BIO Web of Conferences **125**, 01005 (2024) https://doi.org/10.1051/bioconf/202412501005
ABS 2024

Effect of asbestos cement contamination in irrigation water on physiological and germination parameters of *Trifolium pratense* and *Solanum lycopersicum* seeds

Gergely Zoltán Macher[1,2*], and *Dóra* Beke[3]

[1]Department of Applied Sustainability, Albert Kázmér Faculty of Agricultural and Food Sciences of Széchenyi István University in Mosonmagyaróvár, Széchenyi István University, 9026 Győr, Hungary.
[2]Wittmann Antal Crop-, Animal- and Food Sciences Multidisciplinary Doctoral School, Albert Kázmér Faculty of Agricultural and Food Sciences of Széchenyi István University in Mosonmagyaróvár, Széchenyi István University, 9200 Mosonmagyaróvár, Hungary.
[3]Department of Plant Sciences, Albert Kázmér Faculty of Agricultural and Food Sciences of Széchenyi István University in Mosonmagyaróvár, Széchenyi István University, 9200 Mosonmagyaróvár, Hungary.

Abstract. This study aims to examine the plant stress responses induced by the water transport of matrix materials from the eroded and degraded asbestos cement materials. The paper includes a general assessment of the exposure and risk factors of the plant-water-soil system to asbestos cement products. Furthermore, the results of the experimental analysis provide empirical support for the plant stress response results according to the physiological and germination parameters of the tested plants. The background to the topic is that the contamination of irrigation water by asbestos cement raises serious environmental concerns, with toxicity to plants and soil contamination potentially having negative consequences for vegetation health and soil quality. In the presence of asbestos in water, plants are exposed to toxic stress, which can inhibit photosynthesis and nutrient uptake, but can also affect germination processes. The growth, reproduction and flourishing of plants also be at risk, as asbestos has adverse effects on cell division and metabolism. In addition, environmental stress can make plants more susceptible to disease and insect attack. This paper analysed the effects of pre-set dose concentrations of irrigation water containing asbestos cement matrix on the germination and physiological parameters of *Trifolium pratense* and *Solanum lycopersicum* in a germination experiment. The research area of the paper was influenced by the lack of minimum international practice, standards, and methodology. Therefore, the used methodology provides an opportunity for methodological development. The results can be used as a situation analysis for environmental plant protection and analytical professionals.

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* Corresponding author: macher.gergely.zoltan@sze.hu

