ЛЕСОВОССТАНОВЛЕНИЕ И ЛЕСОРАЗВЕДЕНИЕ
FOREST REGENERATION AND FOREST GROWING

УДК 630*232.216

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FEATURES OF MOISTURE RETENTION IN SOIL USING A WETTING AGENT FOR FOREST RESTORATION PURPOSES IN LEBANON

This study delves into the pivotal role of wetting agents in bolstering soil moisture retention capabilities, a critical factor for enhancing reforestation efforts in Lebanon's arid and semi-arid regions. Amid escalating climate change impacts, characterized by rising temperatures and dwindling precipitation levels, Lebanon's reforestation initiatives face significant challenges. This research provides a comprehensive analysis of various wetting agents' effectiveness in improving soil water retention, aiming to mitigate drought stress on newly planted seedlings. Through rigorous laboratory experiments and field trials, we evaluated the impact of different concentrations of wetting agents on soil moisture dynamics under controlled and natural conditions. The findings reveal that specific wetting agent formulations significantly increase soil's moisture holding capacity, thereby reducing irrigation frequency and enhancing seedling survivability and growth. This study not only identifies the optimal wetting agent concentrations for maximum soil moisture enhancement but also offers practical recommendations for their application in reforestation projects. By integrating wetting agents into reforestation practices, this research contributes to the development of more resilient forest ecosystems in Lebanon, providing a scalable solution to combat the adverse effects of climate change on forest regeneration efforts.

Keywords: wetting agent, forest plantation, soil moisture, soil-water filtration.

For citation: Alam M., Nosnikov V. V. Features of moisture retention in soil using a wetting agent for forest restoration purposes in Lebanon. *Proceedings of BSTU, issue 1, Forestry. Nature Management. Processing of Renewable Resources*, 2024, no. 2 (282), pp. 67–75.
DOI: 10.52065/2519-402X-2024-282-8.

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ОСОБЕННОСТИ УДЕРЖАНИЯ ВЛАГИ В ПОЧВЕ С ПОМОЩЬЮ СМАЧИВАЮЩЕГО АГЕНТА ДЛЯ ЦЕЛЕЙ ЛЕСОВОССТАНОВЛЕНИЯ В ЛИВАНЕ

В этом исследовании рассматривается ключевая роль смачивающих агентов в повышении способности почвы удерживать влагу, что является критическим фактором для активизации усилий по восстановлению лесов в засушливых и полузасушливых регионах Ливана. На фоне нарастающих последствий изменения климата, характеризующегося повышением температуры и уменьшением количества осадков, мероприятия Ливана по восстановлению лесов сталкиваются со значительными проблемами. Данное исследование представляет собой анализ эффективности различных смачивающих агентов с целью улучшения удержания влаги в почве для смягчения стресса от засухи у недавно высаженных сеянцев. С помощью лабораторных экспериментов и полевых испытаний мы оценили влияние различных концентраций смачивающих агентов на динамику влажности почвы в контролируемых и естественных условиях. Результаты показывают, что специальные составы смачивающих агентов значительно увеличивают влагоудерживающую способность почвы, тем самым снижая частоту поливов и повышая выживаемость и рост саженцев. Данное исследование не только определяет оптимальные концентрации смачивателей для максимального повышения влагоудерживающей способности почвы, но и предлагает практические рекомендации по их применению в проектах лесовосстановления. Внедрение смачивающих агентов в практику лесовосстановления способствует развитию более устойчивых лесных экосистем в Ливане, обеспечивая эффективное решение для борьбы с неблагоприятными последствиями изменения климата.

Ключевые слова: смачиватель, лесные насаждения, влажность почвы, фильтрация воды.

Для цитирования: Алам М., Носников В. В. Особенности удержания влаги в почве с помощью смачивающего агента для целей лесовосстановления в Ливане // Труды БГТУ. Сер. 1, Лесное хоз-во, природопользование и перераб. возобновляемых ресурсов. 2024. № 2 (282). С. 67–75 (На англ.). DOI: 10.52065/2519-402X-2024-282-8.

