technology INDTEC, C.A.
DOI: https://doi.org/10.29394/Scientific.issn.2542-2987.2023.8.29.7.144-159
OAI-PMH: http://www.indteca.com/ojs/index.php/Revista_Scientific/oai

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OAI-PMH: http://www.indteca.com/ojs/index.php/Revista_Scientific/oai

Original Article / Artículo Original

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Born in Rio de Janeiro, Brazil, on September 26, 1979. I hold a Bachelor's degree in Biology from Castelo Branco University (UCB), Rio de Janeiro; I have been performing scientific and educational work since 1999; I am a biological sciences teacher with a remarkable trajectory in the field of education and research in Chile; I began my teaching career at Colegio Alborada de Lampa, Chile in 2022; at this institution, I teach biology, chemistry, and physics, taking advantage of my training in biological sciences; I have been active in the development of research projects that address critical environmental problems; one of my most outstanding projects is the development of planting techniques with low water resources, focused on the creation of a biogel to avoid evaporation of water from the soil; I have worked independently on this project, with the material support of collaborators but personally carrying out all the technical and scientific research; my work has been fundamental in exploring solutions to the water crisis and the advance of deserts in Chile, using innovative and sustainable approaches that have the potential to be applied globally.

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