1 Introduction

Asbestos minerals are naturally forming [1] fibrous silicate minerals that have been utilized in a range of insulating, refractory, and construction materials due to their strong fibers and resistance to high temperatures [2]. Asbestos encompasses two types of fibrous minerals: amphiboles and serpentine [3]. These minerals have unique crystalline and chemical properties, as well as structures that provide flexibility, large surface area, and resistance to heat and chemical breakdown. [4]. Chrysotile, which belongs to the serpentine group and is composed of magnesium silicate, is the most prevalent form of asbestos [2, 5]. Chrysotile, also referred to as white asbestos, is the most frequently extracted mineral of asbestos and one of the most regulated serpentine minerals [4]. Chrysotile accounts for over 90% of the asbestos [6] and is also the predominant type of asbestos detected in water samples [7]. Asbestos fibers have a length of over 5 µm, a diameter of less than 3 µm, and a length-to-diameter ratio greater than 3:1 [8]. Exposure to asbestos results in conditions such as asbestosis, mesothelioma, and various forms of cancer affecting the lung, ovary, and larynx [9]. The negative impacts of asbestos were initially documented in 1906, and findings from research on the health consequences of asbestos were made public in 1928. After the 1906 disclosure, a substantial amount of evidence emerged regarding the cancer-causing properties of asbestos, which was ultimately validated by the World Health Organization (WHO) [10, 11]. Despite widespread awareness of the dangers associated with asbestos, this harmful substance still presents a significant global health threat, causing numerous deaths annually and contributing significantly to cancer mortality [12, 13]. Asbestos had numerous and diverse applications. It was widely utilized as an inexpensive raw material in manufacturing building products [14]. Cement composite with asbestos fibers has been extensively used in numerous countries globally since World War II [15], leading to the widespread popularity of asbestos cement products as a construction material. These products constitute the most commonly used forms and have contributed significantly to global asbestos production [16]. Asbestos cement sheets in both flat and corrugated forms were utilized for roofing, while pressed, flat cladding, and panels served as the facades of multi-family buildings [17]. However, asbestos cement is naturally fragile and has limited capacity to withstand impact, making it prone to cracking and breaking from minor impacts, repetitive stress, or faulty fastenings [18]. The degradation and wearing away of asbestos materials result in the dispersion of asbestos fibers into the atmosphere and water runoff, ultimately leading to indirect soil contamination [4]. Asbestos fibers can also be released through general deterioration and damage to asbestos cement materials, as well as from disasters. These incidents may lead to temporary increases in airborne fibers, necessitating complex control measures and costly remediation efforts. In certain instances, the long-term contamination of land with asbestos fragments and fiber bundles persists [9]. Research conducted by Spurny [19] indicated that the surface of an asbestos cement slate slab may be exposed to corrosion at a rate of about 0.01-0.024 mm per year because of natural weathering processes. Degraded and damaged corrugated asbestos cement sheets can release asbestos fibers and matrix materials into rainwater [19], leading to water pollution, soil contamination, and harm to plant life [20]. This poses a risk due to prolonged droughts from climate change and increased use of water for agriculture and horticulture. Zhang et al. [21] pointed out a significant issue with the solution, noting that removing and disposing of slates is a lengthy process. This is due to the widespread use of slates and asbestos cement products in buildings, which results in high removal and disposal costs. While a significant amount of information exists regarding the diseases resulting from inhaling airborne asbestos and similar asbestos-like minerals [22], there remains an inadequate understanding of the potential health hazards associated with suspended fibers in water, which represents one of the most hazardous pathways for their release into the environment [23]. The utilization of polluted groundwater for irrigation is especially significant from the perspective of agricultural and water resource management [24]. Asbestos contamination involves complex processes, one of which is its ability to induce abiotic stress. Studies have shown that asbestos-contaminated water and soil can lead to toxicity, inhibiting seed germination and affecting seed quality characteristics [25, 26]. Research indicates that chrysotile asbestos-contaminated soil negatively impacts plant growth and productivity by disrupting nutrient levels. The adverse effects were measured through various parameters, including plant height, root length, biomass, chlorophyll content, and protein levels.

2 Materials and methods

The paper examined the germination and growth patterns of three types of *Solanum lycopersicum* (Manó, Vilma, Mobil) and three varieties of *Trifolium pratense* (Salino, Rozeta, Altaswede). It also assessed their variability to confirm the negative impacts of asbestos cement-contaminated irrigation water on plant growth in a controlled distilled water experiment. The findings revealed a noteworthy decrease in both the germination rate and percentage across all varieties of *Solanum lycopersicum* and *Trifolium pratense*.

2.1 Arrangement and conditions for germination experiment

Three different types of *Solanum lycopersicum* and *Trifolium pratense* were examined to investigate the impact of stress induced by varying doses. The seeds were surface-sterilized using a 2.0% sodium hypochlorite solution for 2 minutes, followed by three rinses with sterile distilled water. Afterward, batches of 10 seeds were placed in individual sterile Petri dishes containing a moistened cotton pad. Each experimental condition was represented by 5 Petri dishes for analysis. The quantity of test items for each type is 350 (N= 7 × 50). The petri dishes were kept at room temperature and the germination process was monitored.

2.2 Preparation of sample solutions

This study examined a variety of asbestos cement products widely employed in Hungary. These materials were found to contain an average of 8.00% to 10.0% chrysotile-asbestos, with a cement composition ranging from 90.0% to 92.0%. Investigating the specific properties of the asbestos and cement constituents concurrently was essential, as their combined characteristics significantly influenced the erosion and deterioration of the product matrix over time. We prepared solutions at concentrations of 1.00 mg/l, 2.00 mg/l, 5.00 mg/l, 10.0 mg/l, 25.0 mg/l and 50.0 mg/l using doubly distilled water in the laboratory setting. The control group received a double distilled water treatment. Seeds were treated according to their designated dosage and treatment method.