Introduction. Lebanon's forests are in a critical state, grappling with a myriad of environmental challenges that are intensified by climate change. These include severe droughts, rising temperatures, and substantial soil degradation, all of which significantly threaten the survival and growth of both native and reforested plant species. Such adverse conditions are particularly problematic for Lebanon's ambitious reforestation and afforestation initiatives, which aim to combat land degradation and restore forest cover [1]. The efficiency of traditional reforestation techniques is notably diminished in arid environments, prompting the need for innovative approaches to soil moisture management. These approaches are essential to improve seedling survivability and growth. This study seeks to address the research gap concerning the use of wetting agents – a type of substance aimed at enhancing water infiltration and retention in soils – as a viable method to improve soil moisture content in areas undergoing reforestation. Although wetting agents have proven beneficial in agricultural and horticultural applications for improving water use efficiency, their potential benefits for reforestation efforts in semi-arid environments like Lebanon have not been fully explored. Through evaluating the efficacy of various wetting agents in improving soil moisture retention, this research aims to provide valuable insights into sustainable reforestation practices that can better withstand the impacts of climate change. This work aspires to deliver practical guidelines for the optimal selection and application of wetting agents in reforestation projects, thereby significantly reducing water stress on young trees and enhancing the success rates of reforestation in Lebanon and other Mediterranean ecosystems [2, 3].

The forests of Lebanon, once a symbol of greenery and natural wealth, have been facing unprecedented challenges over the past decades. Climate change, characterized by rising temperatures and decreasing precipitation, has exacerbated the vulnerability of these ecosystems to drought, contributing to the degradation of soil quality and the decline in forest cover [1]. This environmental crisis poses a significant threat not only to the biodiversity of Lebanon but also to its socio-economic stability, as forests play a crucial role in water regulation, carbon sequestration, and the provision of livelihoods for local communities.

Historically, Lebanon was famed for its lush cedar forests, which have not only been a source of national pride but also of significant ecological importance. However, relentless human activities, including deforestation for agriculture, urban expansion, and overgrazing, compounded by natural disasters such as wildfires, have led to a drastic reduction in forested areas. From the Phoenician era, where cedars were exported for shipbuilding, to the present day, Lebanon's forests have decreased to a fraction of their original extent [2–7]. It is estimated that the backwoods covers only around 13% of Lebanon's total surface [8].

Recent studies in the 21st century have highlighted the significant impact of climatic changes and habitat loss on biodiversity [9, 10]. These changes are increasingly affecting woodland and forest ecosystems [11–17]. Notably, there has been a significant decline in dieback numbers and growth rates, which have been associated with seasonal and extreme variations in climate, including reduced precipitation and increased temperatures over prolonged periods [13, 14, 17, 18]. This decline is evident across various studies [10–12, 16, 19–22].

In response to these challenges, Lebanon has launched several reforestation initiatives aimed at restoring its green cover. Despite these efforts, the success rates of these initiatives have been limited by the harsh climatic conditions, underscoring the need for innovative approaches to ensure the survival and growth of newly planted seedlings [3]. Among the strategies being explored is the use of wetting agents, substances known to improve water infiltration and retention in the soil. These agents offer a promising solution to enhance soil moisture content, potentially increasing the efficacy of reforestation efforts in arid and semi-arid environments like Lebanon's.

This study aims to investigate the potential of wetting agents in mitigating the effects of soil moisture deficiency on reforestation success. By improving our understanding of how these substances can be effectively applied in the context of Lebanon's reforestation projects, we hope to contribute valuable insights towards sustainable forest management and conservation practices. In doing so, we not only aim to restore Lebanon's forested landscapes but also to enhance their resilience against the ongoing challenges posed by climate change.

Main part. In this study, we delve into the investigation of the efficacy of wetting agents in enhancing water retention capacity across five distinct soil compositions, each representing a unique substrate type. Soil 1, characterized as heavy loam, typically exhibits high water retention due to its fine texture and organic matter content. Through the application of wetting agents, we aim to assess whether this inherent water-holding capacity can be further optimized for improved seedling growth and survival. Soil 2, identified as light loam, and Soil 4, another variant of light loam, offer contrasting characteristics, with varying degrees of water retention potential. By incorporating wetting agents into these soil types, we seek to determine their effectiveness in mitigating potential water stress and promoting favorable conditions for seedling establishment. In contrast, Soil 3, composed of sand, presents inherent challenges in water retention due to its coarse texture and rapid drainage properties. Our investigation focuses on evaluating the capacity of wetting agents to enhance moisture retention in this substrate, potentially mitigating the adverse effects of water scarcity on seedling growth. Soil 5, categorized as medium loam, provides an intermediate substrate with moderate water retention capabilities. Through our experimentation with wetting agents in this soil type, we aim to elucidate whether additional amendments can further optimize moisture levels, thereby facilitating optimal conditions for seedling development. By systematically evaluating the impact of wetting agents across these diverse soil compositions, we aspire to uncover valuable insights into their role in enhancing water retention capacity and ultimately fostering resilient vegetation in various environmental contexts.

