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Crop Disease Detection Using MobileNetV3-Small Convolutional Neural Networks (CNNs) to Support Armenian Agriculture

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ABSTRACT

The agricultural sector of Armenia faces many problems, such as low productivity, small landholdings, limited technological machinery, reliance on low-value crops, and inadequate expertise. This article uses Artificial Intelligence (AI), specifically Convolutional Neural Networks (CNNs) based on MobileNetV3-Small architecture, to improve crop disease detection. The model was trained and validated using fruit and berry colored leaf images from the PlantVillage dataset. The final model achieved an accuracy of 99.25% and a macro F1-score of 0.9891 across 13 plant disease and health categories, which indicates the model's strong potential for accurate crop disease detection.

Introduction

Agriculture is one of the important sectors of Armenia and is the branch that ensures the country's food security (Avetisyan, 2010). However, despite its important role, the sector faces a number of significant problems. High production prices, limited technologies, and a shortage of agricultural specialists slow down the growth of the sector (Alaverdyan, et al., 2015). Also, small land areas, the average size of which is 1.4 hectares per household, together with severe land degradation, hinder agricultural production (International Trade Administration, 2018).

Farmers engaged in the cultivation of high-value crops often face climate risks, as a result of which potential outputs and incomes from them become unstable, hindering the ability to invest in new technologies (Alaverdyan and Nijhoff, 2024).

The development of digital technologies, especially the use of Artificial Intelligence (AI), is of great importance for solving the problems of modern agriculture. The latter helps farmers make smarter decisions using robots, sensors, machine learning (ML), and computer vision. Such technologies make it possible to quickly detect and control harmful organisms, as well as estimate crop yields, monitor soil and water quality, and properly organize irrigation (Meshram, et al., 2025).

However, agriculture in Armenia is only at an early stage of implementing AI, and therefore, investments in localized databases and infrastructure are needed to enable the

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detection of crop pests (IFOAM – Organics International & ICARE Foundation, 2017). Thus, understanding the global potential of AI and the specific context of Armenia is critical for success.

The ML models have already been used to detect the infected crops. In the "Automated Identification of Northern Leaf Blight-Infected Maize Plants from Field Imagery Using Deep Learning" paper by DeChant et al. (2017), CNNs were used to generate heat maps, which a final CNN then processed to classify the entire image of a diseased leaf. The model, as a result, achieved a high accuracy of 96.7% on the test set, as well as 96.8% precision and 97.4% recall.

In another study, "Detection of Plant Diseases with Artificial Intelligence Using the VGG-16 Model" by Alatawi et al. (2022), CNN built on the VGG-16 architecture was developed based on leaf images taken from the PlantVillage (Mohanty, et al., 2016) database. The model was trained on 15,915 mixed images of healthy and diseased leaves (19 types of diseases) of grapes, apples, and corn. The VGG-16 model, using ReLU and Softmax activation functions, achieved 95.2% accuracy and had a test loss of 0.4418.

CNN models can be trained, tested, and validated using datasets like PlantVillage to detect crop diseases as seen in the examples above. Models with high F1-scores, high accuracy, and low loss are considered effective and could be used in local agriculture.

To the best of the Author's knowledge, there have been similar technological attempts to boost productivity among Armenian farmers, yet no documented results were identified in the sources consulted. Hence, this research project has aimed to develop, train, test, and validate a CNN model with high accuracy and reliability to fill this gap as a foundational step, with additional work needed to adapt and implement it to a local system. The research question that guided this study is as follows: "How can AI-based crop disease detection support Armenian farmers in addressing the main productivity challenges in the agricultural sector?"

Materials and methods

This study uses innovative structures and algorithmic neural architecture to provide a balance between accuracy and latency. Howard et al. (2019) came up with the architecture, MobileNetV3, which used inverted residuals with SE blocks, optimized by NAS to increase accuracy and efficiency. Additionally, it has Hard-Swish (HS) and Hard-Mish (HM) activation functions, which balance computing efficiency and non-linearity.

The MobileNetV3 has MobileNetV3-Small and MobileNetV3-Large models, where the small one is needed for resource-constrained situations. As the fruits and berries are one of the widely cultivated crops in Armenia (Hofmann, et al., 2022), the model will be trained, tested, and validated on seven types of crops (Table 1) from PlantVillage dataset (Mohanty, et al., 2016): apples, cherries, peaches, blueberries, oranges, raspberries, and strawberries, and therefore, the model introduced in the paper will use the MobileNetV3-Small architecture.

The main parameters used for the model were as follows:

- Validation split: 0.2 (20% of data)
- Image size: 224x224 pixels
- Batch size: 64
- Class weights: balanced
- Base model: MobileNetV3-Small
- Dropout: 0.3 (30% dropout rate used after base model output)
- Dense: 13 units, softmax activation
- Epochs: 100
- Optimizer: Adam – learning rate: 0.0001 (Beta_1: 0.5, Beta_2: 0.99)
- Loss function: Categorical Cross-entropy

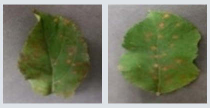
Results and discussions

In this paper, the initial validation accuracy calculated by Equation 1 and loss calculated by Equation 2 of the pre-trained MobileNetV3-Small model were 90.16% and 0.5171, respectively, which improved to achieve a maximum validation accuracy of 99.25% on the 91st epoch and a minimal validation loss of 0.032 on the 95th epoch (Figure 1).

(Eq. 1)

$$Accuracy = \frac{Number\ of\ Correct\ Predictions}{Total\ Number\ of\ Predictions}.$$

Table 1. Crop and Leaf Types with Training and Testing Images and Counts*

Plant Name	Leaf Label	Examples	Train Images	Test Images
Apple	Scab (AS)		504	126
	Black Rot (ABR)		497	124
	Cedar Apple Rust (ACAR)		220	55
	Healthy (AH)		1316	329
Cherry	Powdery Mildew (CPM)		842	210
	Healthy (CH)		684	170
Peach	Bacterial Spot (PBS)		1838	459
	Healthy (PH)		288	72
Blueberry	Healthy (BH)		1202	300
Orange	Huanglongbing (OH)		4406	1101
Raspberry	Healthy (RH)		297	74
Strawberry	Leaf Scorch (SLS)		888	221
	Healthy (St-H)		365	91

*Source: *PlantVillage dataset.*

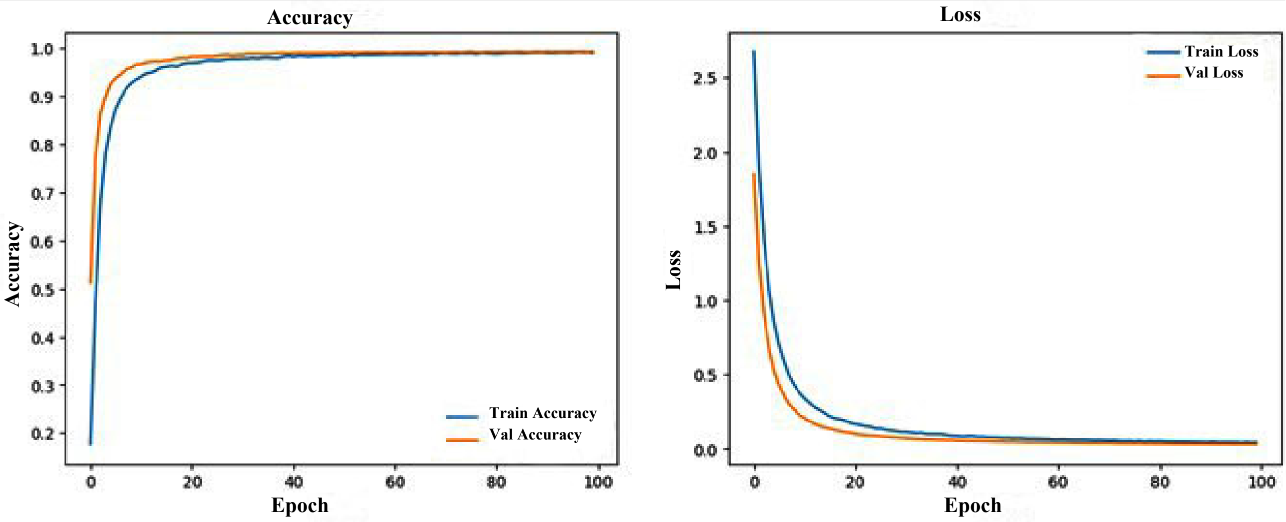


Figure 1. Training and validation loss and accuracy of a model in 100 epochs using Matplotlib (Hunter, 2007) from the Keras training history (Chollet, 2015).