2.3 Germination assessment

During the investigation, we closely monitored and recorded the rate of seed germination, the duration of the germination process, as well as the length of the roots and height of the shoots. The root length measurements accounted for the portion of the root in contact with the surface of the moistened cotton pad and the tip of the primary root. Similarly, the shoot height measurements encompassed both the above-ground and below-ground sections of the shoot at day 31 for the *Solanum lycopersicum* and day 10 for the *Trifolium pratense* plants. Each treatment was replicated multiple times, and our results are presented as mean values ±

standard error. The data underwent thorough statistical analysis along with an evaluation of statistical associations.

3 Results

3.1 Results of *Solanum lycopersicum* analysis

Figure 1 shows the normal germination times of the three tested varieties of *Solanum lycopersicum* according to the control group. The germination rate is 88.0 % for Manó, 86.0 % for Vilma, and 84.0 % for Mobil. Germination of *Solanum lycopersicum* seeds at 25.0°C under light and dark conditions averaged 86.0 ± 2.00 %.

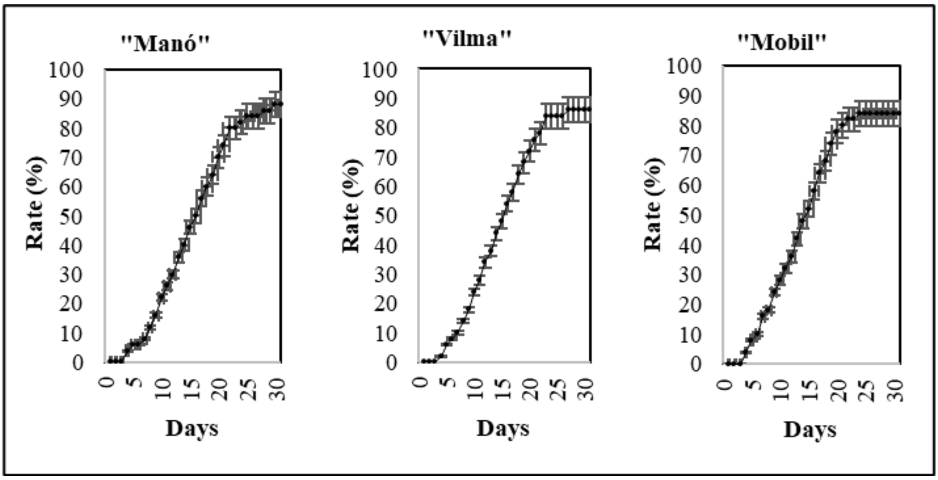

Fig. 1. Comparison of the germination times for control *Solanum lycopersicum* samples.

The tested samples showed that already at a dose concentration of 1 mg/l the germination rate was reduced to 82.0 % in the case of the Manó, to 80.0 % in the case of Vilma and for Mobil. This was reduced to 48.0 % (Manó), 44.0 % (Vilma), and 46.0 % (Mobil) at the 50 mg/l dose, and to 54.5 % (Manó), 51.2 % (Vilma) and 54.8 % (Mobil) as a percentage of the control group. The average value for the whole group is 93.8 ± 1.24 % for 1.00 mg/l and 53.5 ± 2.02 % for 50 mg/l. The average difference in the effect of the two-dose concentrations is -40.3 ± 1.62 %. Figure 2 shows the percentage in the control group for each seed exposed to dose concentration. The linear regression equation of the germination rate values of Manó: $y = -7.6623x + 100.3$, and the coefficient of determination is 0.988. For Vilma, the regression equation is $y = -8.3056x + 99.225$, the determination coefficient is 0.9754. While the linear regression equation of the germination rate values of Mobil: $y = -8.5034x + 103.97$, and the coefficient of determination is 0.9928.