In conducting the experiment, we adopted a method where the soil samples were placed in tubes with volumes varying between 50 to 100 ml. Although a full range from 0 to 100 ml would ideally provide a more extensive data set, for efficiency, the range was limited to 50 to 100 ml. Upon initializing the experiment, water was evenly distributed atop the soil to maintain a constant height of 1 cm above the soil surface. This setup aimed to simulate a consistent rainfall event, allowing us to monitor the soil's absorption rate and water movement through the profile. Critical to our methodology was the recording of the time and volume of water required for the water level to reach the designated 100 ml mark in the tube, signifying the initiation of filtration through the soil. Subsequent to reaching this milestone, additional water was added as needed to sustain the 1 cm water level above the soil, continuing until the first droplet of water exited the tube, marking the commencement of drainage. This phase was monitored for an additional 10 minutes to measure the volume of water that effectively permeated the soil and was collected in the beaker below, alongside the total volume of water introduced into the system throughout the experiment.

The systematic approach to measuring both the time to reach the initial 100 ml filtration mark and the volume of water collected post-filtration provides a robust framework for evaluating the soil's water handling characteristics. These measurements offer invaluable insights into the soil types most conducive to reforestation efforts, particularly in arid and semi-arid regions where water conservation and efficient use are paramount. Our findings are poised to inform targeted reforestation practices, ensuring that seedlings receive the moisture necessary for optimal growth while minimizing water waste, thus enhancing the sustainability and success of reforestation projects under varying climatic conditions.

The results depicted in Fig. 1 illuminate the distinct water retention characteristics of various soil samples, with a particular emphasis on Soil 5's performance in the absence of any wetting agent.

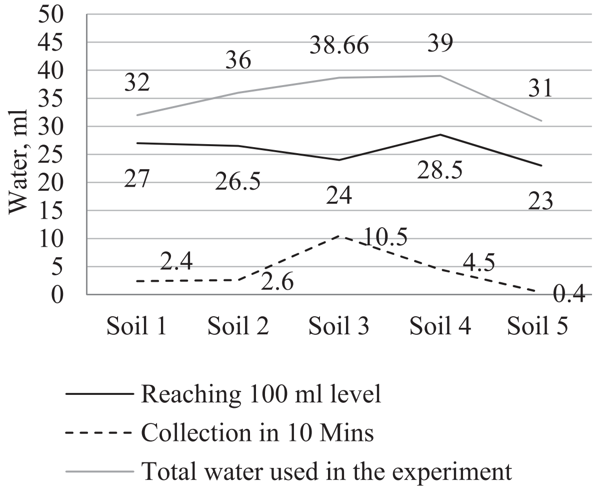

Fig. 1. Water retention and total water used with 0 g wetting agent across the 5 soils

This soil type demonstrated remarkable efficiency in water management: it necessitated only 23 ml of water to achieve a saturation level of 100 ml, underscoring its effective filtration and retention capacities. Furthermore, Soil 5 required a mere total of 31 ml of water throughout the duration of the experiment, marking it as the most water-efficient soil among those tested. This observation suggests that Soil 5 possesses an inherent capability to maintain moisture levels over extended periods, even without the assistance of wetting agents, thereby showcasing its potential suitability for reforestation projects in environments where water conservation is crucial.

Fig. 2 demonstrates that Soil 5 exhibited the lowest percentage of total water utilized during the testing phase.

Further examination, as illustrated in Fig. 3, confirms that Soil 5 also had the most minimal filtration rate among all tested soils. This evidence further solidifies the assertion that Soil 5 outperforms its counterparts in water retention and efficiency, especially in scenarios devoid of wetting agents.

