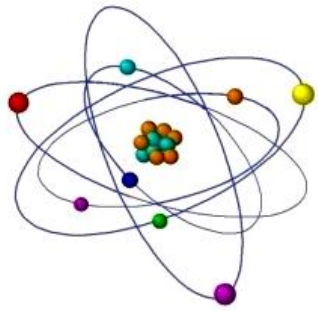
STUDY OF THE RADIONUCLIDE ABSORPTION IN TO THE VEGETATIVE ORGANS OF GRAPES TO INCREASE THE EFFICIENCY OF SOIL MECHANICAL DECONTAMINATION



[1,2]Ivanishvili Nazi*, [1]Gongadze Alex, [2]Kalmakhelidze Sophio, [3]Tulashvili Eremia, [1,2]Gogebashvili Mikheil

[1]Iv.Javakhishvili Tbilisi State University, E. Andronikashvili Institute of Physics, Georgia
[2]I.Beritashvili Center of Experimental Biomedicine, Georgia
[3]Iv.Javakhishvili Tbilisi State University, N. Kekelidze Materials Research Institute, Georgia

*Corresponding author: nazikoivanishvili@gmail.com

ABSTRACT**:** *Several man-made accidents at nuclear power plants and nuclear tests in recent years have highlighted the need to develop countermeasures that can effectively reduce the absorption of radionuclides by grape plants in viticulture. These measures should be cost-effective and easy to implement in everyday agricultural practice. To evaluate these parameters, we conducted experiments on ^{137}Cs contaminated soil. Our studies revealed the dynamics of the distribution of radionuclide contamination across the vegetative parts of the grapevine, the research also highlights the significance of vertical zone depth for the penetration of radiocesium into the plant. It was concluded that shifting the depth of the space between the rows of the vineyard by the deep plow makes it possible to move the soil layer contaminated with radionuclides into relatively deep layers, which will significantly reduce the penetration of radionuclides into the grape plant.*

Key words: Radionuclides, soil, *Vitis vinifera. L*

INTRODUCTION

In the processes of active development of various technologies in human economic activity, a large number of substances used are not found in the natural environment, and are pollutants of natural ecosystems [1]. The chemistry of the pollutants is very diverse, which makes it difficult to develop a universal technology for their utilization [2,3]. Especially radioactive waste is highly dangerous for humans and the environment. In the radioecological aspect, noteworthy are long-lived radionuclides, which can be involved in the metabolic pathways and circulation of substances in living organisms. Transfer and subsequent accumulation of radionuclides in the soil-plant continuum have gained increasing attention. Radionuclides in the soil are taken up by the plants leading to their accumulation in the organisms of food chain and represent a danger for ecosystem. This is the reason for the great interest researchers show in the selection of soil deactivation and the suitable remediation technique [4,5,6]. Over the past decade, many studies aimed at solving the problem of rehabilitating contaminated areas [7,8]. One of the most common and effective methods of soil cleaning is to remove the top layer of soil and store it in a controlled manner for a long time. However, this method generates a large amount of radioactive waste, and the fertile layer of soil is completely removed. It is important to mention that above mentioned method is quite expensive, as it involves expenses for mechanized soil removal, transportation, and burial of large quantities of soil. The method of deep plowing of the soil is more cost-effective and useful for mechanical decontamination of soils associated with the cultivation of perennial plants, where removing the soil cover without harming the plants is technically challenging. This statement can be applied to vineyards. As the cultivation of this culture counts several decades. Our study aimed to localize radionuclide-^{137}Cs marker in the grape's vegetative organs depending on the depth of soil contamination zones. The purpose of this study was to determine if the deep plowing method can increase the efficiency of mechanical soil decontamination in vineyards.

MATERIALS AND METHODS

The object of study was the „Chinese" grape (*Vitis vinifera L*) widespread throughout the Georgian territory. Standard vine sprouts were placed in soil for rooting and then transferred to its permanent place of cultivation. The substrate was soil contaminated with radiocesium, which had been stored in sealed containers for 20 and 30 years to simulate long-term environmental exposure. For radiospectrometric analysis, the material was taken according to the plant's vegetative growth phase. The vegetative parts of the plant were dried, and fragmented in a homogenizer to standard particle sizes, and radioisotope activity was determined in a Marinelli dish.