The dose effect of 1 mg/l resulted reduction to 92.2 % in length of the root compared to the control group in Manó. This was 89.2 % for Vilma and 93.7 % for Mobil. The value as a percentage of the control group because of the 50 mg/l dose effect was 45.3 % for Manó, 43.1 % for Vilma, and 44.4 % for Mobil. This represented an average of 91.7 ± 2.25 % (1.00 mg/l) and 44.3 ± 1.13 % (50.0 mg/l), respectively. Figure 3 shows the percentage in the control group for the length of the root to dose concentration.

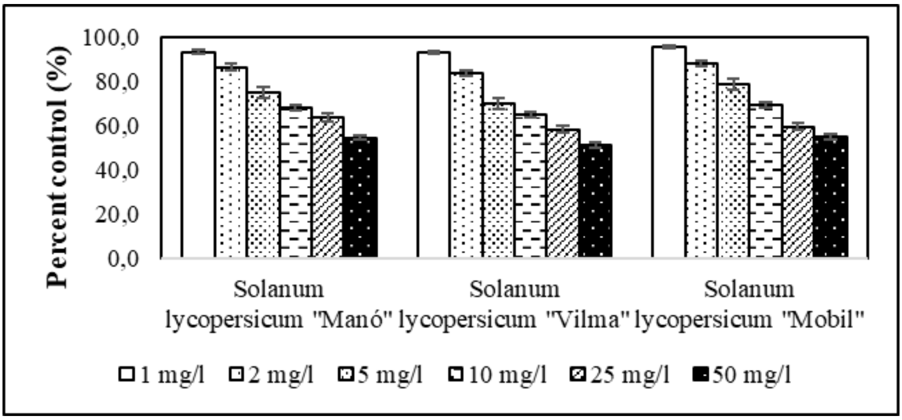

Fig. 2. Germination rates of *Solanum lycopersicum* seeds compared to control (mean values ± standard error, %).

The linear regression equation of the length of the root values of Manó: y = -8.9286x + 100.52, and the coefficient of determination is 0.983. For Vilma, the regression equation is y = -9.2747x + 100.41, the determination coefficient is 0.9802. While the linear regression equation of the length of the root values of Mobil y = -9.2971x + 102.12, and the coefficient of determination is 0.9893.

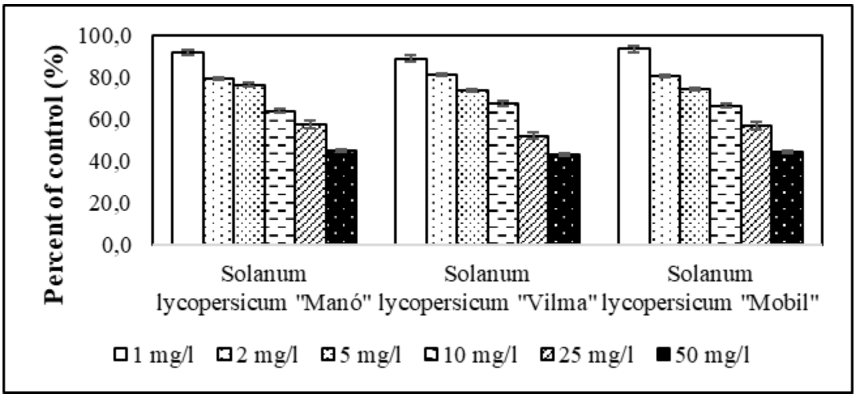

Fig. 3. Root length of *Solanum lycopersicum* samples compared to control (mean values ± standard error, %).