(Eq. 2)

$$Loss = -\sum_{i=1}^{C} y_i \log(\hat{y}_i),$$

where C is the number of classes; y_i is the true label (1 if correct, 0 otherwise); $\hat{y}_i$ is the predicted probability for class i.

As seen in Figure 1, there are no significant fluctuating patterns in both accuracy and loss graphs, which means that the model learned effectively without overfitting.

To evaluate the performance of the MobileNetV3-Small-based model, Table 2 was created using three main classification metrics: precision (Eq. 3), recall (Eq. 4), and F1-score (Eq. 5).

(Eq. 3)

$$\text{Precision} = \frac{\text{True Positives (TP)}}{\text{True Positives (TP)} + \text{False Positives (FP)}}.$$

(Eq. 4)

$$\text{Recall} = \frac{\text{True Positives (TP)}}{\text{True Positives (TP)} + \text{False Negatives (FN)}}.$$

(Eq. 5)

$$\text{F1} = 2 \cdot \frac{\text{Precision (Eq. 3)} \cdot \text{Recall (Eq. 4)}}{\text{Precision (Eq. 3)} + \text{Recall (Eq. 4)}}.$$

Table 2. Precision, recall, and F1-scores for both individual and summary of classes*

Class	Precision	Recall	F1-score
Apple Scab	0.9449	0.9524	0.9486
Apple Black Rot	0.9920	1.0000	0.9960
Cedar Apple Rust	1.0000	1.0000	1.0000
Apple Healthy	0.9759	0.9848	0.9803
Blueberry Healthy	1.0000	1.0000	1.0000
Cherry Powdery Mildew	0.9952	0.9905	0.9928
Cherry Healthy	0.9940	0.9824	0.9882
Orange Huanglongbing	0.9991	0.9991	0.9991
Peach Bacterial Spot	0.9978	0.9847	0.9912
Peach Healthy	0.9595	0.9861	0.9726
Raspberry Healthy	1.0000	1.0000	1.0000
Strawberry Leaf Scorch	1.0000	1.0000	1.0000
Summary Metrics			
Accuracy	—	—	0.9925
Macro Average	0.9875	0.9908	0.9891
Weighted Average	0.9926	0.9925	0.9925

*Composed by the author.

The table 2 provides an understanding of the model's ability to identify 13 different classes of plant health and disease accurately.

The results of the analysis show that the model works effectively on all 13 classes. For many classes, the F1-score exceeds 0.98, and for some classes, such as Cedar Apple Rust, Blueberry Healthy, Raspberry Healthy, and Strawberry Leaf Scorch, it reaches the maximum value of 1.0000. The 0.9891 macro and 0.9925 weighted F1-scores, as well as 99.25% accuracy, show that the model is not only reliable but also performs well when the classes are imbalanced.

The normalized confusion matrix shown in Figure 2 helps to analyze the model's classification behavior further and understand which classes the model distinguished correctly and which classes it mislabeled.

The Y-axis shows the real classes of the crop leaf images, and the X-axis shows the classes predicted by the CNN model. Each cell tells how often a real class was expected as a particular class. The blue cells on the diagonal are correct predictions — darker color means higher accuracy.

The normalized values from 0 to 1 inside the cells show the proportion of predictions for each class.

t-SNE visualization (Figure 3) applied to high-dimensional feature vectors extracted by the final layers of the model additionally helps to understand how the model internally organizes the learned patterns. It is a nonlinear dimensional reeducation technique that projects high-dimensional data onto a 2D space while preserving local structures.

The visualization shows the clusters, which are either well-separated and compact or scattered and partially mixed with others. Blueberry Healthy, Cherry Powdery Mildew, Cherry Healthy, Orange, Cedar Apple Rust, Raspberry Healthy, Strawberry Leaf Scorch, and Strawberry Healthy show isolated clusters. While Apple Black Rot, Peach Bacterial Spot, Peach healthy, and the rest have slight overlaps with each other and feature separation is more challenging, the model showed promising results in these classes.

Overall, this visualization confirms that the model has developed to a stage where it can clearly distinguish between plant leaf conditions.

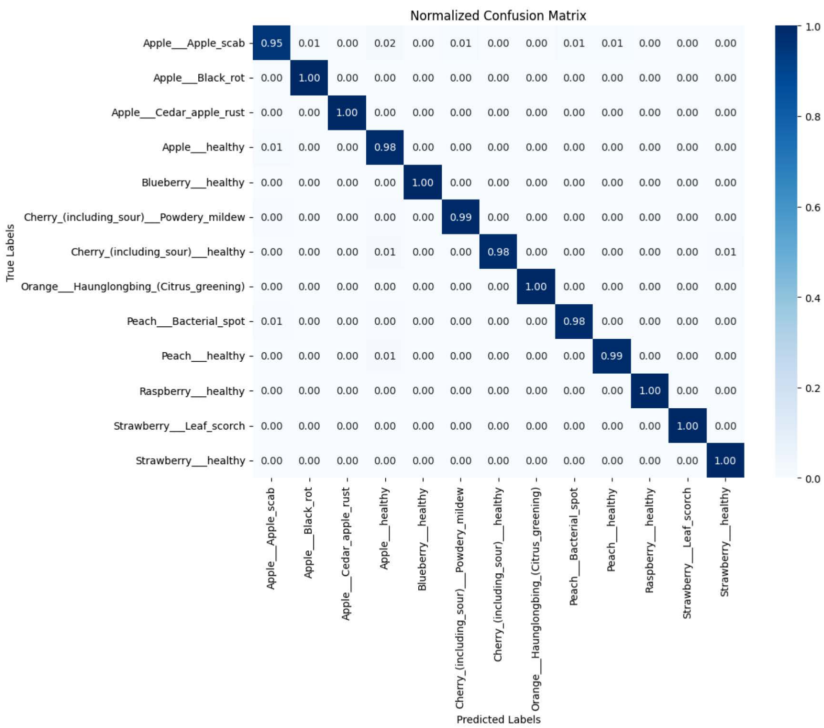


Figure 2. Confusion matrix showing proportions of predictions for each class (*generated using scikit-learn (Pedregosa et al., 2011) for confusion matrix computation and Matplotlib (Hunter, 2007) for visualization*).

Figure 3. t-SNE Visualization (*van der Maaten & Hinton, 2008*) of Feature Embeddings from the model.

Conclusion

The model's accuracy reached 99.25% with a macro-F1 score of 0.9891. It shows a strong potential, primarily when the study was conducted using sparse and unbalanced materials from the PlantVillage dataset.

Class imbalance in the dataset might've skewed the performance; however, the model didn't have any fluctuating results and achieved high outcomes. Nevertheless, the study has some limitations as it didn't consider Armenia-specific factors such as soil conditions or local pests, and did not include field testing and Decision Support Systems (DSS), which limits how useful it is in real farming.

Future research could support Armenian farmers by creating a local dataset (fruits, berries, grains, vegetables), validating the model in the fields, and integrating CNNs with a Decision Support System (DSS) for actionable recommendations. These steps would help reduce crop losses, improve disease monitoring, and boost AI-based disease detection, automation, and adoption in Armenia.

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Justification of the Stability Parameters for the Turning Motion of a Horticultural Robotic Platform

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The authors declare no conflict of interest concerning the research, authorship, and/or publication of this article.

ABSTRACT

The article discusses the issue related to the development of a multifunctional horticultural robot platform. The previous article in this series substantiated the necessity of designing a robot platform for integrated cultivation of inter-row, inter-tree (inter-vine), and near-trunk areas in vineyards and orchards, taking into account the specific soil and climatic conditions of the Republic of Armenia.A structural schematic of the robot platform has been developed, and a kinematic analysis has been conducted, the results of which served as the basis for programming the robot›s control system. Tests of the prototype of the developed robot platform demonstrated that, in order to create a fault-free, four-wheeled robot platform with independently controlled wheels, additional kinematic and dynamic studies are required. As a result of the conducted analyses, mathematical expressions were derived that enabled adjustments to be made in the robot platform's control software with respect to its kinematic parameters. Specifically, the program for controlling the robot platform's turning motion now accounts not only for the correlation between the wheel axes' rotation angles around the vertical axis, but also for those between the angular velocities of the wheels rotating around their own axes. The dynamic studies produced accurate expressions for determining lateral forces, which will enable the development of the robot platform's running and suspension systems that not only minimize soil damage but also ensure high operational reliability and durability.