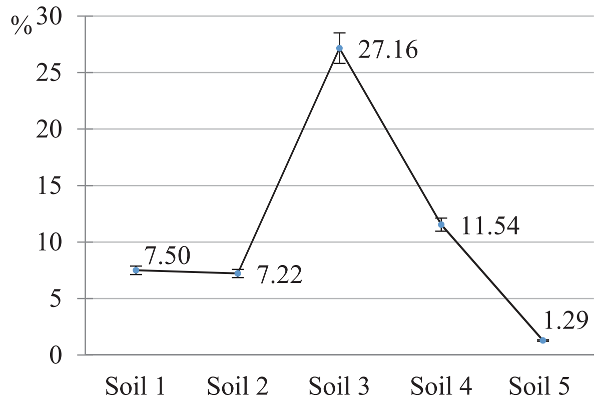

Fig. 2. Percentage of water collected during 10 min across the 5 soils with 0 g of wetting agent

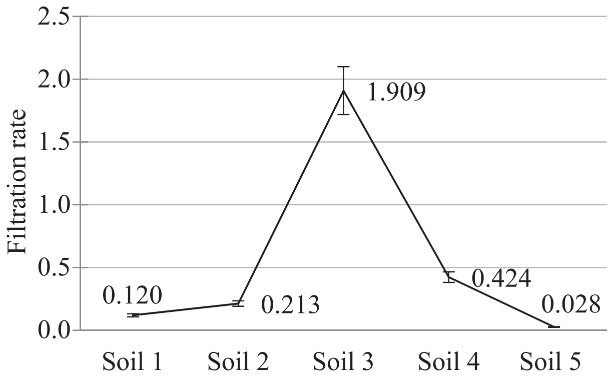

Fig. 3. Filtration rate across the 5 soils with 0 g of wetting agent

Such findings suggest Soil 5's superior adaptability and sustainability for reforestation projects aiming for water conservation in the absence of soil moisture enhancers.

In the analysis presented in Fig. 4, Soil 2 demonstrated a remarkable ability to conserve moisture when treated with 0.1 g of a wetting agent, showcasing the least moisture release over a ten-minute observation period. Although Soil 2 required 25 ml to saturate up to the 100 ml level, it was not the most water-efficient soil.

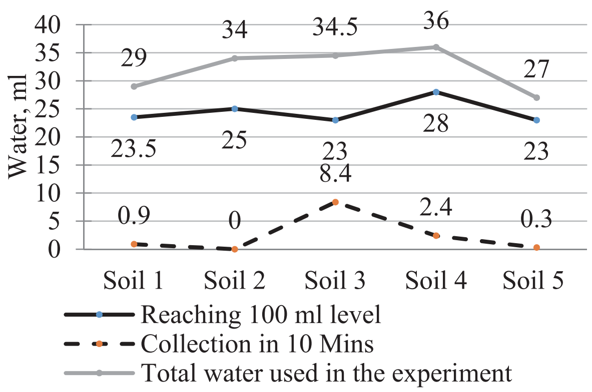

Fig. 4. Water retention and total water used with 0.1 g wetting agent across the 5 soils

This distinction went to Soil 3, which, despite using the least water to reach saturation, released the most moisture (8.4 ml) in the same duration, indicating poorer water retention capabilities.

Contrastingly, Soil 5's performance, with a modest wetting agent application of 0.1 g, was noteworthy for its overall water economy. It consumed only 27 ml in total, surpassing the efficiency of other soils under similar conditions, as depicted in Fig. 4. However, Soil 2 stood out by not releasing any moisture during the ten-minute window, utilizing 25 ml to achieve full saturation, and totaling 34 ml of water usage throughout the experiment. This pattern was further validated by Fig. 5, which highlighted Soil 2's 0% moisture yield rate.

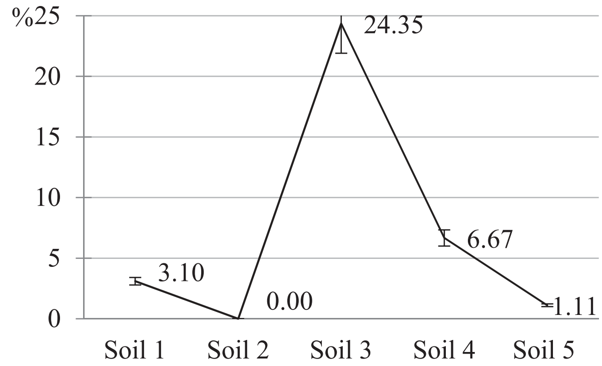

Fig. 5. Percentage of water collected during 10 min across the 5 soils with 0.1 g of wetting agent

However, Soil 2's higher initial water requirement to achieve saturation points to its suitability in scenarios where water availability is less of a concern. Conversely, in water-scarce conditions, Soil 5 emerges as a viable candidate, offering commendable performance with just 0.1 g of the wetting agent, balancing moisture retention with lower water consumption.