The content of radionuclides was determined by gamma-spectrometry (Gamma-Beta Spectrometer, Atomtex-MKC-AT-1315 and Gamma-Spectrometer CANBERRA with liquid nitrogen cooled germanium detector). At the same time, the content of radioisotopes was determined in the soil used.

RESULTS AND DISCUSSION

It is widely recognized that radionuclides primarily accumulate in plant tissues via the root system, where roots absorb water along with water-soluble radionuclides, facilitating their transfer to the vegetative organs through sap flow. The level of radioactivity in plant tissues is influenced not only by species characteristics and radionuclide concentrations in soil layers but also by the interplay between soluble and insoluble fractions in these layers. The intensity of radionuclide accumulation in plants through the root system is evaluated based on factors such as shoot biomass increase, radionuclide distribution in the root system, and the availability of physical and chemical forms of radionuclides in soil profiles. Our study focused on cultivating a specific grape variety in typical soil conditions. Soil activity, determined through spectrometric analysis, revealed levels of 1250 Bq/kg for 137Cs and 980 Bq/kg for 40K. The amount of radionuclide absorbed by a plant is influenced by age-related changes in plant physiology. Each growth phase corresponds to distinct physiological processes, impacting nutrient absorption. Our investigation analyzed radio cesium content in various grape plant tissues throughout different growth stages. The distribution and localization of radiocesium in grape plant tissues vary depending on the plant's seasonal development stages, as illustrated in **Figure 1.** For instance, during germination and growth stages (**Figure 1. a, b**), radiocesium is prominently localized in grape leaves, while in later developmental stages, including periods of physiological rest, it tends to accumulate more intensively in young tissues and sprouts (**Figure 1. c**).

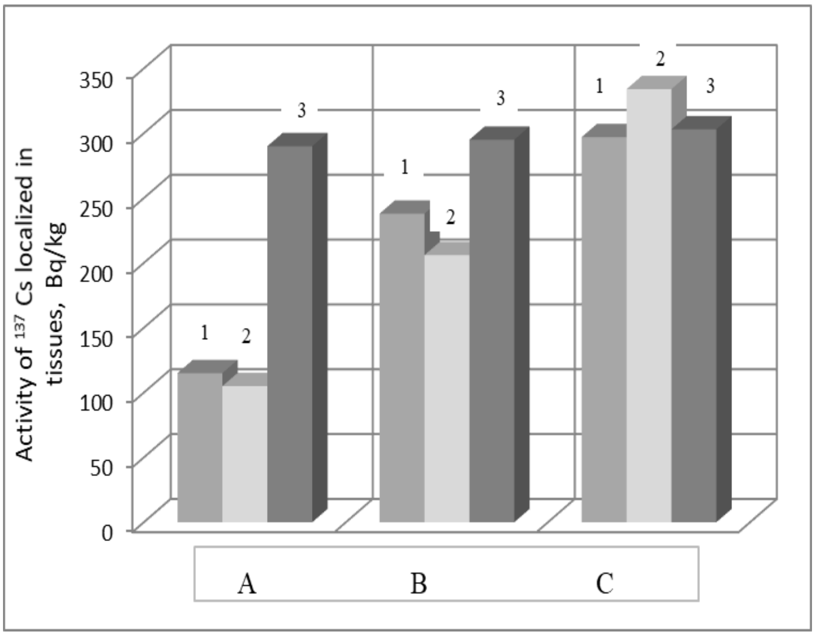


Figure 1. - Distribution of absorbed radioactive cesium in the tissues of vegetative organs depending on the stages of growth and development of grape plant.

A- Germination stage (March-April); **B-** Active growth stage (May-June);
C-physiological resting stage (September-October);
1-Leaves; 2-Sprouts of current year; 3-perineal stem

The transfer of radiocesium within the biological chain is influenced by various factors, with radioactive potassium-40K being particularly noteworthy. Radiocesium shares similar chemical properties with potassium, leading to comparable metabolic processes within biological organisms. The movement intensity of cesium and potassium in plants is approximately similar, with their absorption dependent on the total concentration of both elements and their relative characteristics relative to total concentration. Both cesium and potassium accumulate in similar organs and tissues, and their acceptable ratio is determined by their quantitative content. To explore the dynamics of radioactive potassium accumulation in plant organs alongside radioactive cesium, we determined the activity of radioactive potassium. **Figure 2.** illustrates the distribution of radioactive potassium among plant organs throughout the vegetative cycle. However, unlike radiocesium, a decrease in its activity is observed in the leaves and current-year sprouts.