Introduction

Over the past decade, the trends in the development of agricultural production in all countries have been shaped by one of the most critical global challenges facing humanity—the need to meet the growing demand for food products. Addressing this challenge necessarily implies the preservation and improvement of land resources, compliance with environmental requirements, an increase in production volumes, the production of environmentally friendly products, the complete mechanization of agricultural production, and—most crucially today—the reduction of energy consumption in performing these tasks (Bak, 2003; Abrosimov, 2022).

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It is evident that the comprehensive resolution of this issue is objectively limited when relying solely on existing technologies and technical means. The various sensors and detectors used in fieldwork are quite expensive and generally inaccessible to farmers, particularly in large quantities. Soil analysis is mostly performed manually, and disease observation and assessment require the direct involvement of an agronomist (Abrosimov, 2022).

This is perhaps the reason why two fundamental trends have recently come to the forefront of technological processes in agricultural production worldwide:

- The most prominent and relevant direction of the past decade in agricultural production has been precision agriculture, which is scientifically grounded in the objective fact that even within the boundaries of a single field, significant heterogeneity exists. To detect, record, and assess these heterogeneities, advanced technologies are used, including global positioning systems (GPS, GLONASS, Galileo), specialized sensors, aerial photography, and agro-management software based on geographic information systems (GIS) (Abrosimov, 2022).
- The second direction, without which it is impossible to effectively utilize the data obtained from the aforementioned technologies, is robotized farming. This means that agricultural production must transition toward the cultivation of crops that are comparatively easier to manage using robotic systems, including for harvesting operations. This, in turn, necessitates a specialized approach to the design of fields, which significantly facilitates the development of agricultural robots (Bak, 2003; Zagazezheva, 2021; Skvortsov, 2018).

The stages of robotics development, the rapidly increasing scale of its application in agricultural production, the expansion of functional capabilities, and the technical and agro-technological requirements associated with these advancements were thoroughly discussed in a previous study (Tarverdyan, 2024). The mentioned article, demonstrated that a critical aspect—namely, the development of the running gear—requires further investigation.

For the proposed robot platform, a fundamentally new running gear and suspension system is being developed. To perform the necessary calculations for this system, it is essential to determine the vertical and tangential components of the forces acting on the wheels.

Though the global robotics market is developing at an unprecedented pace—having expanded nearly twentyfold over the past five years (Bak, 2003; Godin, 2020; Exclusive Report, 2024; Navone, 2025, Fountas, 2020)—their application in Armenia's agricultural sector remains highly limited. This is largely due to the high market cost of such technologies, making them inaccessible to most local business entities/producers. Additionally, the structural features of existing robotic systems are designed for other soil and climatic conditions, and their operational reliability is relatively low when used on Armenia's soil types (Tillett, 1991; Tarverdyan, 2024).

These circumstances suggest that the issue can be addressed in one of two ways: either by making structural modifications to existing robots or by developing a new, cost-effective, and universal robot platform that is better adapted to the local terraincharacterized by the presence of stones of various sizes and a rugged relief.

For all agricultural mobile robots, the mobile platform is a critical component that plays a significant role in the overall performance of the system.

Researchers have focused much of their efforts on the development of robust mobile platforms for agricultural robots [Qiu et all, 2018], as well as on improving their control and positioning accuracy, since these aspects are essential and fundamental in precision agriculture [Lipiński et all, 2016; Bayar et all, 2015].

Among the various agricultural mobile platforms, the four-wheel independent drive (4WID) configuration represents the most widely used kinematic solution. The 4WID configuration provides high mobility flexibility to the mobile platform, while simultaneously increasing the complexity of coordinated motion control. For this reason, some researchers often prefer a four-wheel-driven configuration in which the four wheels are not independently steered; instead, a mechanical steering linkage is established between the front and rear wheel pairs, meaning that these wheel pairs are mechanically coupled through a steering mechanism (Qiu et all, 2018; Akimov, 2017; Blasco, 2002; Cho, 2002).

The conceptual design of the proposed robot platform is based on the technical-technological requirements applied to modern agricultural robots. It consists of the following main systems: a base platform with four independently driven and controlled wheels and suspension units; an electronic computer-based control unit; and various tools and implements for executing a wide range of agro-technological operations (Bak, 2003; Tarverdyan, 2024; Toda, 1998; Orebäck, 2003; Cho, 2002).

The present article discusses the results of the kinematic and dynamic analysis of the robot platform's running gear, aimed at accurately determining the parameters necessary for the robot's development

Materials and methods

As previously mentioned, for the robot-platform intended as a transport vehicle for performing agrotechnological operations, the preferred configuration is a four-wheel drive system with independently controlled wheels. The platform's ability to move smoothly in parallel directions allows for high maneuverability in certain scenarios, eliminating the need for turning maneuvers.

Though the use of four independently controlled wheels results in a non-linear vehicle behavior and makes control less straightforward, given the relatively low operational speeds (2–6 km/h), even simple control systems can be effective (Agricultural Robots Market Worth $11.9 Billion by 2026 – Exclusive Report by Markets, Tarverdyan, 2024; Cho, 2002).

A schematic diagram of the proposed and under-development robot-platform is presented in Figure 1. The system consists of: 1. a frame-platform to which various devices and tools for performing agrotechnological operations can be attached; 2. four independently driven and controlled motorized wheels; 3. an electronic control system for managing the movement of the drive wheels;4. a mechanism for steering the wheels; and, 5. a pneumo-hydraulic damping suspension system.

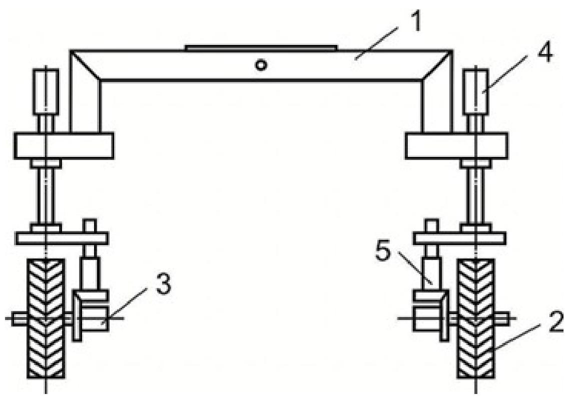

Figure 1. Schematic diagram of the running gear of the proposed robot-platform *(composed by the authors)*.

The electronic-computerized wheel module controls the rotation (axial turning) of the wheels around a vertical axis, based on a software algorithm for the kinematic correlation of the wheel turning angles. It also manages the torque (or current) of the electric motors driving the four wheels. The servo-drive electronics used for steering control provide feedback based on the turning angle of rotation. This is a fundamental principle in the structural scheme of agrorobots (Bak, 2003; Torii, 2000; Toda, 1999; Litvinov, 1971).

As previously mentioned, the first step in the development and design of the agrorobot was to identify the relationship and values of the kinematic parameters of steady motion and turning that would eliminate lateral wheel slippage—a highly undesirable phenomenon.

The robot-platform's straight parallel motion is achieved and maintained in a stable condition through software-supported control and synchronization of the same torque and angular velocity on all four independently driven wheels. As for the turning motion of the robot-platform, it presents particular interest from the perspective of the issue under discussion.

A schematic of the robot-platform's turning motion using all steerable wheels is presented in Figure 2.

The previous article (Tarverdyan, 2024) presented the results of the kinematic analysis of the robot-platform's drive module/running gear. Specifically, the relationship of the wheel turning angles was derived:

$$ctg\theta_1 - ctg\theta_2 = \pm\frac{2B}{L}, \qquad (1)$$

where θ_1 is the steering/turning angle of the outer wheel on the front axle ($\theta_1=\theta_3$, θ_3 *is is the steering angle of the outer wheel on the rear axle)*, θ_2 is the steering angle of the inner wheel on the front axle($\theta_2=\theta_4$, θ_4 *is the steering angle of the inner wheel on the rear axle*). The relationship between θ_1 *and* θ_2 expressed in equation (1), forms the basis for programming the control model of the robot-platform's turning motion.

The average turning angle and angular velocity of the turn have also been determined:

$$tg\alpha = \frac{L}{2R} \ \ and \ \ \omega = \frac{V}{R} = \frac{V \cdot 2tg\alpha}{L}. \qquad (2)$$

The diagram of the forces acting on the wheels of the robot platform during turning (Fig. 2.b) has been discussed, and expressions for determining the slip angles of the wheels have been derived.