Fig. 6 illustrates that Soil 2 had the lowest percentage of total water consumption during the experiment.

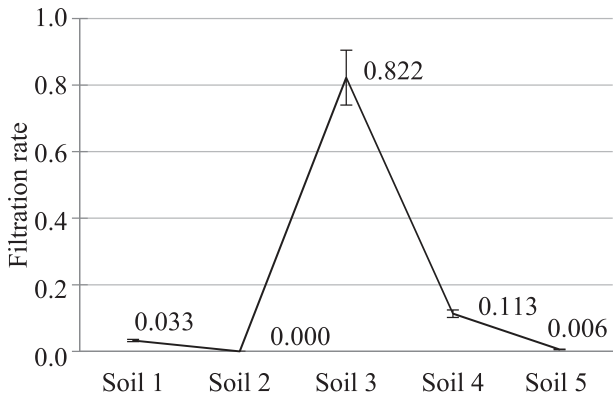

Fig. 6. Filtration rate across the 5 soils with 0.1 g of wetting agent

Fig. 7 reveals that Soil 2 also demonstrated the lowest rate of water filtration among the soils tested. This data underscores Soil 2's efficiency in water usage and its superior ability to minimize water loss, highlighting its potential as an effective medium for reforestation projects where optimal water retention is crucial. This observation further emphasizes that, when water is abundant, Soil 2 is expected to perform optimally with 0.1 g of wetting agent, surpassing the other soils tested in the experiment. Conversely, under conditions of limited water supply, Soil 5 is anticipated to exhibit commendable efficiency with the same concentration of the wetting agent. Fig. 7 provides a comparative snapshot of soil performance with a 0.2 g application of wetting agent.

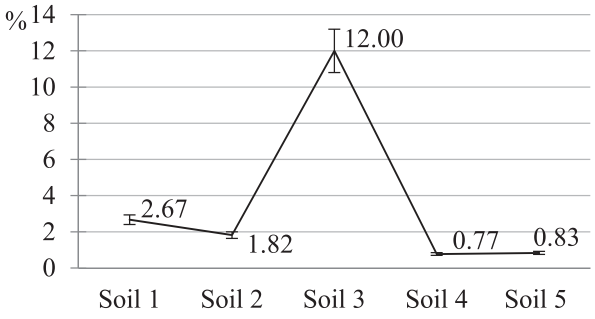

Fig. 7. Water retention and total water used with 0.2 g wetting agent across the 5 soils

Remarkably, Soil 5 released merely 0.2 ml of water over a 10-minute period, showcasing its minimal water usage throughout the experiment. However, it's notable that Soil 5 required a relatively high volume of water to achieve the 100 ml saturation point, ranking second among the soils tested in terms of water intake for saturation. Incorporating 0.2 g of wetting agent, Soil 5's efficacy surpasses that of its counterparts, as highlighted in Fig. 7. This superiority is further evidenced in Fig. 8, where Soil 5 demonstrates efficient water usage, only surpassed by Soil 4 in terms of the percentage of total water utilized throughout the experiment.

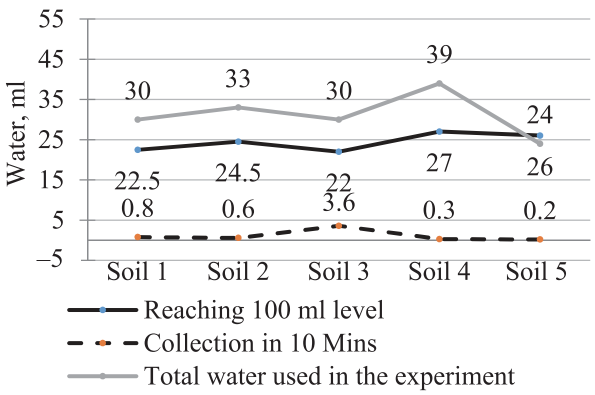

Fig. 8. Percentage of water collected during 10 min across the 5 soils with 0.2 g of wetting agent