The dose effect of 1 mg/l resulted a reduction to 97.7 % in the height of the shoot compared to the control group in Manó. This was 98.9 % for both Vilma and Mobil. The value as a percentage of the control group because of the 50 mg/l dose effect was 59.8 % for Manó, 61.8% for Vilma, and 60.2 % for Mobil. This represented an average of 98.5 ± 0.67 % (1.00 mg/l) and 60.6 ± 1.06 % (50.0 mg/l), respectively. Figure 4 shows the percentage in the control group for the height of the shoot to dose concentration. The linear regression equation of the height of the shoot values of Manó: y = -7.0936x + 106.82, and the coefficient of determination is 0.9531. For Vilma, the regression equation is y = -7.1589x + 106.89, the determination coefficient is 0.9828. While the linear regression equation of the height values of Mobil: y = -7.5325x + 108.18, and the coefficient of determination is 0.9808.

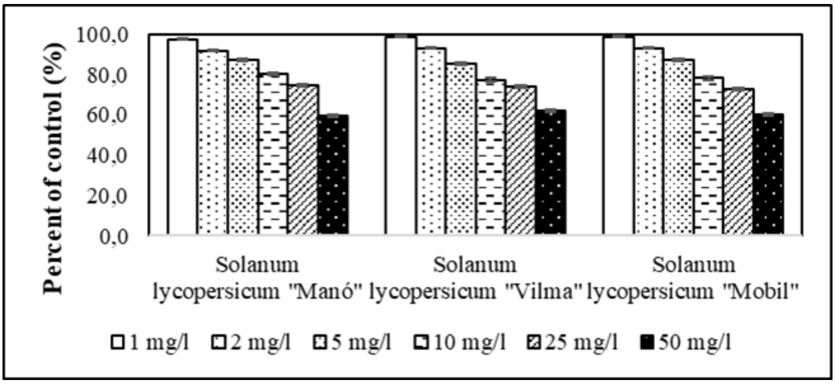

Fig. 4. Shoot height of *Solanum lycopersicum* samples compared to control (mean values ± standard error, %).

3.2 Results of *Trifolium pratense* analysis

Figure 5 shows the normal germination times of the three tested varieties of *Trifolium pratense* according to the control group. The germination rate is 82.0 % for Salino, 80.0 % for Rozeta and 84.0 % for Altaswede. Germination of *Trifolium pratense* seeds at 25.0°C under light and dark conditions averaged 82.0 ± 2.00 %.

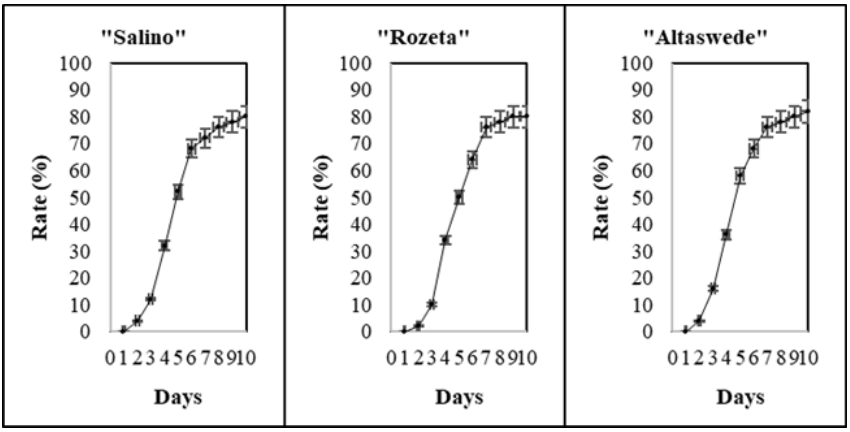

Fig. 5. Comparison of the germination times for control *Trifolium pratense* samples.

The tested samples showed that already at a dose concentration of 1 mg/l the germination rate was reduced to 78.0 % in the case of the Salino and Rozeta and 76.0 % for Altaswede. This was reduced to 42.0 % (Salino), 38.0 % (Rozeta), and 40.0 % (Altaswede) at the 50 mg/l dose, and to 51.2 % (Salino), 47.5 % (Rozeta) and 47.6 % (Altaswede) as a percentage of the control group. The average value for the whole group is 94.4 ± 3.57 % for 1.00 mg/l and 48.8 ± 2.11 % for 50 mg/l at the percentage of the control group. The average difference in the effect of the two-dose concentrations is -45.6 ± 3.86 %. Figure 6 shows the percentage in the control group for each seed exposed to dose concentration. The linear regression equation of the germination rate values of Salino: $y = -8.5714x + 103.58$, and the coefficient of determination is 0.9967. For Rozeta, the regression equation is $y = -10.286x + 106.83$, the determination coefficient is 0.9896. While the linear regression equation of the germination rate values of Altaswede: $y = -8.7075x + 98.73$, and the coefficient is 0.9946.