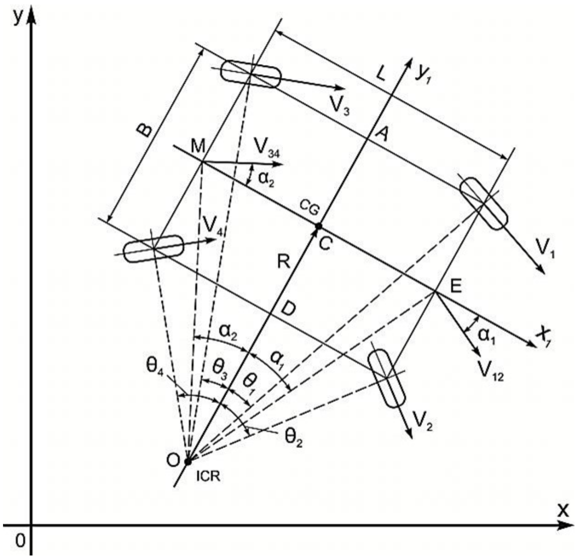

Figure 2. Kinematic diagram of the all-wheel-steering robot platform's turning *(composed by the authors)*.

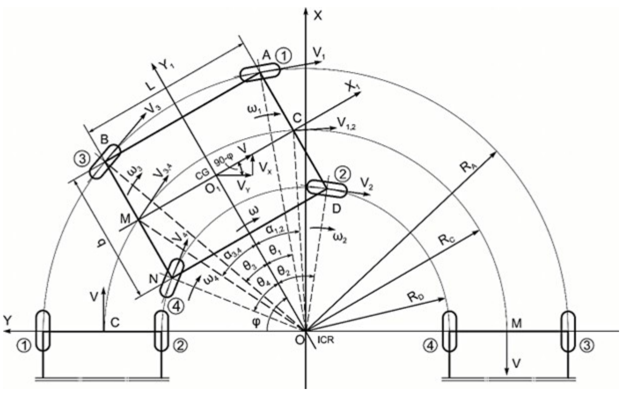

Figure 3. Diagram for determining the angular velocities of the robot platform's wheels during turning *(composed by the authors)*.

$$\varepsilon_1 = \frac{m\upsilon^2}{R'} \cdot \frac{b}{L \cdot K_1} \ \ and \ \ \varepsilon_2 = \frac{m\upsilon^2}{R'} \cdot \frac{a}{L \cdot K_2}. \qquad (3)$$

It has been established that, given the geometric and kinematic parameters of the robot platform under development and design, and assuming the use of rigid wheels, the slip angles of the wheels are approximately 15 times smaller than the average turning angle (Tarverdyan, 2024).

However, it should be noted that tests of the prototype model of the robot platform revealed a significant deviation between the theoretically obtained and experimental data, which naturally implies the need for further research to refine the values used in the programming of the control system.

Results and discussions

As already mentioned, preliminary tests of the prototype model of the robot platform under development showed that, during turning, incorporating the relationship between the rotation angles of the inner and outer wheels into the programming of the driving system is important but not sufficient for developing and designing a reliable driving mechanism that ensures high maneuverability and eliminates the phenomenon of wheel slip. This aspect becomes extremely important, as the resulting optimal parameters are used as the basis for programming the control systems of the robot platform's driving mechanism.

Since all four wheels of the robot platform are controlled independently in terms of both the driving torques applied to the wheel axles and their rotation angles around the vertical axis during turning, the angular velocities of each wheel's rotation around its own axis must also be programmatically controlled.

Otherwise, slippage and spinning/skidding in place may occur, which has a highly negative effect— not so much in terms of potential damage to the soil, but rather due to unacceptable deformations and wear of the driving system components, thereby undermining operational reliability and durability.

Let us assume that the robot platform makes its turn at the end of rows of trees or other crops along a circular arc with a constant velocity V, which is equal to the speed of the aggregate's linear motion (Figure 3).

The angular velocity of the turn is: $\omega = \frac{V}{R_c} \cdot$ Considering that in the case of four steerable wheels, during turning: $V_1 = V_3 = \omega \cdot R_A$ and $V_2 = V_4 = \omega \cdot R_D$, the angular velocities of the wheels around their own axes will be:

$$\omega_1 = \omega_3 = \frac{V_1}{r}, \quad \omega_2 = \omega_4 = \frac{V_2}{r}, \quad or$$
$$\omega_1 = \frac{\omega R_A}{r}; \quad \omega_2 = \frac{\omega R_D}{r}, \qquad (4)$$

where r is the radius of the outer ring of the wheels.

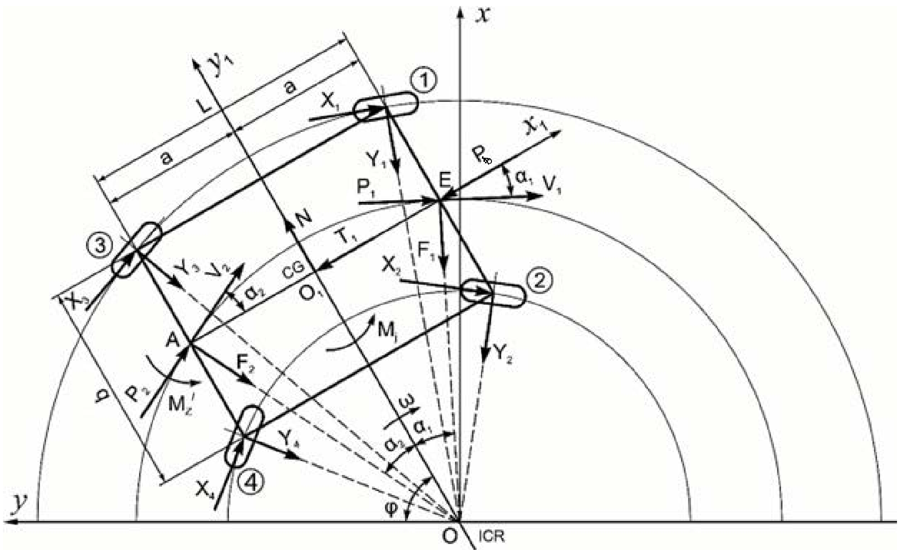

Figure 4. Diagram of the forces acting on the robot platform *(composed by the authors)*.

According to the diagram (Fig. 3):

$$R_A=R_c+0.5B;\;\; R_D=R_c-0.5B \text{ or}$$

$$R_A=0.5Lctg\theta_1;\;\; R_D=0.5Lctg\theta_2.$$

Therefore:

$$\left.\begin{aligned}\omega_1 &= \frac{\omega\cdot 0.5Lctg\theta_1}{r}\\ \omega_2 &= \frac{\omega\cdot 0.5Lctg\theta_2}{r}\end{aligned}\right\}, \quad (5)$$

the relationship between will be:

$$M_j = m\rho^2\frac{d\omega}{dt}. \quad (6)$$

In addition to expression (1), expression (6) must also be incorporated into the programming base.

To determine the force factors acting on the driving system of the robot platform, an analysis was carried out of the forces acting on the wheels, and consequently on the frame during turning.

The task is reduced to determining the total lateral reaction forces F_1 and F_2 acting on the conditionally defined front and rear wheels.

The diagram of the forces acting on the robot platform in the horizontal plane is presented in Figure 4.

During turning, the robot platform is subject to several forces: the tangential forces of all four wheels - X_1, X_2, X_3 and X_4, which result from the driving torques generated by the motors; the lateral (slip) forces of the wheels Y_1, Y_2, Y_3 and Y_4; the normal and tangential components of the inertial forces - N and T; the resultant torque caused by the differences in forces acting on the wheels - $X_i = M_m\frac{K\cdot i_0\cdot\eta}{r_k}$, and the inertial moment - M_j .

The resultant of the tangential forces (X_i) at the contact surface between the wheels and the ground is determined as follows (Litvinov, 1971):

$$X_i = M_m\frac{K\cdot i_0\cdot\eta}{r_k}, \quad (7)$$

where M_m is the driving torque developed by the motor (Nm); K is the torque distribution coefficient (in this case, $K = 1$, as the motors driving the wheels are of equal power and operate independently); i_0 is the gear ratio, in case of direct transmission , $i_0=1$, η- is the transmission efficiency; r_k is the radius of the wheel (in meters).

As mentioned above in the case of rigid wheels, the slip angle (ε) is significantly smaller than the average turning angle (α). Taking this into account, the forces X_1 and X_2, as well as X_3 and X_4, can be represented with their respective resultants P_1 and P_2, which can be applied at points E and A of the frame, respectively. Specifically: $P_1=X_1+X_2$; $P_2=X_3+ X_4$. Using the same logic, the resultant lateral forces (F_1 and F_2) can also be applied at the corresponding points.