Moreover, Fig. 8 illustrates Soil 5's optimal water consumption and its release of the second-lowest percentage of total water used, reinforcing its high performance with a 0.2 g wetting agent across all soils in the study. This consistent performance is supported by the filtration rate data in Fig. 9, where Soil 5 exhibits the second-lowest filtration rate, closely following Soil 4. These findings collectively underscore Soil 5's remarkable efficiency and potential as the most suitable soil for projects requiring a 0.2 g wetting agent, particularly in optimizing water retention and reducing wastage. The results suggest that Soil 5 demonstrates enhanced performance under conditions of water scarcity when treated with 0.2 g of wetting agent. In environments where water is more readily available, Soil 4, when similarly treated with 0.2g of the wetting agent, is expected to yield comparable outcomes.

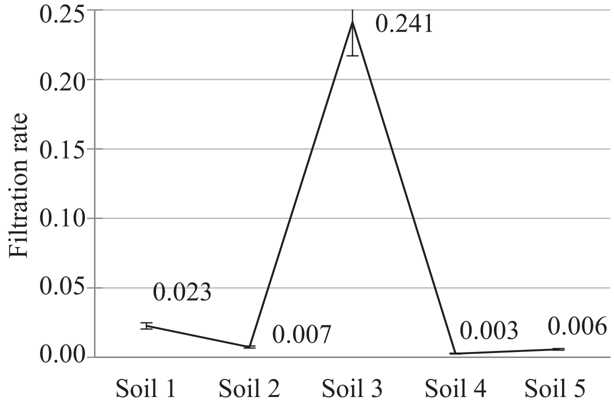

Fig. 9. Filtration rate across the 5 soils with 0.2 g of wetting agent

Fig. 10 reveals that with the application of 0.3 g wetting agent, Soil 1 is more efficient in terms of water usage, absorbing less water to become saturated and releasing only 0.1 g of water.

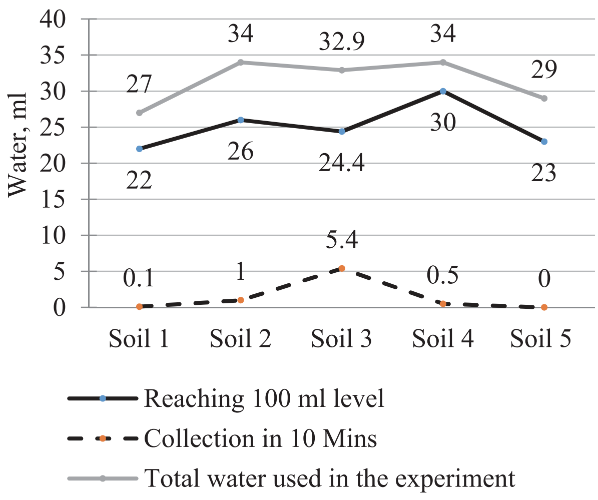

Fig. 10. Water retention and total water used with 0.3 g wetting agent across the 5 soils

Conversely, Soil 5 effectively retains moisture but demands a higher quantity of water for saturation and to reach the 100 ml threshold. Consequently, Soil 1 is more suitable in conditions of limited water supply when treated with 0.3 g of wetting agent, whereas Soil 5 is preferable in situations with ample water availability.

This distinction is further supported by the data shown in Fig. 11, which illustrates that Soil 5 used the least percentage of total water during the experiment, while Fig. 12 highlights that Soil 5 exhibits the lowest filtration rate among the soils tested.

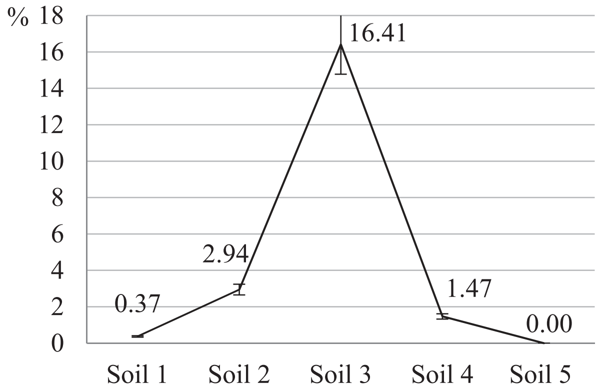

Fig. 11. Percentage of water collected during 10 min across the 5 soils with 0.3 g of wetting agent