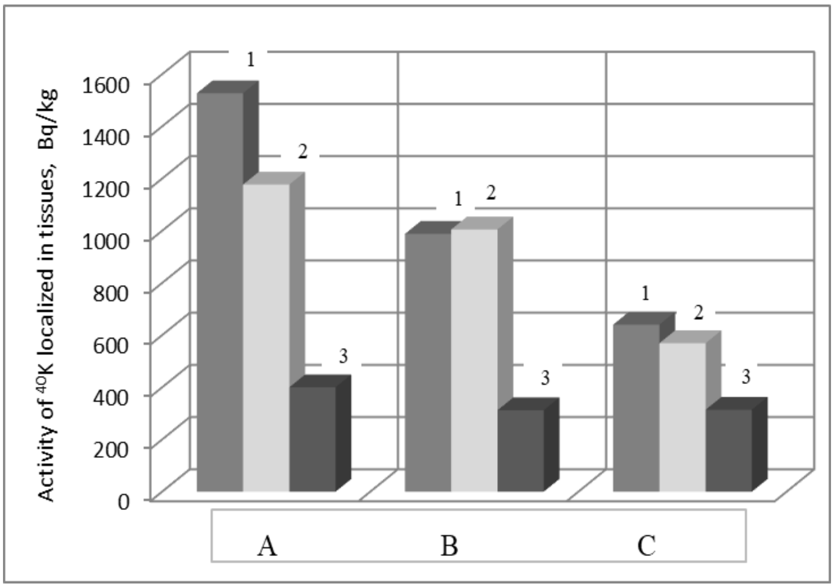


Figure 2.-Distribution of absorbed radioactive potassium in the tissues of vegetative organs depending on the stages of growth and development of grape plant

A-Germination stage (March-April); **B**- Active growth stage (May-June); **C**-physiological resting stage (September-October); 1-Leaves; 2-Sprouts of current year; 3-perineal stem

Potassium is a vital nutrient for plants, but unlike nitrogen and phosphorus, it is not a part of the organic matter of plants. It exists in the form of ions, soluble salts or forms unstable complexes with cytoplasmic colloids in cells. This explains why potassium is highly mobile during the various stages of plant growth and development. Potassium compounds can actively move in plant tissues, allowing for their reuse by moving from old to young tissues. The refore, this movement can result in varying levels of potassium content in leaves and stems.

The data obtained from the study show that it is feasible to use plants in the stage of physiological dormancy to study the deep distribution of radionuclides in soil. At this stage, the migration of radionuclides is almost complete and the total absorption rate of radionuclides for one season can be calculated.

In the next stage of research, we used the factor of radionuclide penetration into vegetative parts of plants by modeling the level of vertical distribution of pollution zones. The soil contaminated with radionuclides was added layers in the experimental soil and as a result, we identified three zones of radionuclide contamination in the soil:1-Superficial contamination zone (1-25 cm); 2-Total contamination zone (1-50 cm) and 3-Deep contamination zone (25-50 cm) **Figure 3.**

Figure 3. shows that grapes grown in vertically contaminated soil have the greatest absorption of radionuclides in a specific zone. The first zone contains 95.8% of the total radiocesium absorption, while the third zone contains only 5.9%. However, maintaining clear boundaries between contamination zones during long-term cultivation can be technically challenging, although the pattern of radionuclide distribution into the plant's vegetative parts is evident. The obtained results show the main ways of the penetration of radionuclides into the grape plant; Namely, with air pollution of agrocenosis, radiocesium appears mainly in the upper soil layer [9,10,11,12]. which has been observed for different nature zones and the entire territory of

Georgia [13], and this value, as a rule, does not exceed 15-20 centimeters in depth. Therefore, an effective method of reducing the absorption of radionuclides into the plant is to deep plow and transfer the contaminated upper layer of soil to deeper horizons.