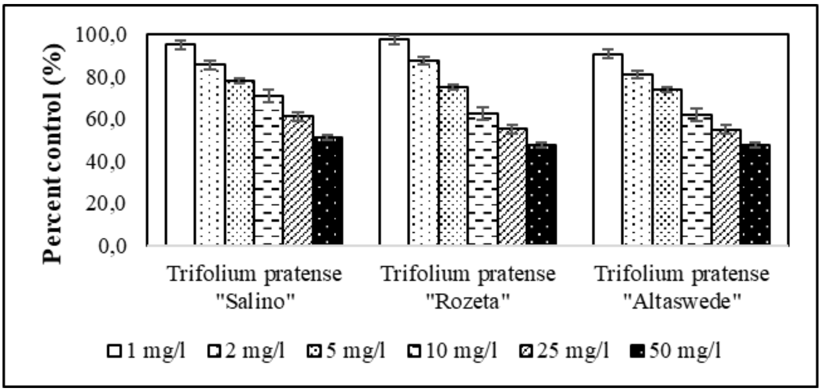

Fig. 6. Germination rates of *Trifolium pratense* seeds compared to control (mean values ± standard error, %).

The dose effect of 1 mg/l resulted in a reduction to 91.3 % in root length compared to the control group in Salino. This rate was 88.0 % for Rozeta and 95.5 % for Altaswede. The values as a percentage of the control group because of the 50 mg/l dose effect were 30.4 % for Salino, 20.0 % for Rozeta, and 22.7 % for Altaswede. Figure 7 shows the percentage in the control group for the length of the root to dose concentration. This represented an average of 91.6 ± 3.74 % (1.00 mg/l) and 24.4 ± 5.41 % (50.0 mg/l), respectively. The linear regression equation of the length of the root values of Salino: $y = -12.422x + 102.9$, and the coefficient of determination is 0.9967. For Rozeta, the regression equation is $y = -13.714x + 102.67$, the determination coefficient is 0.9922. While the linear regression equation of the length of the root values of Altaswede: $y = -14.286x + 109.09$, the coefficient of determination is 0.9934.

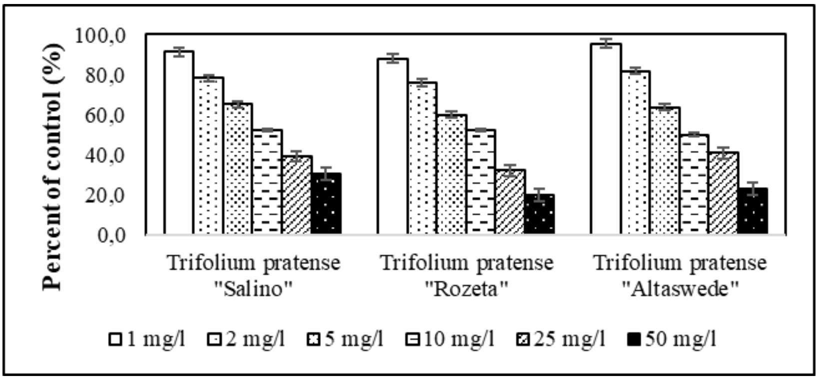

Fig. 7. Root length of *Trifolium pratense* samples compared to control (mean values ± standard error, %).