To identify the phenomenon of lateral slipping of the robot platform's wheels during turning, it is necessary to examine the conditions of its relative equilibrium. In this context, equilibrium refers to a stable and uniform motion regime.

Let us consider the equilibrium conditions in the coordinate system x_1, o_1, y_1, where the origin is aligned with the center of gravity (CG), x_1 and y_1 axes coincide with the longitudinal and transverse axes of the platform. The equilibrium equations will be:

$$\Sigma X_1=0;\ P_1Cos\alpha_1-F_1sin\alpha_1-T+P_2Cos\alpha_2+F_2sin\alpha_2=P_b. \quad (8)$$

$$\Sigma Y_1=0;\ N-P_1sin\alpha_1-F_1Cos\alpha_1+P_2sin\alpha_2-F_2Cos\alpha_2=0. \quad (9)$$

$\Sigma M_z=0$; (Z axis passes through point o_1 and is perpendicular to the $x_1\ o_1\ y_1$ plane),

$$M_z'+M_j-P_1asin\alpha_1-F_1aCos\alpha_1-P_2asin\alpha_2+F_2aCos\alpha_2=0. \quad (10)$$

In the case of the robot platform's presented diagram and rigid wheels, we can assume that: $\alpha_1=\alpha_2=\alpha$, $P_1=P_2=P$, $F_1=F_2=F$. In that case, expressions (8), (9) and (10) will take the following forms:

$$2Pcos\alpha-T=P_b. \quad (11)$$

$$N-2F_1cos\alpha=0. \quad (12)$$

$$M_z'+M_j-2Pasin\alpha=0. \quad (13)$$

In the last three expressions, it is necessary to present the force components M_z'; M_j; N and T in explicit form.

The moment M_z' results from the parallel displacement of the driving tangential forces of the four driving wheels (X_1, X_2, X_3 and X_4) from their original points of application to points E and A.

As a result of this parallel displacement of forces, additional moments are generated, the values of which will be as follows (see Figs. 3 and 4):

$$\begin{aligned} M'_{z1}&=-X_1\frac{B}{2}\cos\theta_1; \quad M'_{z2}=-X_2\frac{B}{2}\cos\theta_2; \\ M'_{z3}&=-X_3\frac{B}{2}\cos\theta_3; \quad M'_{z4}=-X_4\frac{B}{2}\cos\theta_4. \end{aligned} \quad (14)$$

Considering that the vectors X_1, X_2, X_3 and X_4 are equal in modules, in the moment expressions (14), we can assume them to be equal to each other and denote them as X. Additionally $\theta_1=\theta_3$; $\theta_3=\theta_4$. The total moment M_z' will be determined by the following expression:

$$M_z'=XB(cos\theta_2-cos\theta_1). \quad (15)$$

The inertial moment (M_j) acting on the robot-platform during the turn is determined by the following well-known expression:

$$M_j=m\rho^2\frac{d\omega}{dt}, \quad (16)$$

where m is the total mass of the robot-platform ($m=\frac{G}{g}$, where G is the weight of the robot-platform), ρ is the radius of gyration of the robot-platform's mass m with respect to the vertical axis (Z), $\frac{d\omega}{dt}$ - is the angular acceleration of the robot-platform in the turning zone (in the general solution of the problem, it is assumed that the robot-platform is moving with acceleration).

The inertial forces N and T are determined by the products of the robot-platform's mass (m) and the normal and tangential accelerations of the center of gravity (CG).

The acceleration components of the gravity center have been determined by considering the platform's motion along a circular arc as a rotational movement around the center O within the xOy coordinate system (Figs. 3 and 4). Let us assume that in the current position, the radius from the origin to the center of gravity (OCG) has rotated by an angle φ relative to its initial position (Figs. 3 and 4); in that position, the velocity vector V forms an angle of ($90°-\varphi$) with the Oy axis.

The components of velocity (V) along the y and x axes will be:

$$V_y=Vsin\varphi;\ V_x=Vcos\varphi. \quad (17)$$

Considering that the angular velocity is $\omega=\frac{d\varphi}{dt}$ and the angular acceleration is $\varepsilon=\frac{d\omega}{dt}$, by differentiating expressions (17), we obtain the components of the acceleration of the gravity center.

$$\left.\begin{aligned} W_y&=\frac{dV_y}{dt}=\frac{dV}{dt}\sin\varphi+V\cdot\omega\cdot\mathrm{Cos}\,\varphi \\ W_x&=\frac{dV_x}{dt}=\frac{dV}{dt}\mathrm{Cos}\,\varphi-V\cdot\omega\cdot\sin\varphi \end{aligned}\right\}. \quad (18)$$

By projecting the acceleration components along the y and x axes onto the X_1 and y_1 axes passing through the platform's center of gravity (O_1, or CG), we obtain:

$$\left.\begin{aligned} W_n &= W_y \cos\varphi - W_x \operatorname{Cos}(90-\varphi) \\ W_t &= -W_y \operatorname{Cos}(90-\varphi) - W_x \cos\varphi \end{aligned}\right\}. \quad (19)$$

Substituting the values of W_y and W_x from expressions (18) into (19), and after transformations, we obtain:

$$\left.\begin{aligned} W_n &= V \cdot \omega \\ W_t &= -\frac{dV}{dt} \end{aligned}\right\}. \quad (20)$$

It should be noted that the ‘sign’ of W_t is determined by the nature of the motion—whether it is accelerating or decelerating—but in the problem under consideration, it does not play any role, as it has no effect on the lateral forces.

In the general case, for the inertial forces, we will have:

$$N = m\omega v; \quad T = \pm m\frac{dV}{dt}. \quad (21)$$

After determining the force factors, by considering the equilibrium conditions of the system with respect to the vertical axes passing through points A and E of the platform (Fig. 4), we determine the lateral forces F_1 and F_2:

$$\Sigma M_{z(A)} = M_z' + M_j + Na - F_1 L\cos\alpha - P_1 L\sin\alpha = 0,$$

wherefrom:

$$F_1 = \frac{M_z' + M_j + Na - P_1 L\sin\alpha}{L\cos\alpha}. \quad (22)$$

$$\Sigma M_{z(E)} = M_z' + M_j - Na - P_2 L\sin\alpha + F_2 L\cos\alpha = 0,$$

wherefrom:

$$F_2 = \frac{Na + P_2 L\sin\alpha - M_z' - M_j}{L\cos\alpha}. \quad (23)$$

The slip angles of the front and rear wheels of the robot-platform will be:

$$\varepsilon_1 = K \cdot F_1; \quad \varepsilon_2 = K \cdot F_2,$$

where K is the slip coefficient of the wheels.

Thus, as a result of a more detailed force analysis of the robot-platform, refined expressions (22) and (23) have been obtained for determining the lateral forces of the wheels, which will make it possible to introduce appropriate adjustments in the programming process of the running gear control system, with the aim of reducing the lateral forces acting on the running gear.

Conclusions

1. To achieve stable turning performance of the multifunctional horticultural robot platform, independent wheel-control programming is required. The control logic is defined strictly by analytical relationships between the wheel-steering angles and their angular velocities.
2. Dynamic analysis of the platform’s turning motion yielded analytical expressions that guide for designing of the chassis and suspension system. These results eliminate wheel lateral skidding and ensure reliable and durable operation.

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Assessment of the Quantitative Impact of the Russian Ruble Exchange Rate on Particular Indicators Characterizing the Development of the RA Agriculture

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ABSTRACT

Among the factors influencing the indicators characterizing the development of agriculture in the Republic of Armenia (RA), the exchange rate of the Russian ruble stands out, given that a significant portion of Armenia's agricultural exports and the import of essential material resources are directed to and sourced from Russia. A comprehensive understanding of the impact of the Russian ruble exchange rate on these indicators is impossible without a quantitative assessment. This aspect has so far received insufficient attention in the economic literature. In this article, such an assessment was carried out using a regression model. As a result, indicators were identified – namely, the gross output value of agriculture, the level of marketability, and the import volume of product of agricultural origin – that exhibit a statistical relationship with the Russian ruble exchange rate. Additionally, a regression-correlation analysis was performed to characterize the individual impact of this factor, and appropriate conclusions were drawn based on the results. At the same time, substantiated approaches were proposed to mitigate the negative effects of fluctuations in the Russian ruble exchange rate on specific agricultural development indicators in the RA. These approaches include the development of certain types of local agricultural production, import substitution, and the diversification of both supply and export markets.