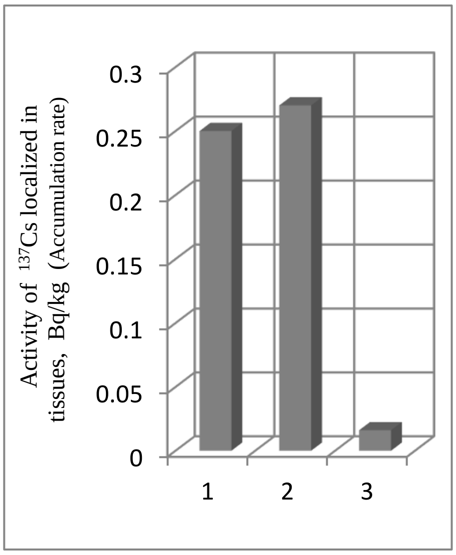


Figure 3. Three zones of cesium radionuclide contamination in the soil concerning the accumulation of radioisotopes in plants

1-Radioactive contamination zone 1-25 cm;
2-Radioactive contamination zone 1-50 cm;
3-Radioactive contamination zone 25-50 cm

CONCLUSION

Based on the conducted studies, we can conclude that mechanical cleaning of radiocesium contaminated soil surface layer significantly reduces the penetration of radiocesium into the vegetative parts of the grape plant, thereby preventing the dangers of radiation contamination in vineyards.

REFERENCES

[1]. Ranjeet Kumar Mishra, Spandana Samyukthalakshmi Mentha, Naveen Dwivedi Emerging pollutants of severe environmental concern in water and wastewater: A comprehensive review on current developments and future research. Water-Energy Nexus. Volume 6, 2023, Pages 74-95.

[2]. Vikas Kumar, Chadetrik Rout, S. Baskoutas. A review on the clean-up technologies for heavy metal ions contaminated soil samples. Heliyon, Volume 9, Issue 5, 2023, e15472.

[3]. B. Senthil Rathi, P. Senthil Kumar, Dai-Viet N. Vo, Critical review on hazardous pollutants in water environment: Occurrence, monitoring, fate, removal technologies and risk assessment. Science of The Total Environment, Volume 797, 2021, 149134.

[4]. Friederike Strebl, Sabine Ehlken, Gerald Kirchner. Behavior of radionuclides in soil/crop systems following contamination Radioactivity in the Environment, 2007.

[5]. Y. G Zhu, G Shaw. soil contamination with radionuclides and potential remediation, Chemosphere, 2000.

[6]. M. A. Edomskaya, S. N. Lukashenko, S. V. Korovin. Estimation of radionuclides global fallout levels in the soil contamination with radionuclides and potential remediation of CIS and eastern Europe territory. Journal of Environmental Radioactivity, 2022.

[7]. Neil Willey, Chris Collins, Phytoremediation of soil contaminated with radionuclides. Radioactivity in the Environment, 2007.

[8]. B.J. Merkel, M. Hoyer. Radionuclide Behaviour in the Natural Environment, Science, Implications and Lessons for the Nuclear Industry Woodhead Publishing Series in Energy, 2012, Pages 601-645.
[9]. Gerald Kirchner, Friederike Strebl, Martin H. Gerzabek. Vertical migration of radionuclides in undisturbed grassland soil Journal of Environmental Radioactivity September 2009 Journal of Environmental Radioactivity. Volume 100, Issue 9, 2009, Pages 716-720
[10]. S. Askbrant, J. Melin, J. Sandalls, G. Rauret, R. Vallejo, T. Hinton, A. Cremers, C. Vandecastelle, N. Lewyckyj, Y.A. Ivanov, S.K. Firsakova, N.P. Arkhipov, R.M. Alexakhin. Mobility of radionuclides in undisturbed and cultivated soils in Ukraine, Belarus and Russia six years after the Chernobyl fallow. Journal of Environmental Radioactivity. Volume 31, Issue 3, 1996, Pages 287-312.
[11]. P. Bouisset, M. Nohl, A. Bouville, G. Leclerc. Inventory and vertical distribution of ^{137}Cs, $^{239+240}Pu$ and ^{238}Pu in soil from Raivavae and Hiva Oa, two French Polynesian islands in the southern hemisphere. Journal of Environmental Radioactivity. Volume 183, 2018, Pages 82-93.
[12]. Tengiz F. Urushadze, Dimitriy V. Manakhov. Radioactive contamination of the soils of Georgia. Annals of Agrarian Science. Volume 15, Issue 3, 2017, Pages 375-379