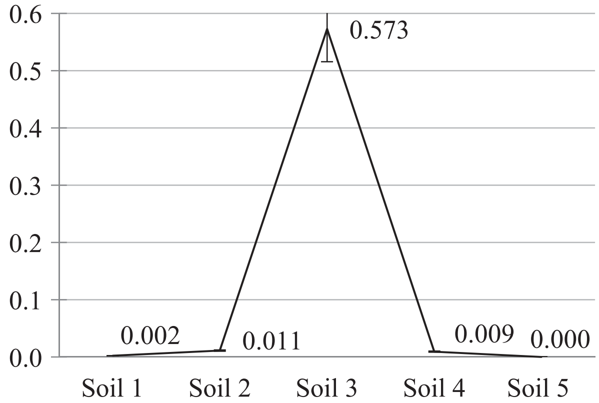

Fig. 12. Filtration rate across the 5 soils with 0.3 g of wetting agent

This evidence strengthens the argument that Soil 5, with a 0.3 g application of wetting agent, is positioned to outperform other soils in the experiment, showcasing superior water retention capabilities and efficiency.

Conclusion. In concluding the study, it is imperative to delve into a detailed analysis of the results obtained, particularly focusing on how the mechanical composition of soils impacts the water regime, the comparative efficacy of wetting agents across different soil types at the same concentration, and the effects of increasing concentration on the water regime of each soil. Through this analysis, we aim to identify the optimal concentration of wetting agents for achieving the fastest absorption of water and maximum retention across various soil compositions, thereby informing reforestation practices effectively.

Impact of Soil Mechanical Composition on Water Regime: Our study encompassed five distinct soil compositions, each representing a unique substrate type. These soils varied in their mechanical composition, influencing their water retention capacities. Soil 1, characterized as heavy loam, exhibited high water retention due to its fine texture and organic matter content. Conversely, Soil 3, composed of sand, presented challenges in water retention due to its coarse texture and rapid drainage properties.

Through experimentation, we observed that the mechanical composition of soils significantly influenced their water regime. Soils with finer textures, such as Soil 1, demonstrated higher water retention capabilities compared to coarser soils like Soil 3. This variation underscores the importance of evaluating potential problems associated with different soil types and devising appropriate solutions to ensure successful reforestation efforts. Comparative Efficacy of Wetting Agents at the Same Concentration: Our study also assessed the efficacy of wetting agents across different soil types at the same concentration. By applying a consistent concentration of wetting agent to each soil type, we aimed to evaluate their effectiveness in enhancing water retention uniformly.

Results indicated that the performance of wetting agents varied across soil types. While certain soils exhibited remarkable efficiency in water retention even without the assistance of wetting agents, others benefited significantly from their application. Soil 5, for instance, demonstrated notable water retention capabilities without a wetting agent, showcasing its inherent suitability for reforestation projects in water-scarce environments. However, the application of wetting agents further enhanced moisture retention in soils with poorer water retention capacities, such as Soil 3.

Effects of Increasing Concentration on Water Regime: Furthermore, we investigated how increasing the concentration of wetting agents affected the water regime of each soil type. By incrementally increasing the concentration of wetting agents, we aimed to discern the optimal concentration at which water absorption is expedited, and maximum retention is achieved.

Results revealed that increasing the concentration of wetting agents led to improved water retention across all soil types. However, the rate of improvement varied depending on the soil's initial water retention capacity. Soils with lower inherent water retention capabilities exhibited more significant improvements with increasing concentrations of wetting agents compared to those with higher natural retention capacities.

Conclusion on the Optimal Concentration: Based on our findings, we conclude that the optimal concentration of wetting agents for achieving the fastest absorption of water and maximum retention varies depending on the soil type. Soils with poorer water retention capacities, such as Soil 3, benefitted from higher concentrations of wetting agents, while soils with higher inherent retention capabilities, like Soil 1, required lower concentrations for optimal performance.

In summary, our study underscores the importance of considering the mechanical composition of soils, the efficacy of wetting agents at uniform concentrations, and the effects of increasing concentration on water regime when determining the best concentration for reforestation efforts. By tailoring wetting agent concentrations to specific soil types, reforestation practitioners can optimize water retention and enhance the success of reforestation initiatives across diverse environmental contexts.

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Received 15.03.2024