Introduction

It is known that the exchange rate plays an important role in the economic activity of any country. It is quite acceptable that "The exchange rate is an important factor in the development of the national economy of any state. In addition to the financial market, this factor also affects other sectors of the economy, since financial means themselves are the only measure of the value of goods and services"

(Shilets, et al., 2018). Moreover, the role of the currency exchange rate gains greater importance due to its impact on the export sector of the economy, domestic production, services, investments, as well as the pricing of goods within the country (Burnusuzyan, 2014). As for the result of the exchange rate impact, it is acceptable that the effect of the exchange rate in a given country is determined by the characteristics of its economy: the composition of exports and imports, the level of development of financial markets, the debt burden in foreign currency, and the availability of unused production resources. Herewith, it should be considered that economic conditions are not immutable, the nature and extent of the exchange rate impact can change significantly under the influence of structural changes (for example, as a result of implementation of economic reforms: the change of the currency exchange rate regime, the introduction of budgetary rules, etc.) and external factors (sanctions, interaction with economic unions) (Babakin, 2022). The exchange rate of the Russian ruble of interest to us is no exception, the impact of which is felt not only within the territory of the Russian Federation, but also to a certain extent outside its borders. That external influence, of course, is not equivalent to the influence of the US dollar. It is correctly stated, that the Russian ruble does not occupy the same positions in the international arena as the American dollar. Currently, it is classified as a domestic currency, circulating mainly within its own country. The Russian ruble doesn't have high international demand also because of the insufficient capacity of the financial market in Russia (Vsyakikh, et al., 2015).

Moreover, the Russian economy is currently experiencing a significant weakening of the Ruble (Vsyakikh, et al., 2015). Highlighting the necessity to strengthen the ruble exchange rate, some authors consider sanctions from Western countries, which may result in continued capital outflows, as well as changes in the currency regulation of the Russian market, as obstacles to this. In their opinion, strengthening the ruble requires maintaining high oil prices and attracting new investors from the markets of friendly countries (Zhihong, 2022).

Despite the relatively limited scale of the impact of the Russian ruble exchange rate, its impact on the economies of the EAEU countries is still quite noticeable. Our republic, which has quite close economic ties with the Russian Federation, is no exception. Moreover, most of the RA foreign trade turnover falls on that country. In this context, the sensitivity of Armenia's open economy, characterized by limited resource capabilities compared to many countries of the world, to fluctuations in the Russian ruble exchange rate, becomes understandable. The impact of these fluctuations is felt on the entire economy, its particular spheres, sectors, and indicators. This impact is particularly significant on agriculture, a considerable portion of the export of product and the import of necessary material resources of which falls on Russia. The mentioned impact is not limited to export and import volumes and also applies to other indicators, especially production, investment volumes, profitability. In this context, it is important to identify not only the direction of that impact on the specified indicators, but also to determine its magnitude through quantitative assessment. The latter allows to form a more complete picture not only of the mentioned impact, but also to separate those indicators on whose magnitude fluctuations in the Russian ruble exchange rate have greater impact. In this context, the assessment of the quantitative impact of the Russian ruble exchange rate on the magnitude of particular indicators characterizing the development of the RA agriculture becomes relevant.

Materials and methods

We have considered the Russian ruble exchange rate as a factor indicator and have tried to separately examine its impact on various indicators characterizing the development of the RA agriculture.

Within the framework of the research, the problem is posed to clarify the range of indicators between which and the Russian ruble exchange rate there is a statistical relationship, as well as to perform a regression-correlation analysis characterizing the influence of the mentioned factor (which we carried out using the MS Excel program).

The econometric calculations we performed show that there is a statistical relationship between not all output indicators important for the RA agriculture and the Russian ruble exchange rate. Therefore, we focused on those indicators in case of which that connection exists. We are talking about gross output value of agriculture, marketability level, import volume of product of agricultural origin. We have examined the quantitative impact of the Russian ruble on the listed performance indicators using the long-term data (2004-2024) presented in Table 1, reflecting their values.

The separated quantitative impact of the Russian ruble on the performance indicators reflected in Table 1 was assessed using a regression model, as a result of calculating the correlation, regression, and determination coefficients.

Table 1. Russian ruble exchange rate, gross output value of agriculture, marketability level and import volume of product of agricultural origin, 2004-2024*

Years	Indicators			
	Average annual exchange rate of 1 Russian ruble, dram[1]	Gross output value of agriculture, billion drams[2,3]	Marketability level of agriculture, %[4]	Import volume of product of agricultural origin, thousand US dollars[5]
2004	18.52	504.1	55.7	278173.5
2005	16.19	493.0	55.8	315939.5
2006	15.29	555.9	54.2	343274.4
2007	13.36	633.9	57.3	538386
2008	12.35	628.1	54.6	755836.2
2009	11.50	555.7	56.2	611950
2010	12.32	636.7	55.8	675977.7
2011	12.70	795.0	56.0	781227.3
2012	12.94	841.5	56.1	812549.9
2013	12.88	919.1	56.4	845956.1
2014	10.98	993.5	56.2	810763.2
2015	7.89	945.4	58.6	658086.9
2016	7.19	878.5	57.3	633672.3
2017	8.28	908.6	56.7	726667.5
2018	7.73	892.9	56.5	804431.1
2019	7.43	853.3	56.3	872598.7
2020	6.79	833.3	57.2	834229.9
2021	6.84	934.4	57.0	964620.9
2022	6.48	1021.7	57.3	1366641.5
2023	4.66	948.3	57.2	1306833.5
2024	4.25	958.8	57.1	1488787.9

Note: 1. Socio-economic situation. 2005.-page 151; 2006.- page 143; 2007.- page 134; 2008.- page 131; 2009.- page 125; 2010.- page 127; 2011.- page 131; 2012.- page 127; 2013.- page 125; 2014.- page 130; 2015.- page 124; 2016.- page 124; 2017.- page 127; 2018.- page 134; 2019.- page 137; 2020.- page 141; 2021.- page 145; 2022.- page 152; 2023.- page 172; 2024.- page 174; 2025.- page 157.

2. Statistical yearbook of Armenia. 2008.- page 275; 2010.- page 298; 2015.- page 290; 2020.- page 344; 2023.- page 363; 2024.- page 371.

3. Socio-economic situation. 2025.- page 22.

4. Realization (Use) of Agricultural Product... 2007.- page 2; 2011.- page 2; 2016.- page 2; 2020.- page 4; 2025.- page 4.

5. Socio-economic situation. 2005.- page 149; 2007.- page 130; 2009.- page 122; 2011.- page 125; 2013.- page 120; 2015.- page 119; 2017.- page 122; 2019.- page 132; 2021.- page 140; 2023.- page 157; 2025.- page 141.

*Composed by the author based on data from the SC of the RA, www.armstat.am.

Results and discussions

First, let us present the results of the assessment of the quantitative impact of the average annual exchange rate of the Russian ruble on the gross output value of agriculture, which are reflected in Table 2.

Table 2. Results of the regression-correlation analysis of the impact of the average annual exchange rate of the Russian ruble on the gross output value of agriculture*

Indicators	Results
Correlation coefficient	R=-0.795
Coefficient of determination	R_2=0.632
Regression model	$\hat{y}_t = 1159.8\text{-}35.208x_t$
Elasticity coefficient	E=-0.456
Significance of the regression coefficient	a_1 (p-value=1.68E-05)
Model significance	F=32.56 (signif.=1.68E-05)

*Composed by the author based on the results of regression-correlation analysis conducted using MS Excel.

Analyses show that an increase in the average annual exchange rate of the Russian ruble by 1 dram leads to a decrease in the gross output value of agriculture of the Republic of Armenia by 35.208 billion drams. That is due to the increase in the prices of imported material resources necessary for agricultural production (in particular, fertilizers, pesticides, diesel fuel, etc.) and a certain decrease in the physical volumes of their import as a result of the appreciation of the Russian ruble.

The connection between the analyzed indicators is strong and inverse (R=-0.795) (Eliseeva, et al., 2010). According to the coefficient of determination (R^2=0.632), 63.2% of the fluctuations in the gross output value of agriculture are due to fluctuations in the average annual exchange rate of the Russian ruble, and the rest are due to not being included in the model and other random factors. The model is significant (signif. F<0.05).

Let us also present the elasticity coefficient: E=-0.456 %. Thus, a 1% increase in the average annual exchange rate of the Russian ruble leads to a decrease in the gross output value of agriculture by 0.456 %.