The dose effect of 1 mg/l resulted in a reduction to 95.2 % in the height of the shoot compared to the control group in Salino. Figure 8 shows the percentage in the control group for the height of the shoot to dose concentration. This was 94.7 % for Rozeta and 85.0 % for Altaswede. The average value as a percentage of the control group because of the 50 mg/l dose effect was 23.8 % for Salino, 23.7 % for Rozeta, and 15.0 % for Altaswede. This represented an average of 91.7 ± 5.77 % (1.00 mg/l) and 20.8 ± 5.05 % (50.0 mg/l), respectively. The linear regression equation of the height of the shoot values of Salino: y = -

14.422x + 107.62 and the coefficient of determination is 0,9908. For Rozeta, the regression equation is y = -15.113x + 110.35, the determination coefficient is 0.9835. While the linear regression equation of the height of the shoot values of Altaswede: y = -14.929x + 105.17, and the coefficient of determination is 0.9768.

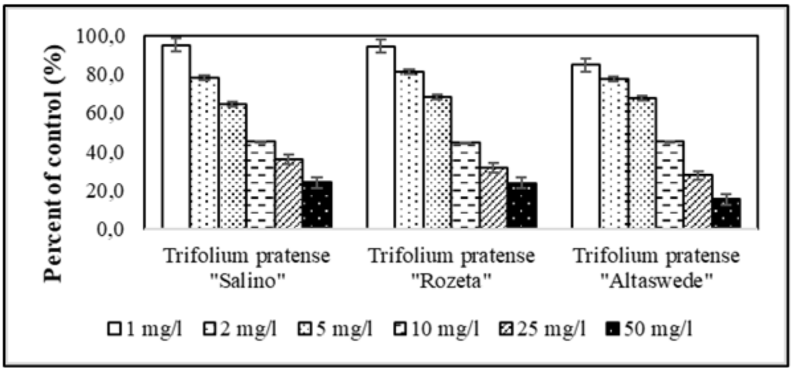

Fig. 8. Shoot height of *Trifolium pratense* samples compared to control (mean values ± standard error, %).

4 Discussion

Asbestos is a major health concern due to its extensive use in construction materials, leading to the release of asbestos fibers that contaminate air, soil and water. This contamination can adversely impact plant growth and seed germination in agriculture. Research suggests that asbestos-polluted soil has a detrimental effect on crop productivity and growth, posing an ongoing challenge for managing environmental and health risks from asbestos pollution. Prior studies have investigated the underlying causes of this issue, corroborating earlier hypotheses. The results indicate that exposure to escalating concentrations of asbestos cement led to decreased germination rates, root length, and shoot height in both plant varieties. The decline in seed germination is attributed to the presence of chrysotile asbestos, which exerts an adverse effect on the internal and external factors governing the germination process. Furthermore, asbestos cement pollution can be a significant stress factor for plant development, highlighting the importance of understanding the impact of external elements on plants in human-influenced environments [27].

5 Conclusions

This paper seeks to model the impact of asbestos cement contamination in irrigation water on plant growth. Initially, under standard conditions, the germination rates of the Manó, Vilma, and Mobil varieties were determined to be 88.0%, 86.0%, and 84.0% respectively. However, exposure to escalating concentrations of the substance led to a notable decrease in germination rates, with the highest concentration (50 mg/l). The research also evaluated the impact of the compound on root length and shoot height. The root length experienced a change in magnitude of -55.7 % compared to the control, while the shoot height demonstrated a -39.4 % change in magnitude. The paper analysed the germination and growth responses of three varieties of *Trifolium pratense* (red clover) too. Initially, under normal conditions, germination rates were found to be 82.0%, 80.0%, and 84.0% for Salino, Rozeta, and Altaswede respectively. However, exposure to increasing doses of the substance resulted in significant reductions in germination rates. In connection with the *Trifolium pratense*, the root length changes in magnitude of -75.6 % compared to the control, while the shoot height demonstrated a -79.2 % change in magnitude. The results emphasize the need to understand the impact of external elements on plant development in human-influenced environments.

Acknowledgements

This research is supported by the ÚNKP-23-3-I New National Excellence Program of the Ministry for Culture and Innovation from the source of the National Research, Development and Innovation Fund.

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