The impact of the Russian ruble exchange rate on the gross output of agriculture of RA is caused by the increase or decrease in the volumes of exports and production of agricultural products, the corresponding impact of the appreciation or depreciation of that foreign currency on the prices of imported material resources necessary for agricultural production and the physical volumes of their import. The relationship between the gross output of agriculture of RA and the Russian ruble exchange rate is obvious from this impact. In connection with the mentioned impact, let us add that the appreciation or depreciation of the Russian ruble also affects the volume of exports of material resources necessary for agricultural production from the Russian Federation to our country or the volume of imports of Armenian agricultural products to the Russian Federation. In this context, it is acceptable that "The decline in the national currency exchange rate leads to a decrease in the prices of national goods in the world market, which contributes to the growth of exports. The prices of foreign goods expressed in the national currency become high, as a result of which imports are reduced" (Shibaeva et al., 2007).

The results of the assessment of quantitative impact of the average annual exchange rate of the Russian ruble on the marketability level of agriculture are reflected in Table 3.

Analyses show that an increase in the average annual exchange rate of the Russian ruble by 1 dram leads to a decrease in the marketability level of agriculture by 0.163 percentage point. Under conditions of the Ruble appreciation, the prices of imported material resources necessary for agricultural production rise, which in turn reduces the physical volumes of imports and, as a result, the volumes of agricultural production reduce. The latter in turn has an adverse effect on the marketability level.

The relationship between the analyzed indicators is average and inverse (R=-0.656) (Eliseeva, et al., 2010).

According to the coefficient of determination (R^2=0.430), 43.0% of the fluctuations in the marketability level of agriculture are due to fluctuations in the average annual exchange rate of the Russian ruble, and the rest are due to not being included in the model and other random factors. The model is significant (signif. F<0.05).

The elasticity coefficient: E =-0.030 %. So, a 1% increase in the average annual exchange rate of the Russian ruble leads to a decrease in the marketability level of agriculture by 0.030%.

The impact of the Russian ruble exchange rate on the marketability level of agriculture of RA is caused by the impact on the prices of imported material resources necessary for agricultural production, the physical volumes of their import and the volumes of mentioned production, which influences the marketability level of the sector. As noted, under conditions of the Ruble appreciation, the prices of imported material resources necessary for agricultural production rise, because of this the physical volumes of import decrease and, as a result, the volumes of agricultural production reduce.

Table 3. Results of the regression-correlation analysis of the impact of the average annual exchange rate of the Russian ruble on the marketability level of agriculture*

Indicators	Results
Correlation coefficient	$R=-0.656$
Coefficient of determination	$R^2=0.430$
Regression model	$\hat{y}_t = 58.14-0.163x_t$
Elasticity coefficient	$E=-0.030$
Significance of the regression coefficient	a_1(p-value=0.001)
Model significance	F=14.39 (signif.=0.001)

* Composed by the author based on the results of regression-correlation analysis conducted using MS Excel.

Table 4. Results of the regression-correlation analysis of the impact of the average annual exchange rate of the Russian ruble on the import volume of product of agricultural origin*

Indicators	Results
Correlation coefficient	$R=-0.802$
Coefficient of determination	$R^2=0.643$
Regression model	$\hat{y}_t = 1444313.6-64200.9x_t$
Elasticity coefficient	$E=-0.846$
Significance of the regression coefficient	a_1(p-value=1.22E-05)
Model significance	34.29 (signif.=1.22E-05)

*Composed by the author based on the results of regression-correlation analysis conducted using MS Excel.

The latter has an adverse effect on the marketability level. Under the condition of the depreciation of the Ruble against the Armenian dram, the exact opposite occurs. From the above-mentioned impact of the Russian ruble exchange rate on the marketability level of the agriculture of RA the relationship between them is obvious.

Let us present the results of the assessment of the quantitative impact of the average annual exchange rate of the Russian ruble on the import volume of product of agricultural origin, which are reflected in Table 4.

Analyses show that an increase in the average annual exchange rate of the Russian ruble by 1 dram leads to a decrease in the import volume of product of agricultural origin by 64200.9 thousand US dollars. This is explained by the increase in the price of imported Russian product due to the appreciation of the Ruble, giving preference to similar or local product of other countries.

The relationship between the analyzed indicators is strong and inverse (R=-0.802) (Eliseeva, et al., 2010).

According to the coefficient of determination (R^2=0.643), 64.3% of the fluctuations in the import volume of product of agricultural origin are due to fluctuations in the average annual exchange rate of the Russian ruble, and the rest are due to not being included in the model and other random factors.The model is significant (signif. F<0.05).

The elasticity coefficient: E=-0.846%. So, a 1% increase in the average annual exchange rate of the Russian ruble leads to a decrease in the import volume of product of agricultural origin by 0.846%.

The impact of the Russian ruble exchange rate on the import volume of product of agricultural origin is manifested in the corresponding decrease or increase in the volume as a result of the appreciation of that foreign currency or its depreciation against the Armenian dram. The relationship between the import volume of product of agricultural origin and the Russian ruble exchange rate is obvious from this impact.

The results of the constructed regression models are considered important for the development of substantiated approaches to mitigate the negative impact of Russian ruble exchange rate fluctuations on particular indicators characterizing the development of agriculture of the RA and to make the most of the opportunities provided by the positive ones. Making the most of the mentioned opportunities isn't possible without the development of certain types of local agricultural production, import substitution, diversification of supply and export markets. The development and import substitution of certain types of local agricultural production (in particular, poultry and pork, grain crops, their seeds, compound feeds, etc.) makes it possible to reduce import dependence and the risks of negative impacts of fluctuations in the Russian ruble exchange rate. All of this can be significantly contributed to by state-private sector cooperation, the development of local seed and feed production within the framework of support programs aimed at local agricultural production and import substitution, etc.

In the event of an appreciation of the Russian ruble exchange rate as a result of diversification of supply markets, it becomes clearly expedient to import the same product from other countries at more affordable prices, and in the event of a decrease in the exchange rate as a result of diversification of export markets, it is more profitable to export products with export potential.

Conclusion

As a result of the regression-correlation analysis of the quantitative impact of the Russian ruble exchange rate on indicators characterizing the development of agriculture of the RA, we have come to the following conclusions, as well as proposed approaches aimed at mitigating the risks associated with that exchange rate:

- The performed calculations and analyses have shown that an increase in the average annual exchange rate of the Russian ruble by 1 dram leads to a decrease in the gross output value of agriculture of the Republic of Armenia by 35.208 billion drams. Such dependence is due to the increase in the prices of imported material resources necessary for agricultural production (in particular, fertilizers, pesticides, diesel fuel, etc.) as a result of the appreciation of the Russian ruble. The latter in turn has an adverse effect on the gross output value of the sector. According to calculations, 63.2% of the fluctuations in the gross output value of agriculture are due to fluctuations in the average annual exchange rate of the Russian ruble.
- According to calculations, an increase in the average annual exchange rate of the Russian ruble by 1 dram leads to a decrease in the marketability level of agriculture by 0.163 percentage point. 43.0% of the fluctuations in the marketability level of agriculture are due to fluctuations in the average annual exchange rate of the Russian ruble.
- According to the results of econometric research, an increase in the average annual exchange rate of the Russian ruble by 1 dram leads to a decrease in the import volume of product of agricultural origin by

64200.9 thousand US dollars (as a result of a 1% increase in the exchange rate, the decrease in this indicator is 0.846%). 64.3% of the fluctuations in the import volume of product of agricultural origin are due to fluctuations in the average annual exchange rate of the Russian ruble.

- Research show that the risks associated with the Russian ruble exchange rate can be mitigated as much as possible by ensuring favorable conditions for the development of certain types of local production, import substitution, diversification of supply and export markets.

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Dynamics of Karate Zeon and Calypso Detoxification in Carrot Roots and their Impact on Crop Quality

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ABSTRACT

The dynamics of detoxification of the pesticides Karate Zeon (lambda-cyhalothrin) and Calypso (thiacloprid) in carrot roots, as well as their impact on the main quality indicators of the crop, were studied. The experiments were conducted in the Mantash community of Shirak province, where carrot crops were sprayed with Karate Zeon (at a rate of 0.2 L/ha) and Calypso (0.1–0.15 L/ha). Following the treatments, the dynamics of pesticide detoxification in the root crops were monitored, and at harvest, the main quality indicators of both treated and untreated carrots were assessed. The results showed that Calypso detoxifies more rapidly than Karate Zeon. Fifteen days after application, the concentration of Calypso in carrot roots had decreased to the maximum residue level (MRL) of 0.05 mg/kg. In contrast, residues of Karate Zeon at this point still exceeded the permissible limit by more than tenfold (MRL = 0.01 mg/kg). However, by the end of the “waiting period” - 20 days after application - both pesticides had fully dissipated, and no residues were detected in the carrot roots. Under the conditions of the Shirak region, the use of these pesticides in carrot cultivation does not negatively affect the main quality indicators of the crop. On the contrary, a statistically significant accumulation of β-carotene was observed in the treated roots.

Introduction

Carrots *(Daucus carota L.)* are among the most important root vegetables cultivated worldwide. They are rich in essential nutrients, including vitamins, carotenoids, minerals (such as potassium, magnesium, iron, phosphorus, and calcium), soluble carbohydrates, and dietary fiber. Of particular note is their high content of β-carotene, a precursor of vitamin A, which plays a vital role in human health. β-carotene and vitamin A possess strong antioxidant properties, helping to protect cellular membranes - particularly in the brain - against oxidative damage by neutralizing reactive radicals derived from polyunsaturated fatty acids and hydrogen. Carrots are also an important source of nicotinic acid (vitamin PP), a key coenzyme involved in redox reactions, metabolic regulation, and the restoration of damaged tissues (Victoria-Campos, et al., 2022; Miazek, et al., 2022; Kim, et al., 2023; Tufail, et al., 2024; Tian, et al., 2024).

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Like all root vegetables, carrots are susceptible to damage from various pests, which can significantly impact both the yield and quality of the crop.

Calypso and Karate Zeon insecticides are among the preparations used to control the main carrot pests, the carrot fly and the leafhopper.

Carrots, as root vegetables, accumulate agrochemical residues differently from foliar crops, making it essential to investigate how systemic and non-systemic insecticides behave within their tissues over time. Moreover, beyond their pesticidal role, such chemicals may interact with plant metabolic pathways, influencing the synthesis of important bioactive compounds such as antioxidants and sugars.

This study aims to evaluate the detoxification dynamics and physiological effects of Calypso and Karate Zeon in carrot roots following foliar application. Special attention is given to their impact on key quality indicators, including ascorbic acid, β-carotene, and soluble sugars. By comparing these two insecticides, we aim to clarify the trade-offs between efficacy, residue safety, and potential nutritional implications in carrot cultivation.

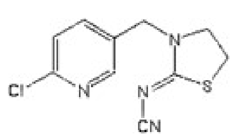
Materials and methods

The field trials were carried out in the Mantash community of the Shirak region. Carrot crops were treated with Calypso (0.15 L ha^{-1}) and Karate Zeon (0.20 L ha^{-1}) to control carrot flies *(Psila rosae)* and leafhoppers *(Empoasca spp.)*.

Calypso (active ingredient: thiacloprid)

Calypso is a systemic insecticide designed to control a wide range of pests in vegetables, field crops, orchards, and herbs. Calypso acts as both a contact and stomach poison, exhibiting systemic activity. It is effective at relatively low application rates and is known for its excellent compatibility with plants.

Structural formula:

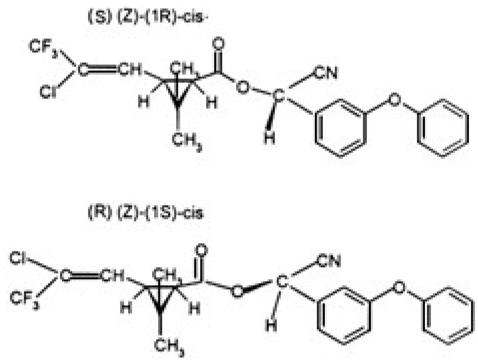


N-[3-(6-chloropyridin-3-ylmethyl)-thiazolidin-2-ylidene]-cyanimide(IUPAC).

Karate Zeon (active ingredient: lambda-cyhalothrin)

A pyrethroid insecticide intended for the protection of potato, grain, technical, vegetable, fruit, and many other crops from a complex of leaf-gnawing and sucking pests, including mites. It is a fast-acting, broad-spectrum contact insecticide. It works by disrupting the function of sodium channels in insect nerve cells, leading to paralysis and death.

Structural formula:



(S,R)--cyano-3-phenoxybenzoic (1R,1S)-cis-3-(2-chloro-3,3,3-terfluoropropenyl)-2,2-termethyl-cyclopropanecarboxylate (1:1)

The chemical group and physical properties of these compounds are presented in Table 1.

Table 1. Chemical Group and Physical Properties of Thiacloprid and Lambda-Cyhalothrin*

Property	Thiacloprid (Calypso)	Lambda-cyhalothrin (Karate Zeon)
Chemical group	Neonicotinoid	Pyrethroid
Water solubility	High (~184 mg/L)	Very low (~0.005 mg/L)
Lipophilicity	(Log Kow) ~1.26 (moderate)	~6.9 (very high)
Volatility	Low (≈ 3.3×10^{-7} Pa)	Low (≈ 2×10^{-5} Pa)

The values come from EFSA, FAO, and PubChem pesticide profiles

*Composed by the authors.

To determine the residues of the insecticides mentioned, carrot root samples were collected at 1.5, 10, 15, and 20 days after spraying.

The main qualitative indicators of carrots were assessed at the peak of ripening. In carrot roots, titratable acidity was measured by titration, sugar content by Bertrand's method, ascorbic acid by Murry's method, and β-carotene by the colorimetric method (Yermakov, et al., 1987).

Residual amounts of Karate Zeon and Calypso in the root crops were determined using TLC on Silufol plates (Guideline, 1992).

Statistical Analysis: All experiments were performed in quadruplicate, and the results are presented as Mean ± SD (Standard Deviation). Statistical comparisons were conducted using one-way ANOVA with a significance level of $p \leq 0.05$. Significant differences between treatments for various traits were assessed using the least significant difference (LSD) method Tukey HSD analysis.

Results and discussions

Studies on the detoxification dynamics of Karate Zeon and Calypso showed that within the first five days after application, their dissipation rates in carrot roots are nearly identical (Table 2).

During the first five days after application, residue levels of both pesticides decreased by 38.3–38.9 % compared to the first day. This rate of decline is typical for many pesticides, as plants recognize these compounds as foreign substances and activate defense mechanisms - such as enhanced metabolism, increased enzyme activity, and physiological responses - to neutralize them. Over time, this response diminishes as the residues no longer pose a significant threat to plant function (Zhang, et al., 2024).

Although both insecticides exhibited some similarity in early-phase detoxification kinetics - particularly within the first 24 hours - their long-term residue dynamics diverged markedly. Fifteen days after application, Calypso residues in carrot roots had decreased to the maximum permissible level (MRL = 0.05 mg/kg, ГН 1.2.3539-18), while residues of Karate Zeon remained over ten times higher than its MRL (0.01 mg/kg). Nevertheless, by day 20 - the standard pre-harvest interval - residues of both compounds were undetectable, indicating eventual detoxification through distinct pathways.

The observed detoxification dynamics of Calypso in carrots align with previous reports highlighting the rapid dissipation of thiacloprid in various crops. In Serbia, field trials revealed a 72 % decline in pepper fruit residues within two days post-application (Lazić, 2015), and studies on cowpeas indicated a short half-life of 1.1–1.5 days (Li, 2022), underscoring the compound's fast degradation rate.

These differences in detoxification patterns and physiological behavior reflect the distinct chemical nature, systemic properties, and modes of action of the two insecticides. The rapid decline of thiacloprid, particularly characteristic of systemic insecticides like Calypso, is closely tied to plant detoxification physiology. Enzymatic activity is most pronounced in the leaves, where systemic compounds are initially translocated. As thiacloprid reaches root tissues, the reduced metabolic activity slows its breakdown. In contrast, non-systemic insecticides such as Karate Zeon may bind to soil particles and be taken up passively by the roots, leading to prolonged persistence in root tissues. Over time, their concentrations decline through slower metabolic degradation, dilution from root growth, or environmental dissipation.

At the biochemical level, the degradation of lambda-cyhalothrin - the active ingredient in Karate Zeon - occurs through photolysis, hydrolysis, microbial metabolism, and plant enzymatic detoxification. The compound undergoes typical degradation routes involving soil and plant cytochrome P450 monooxygenases, while microbial species such as Pseudomonas, Serratia, and Bacillus spp. further catalyze its breakdown. These processes also transform its major metabolite, 3-phenoxybenzoic acid (3-PBA), contributing to overall detoxification. (He, et al., 2008; Djouaka, et al., 2018).

In contrast, thiacloprid is metabolized primarily through plant-mediated enzymatic pathways involving esterases, cytochrome P450s, and glutathione S-transferases (GSTs), ensuring more rapid detoxification (Homayoonzadeh, et al., 2021).

Table 2. Dynamics of Karate Zeon and Calypso detoxification in carrot roots (mg/kg)*

Preparation	Days after treatment				
	1	5	10	15	20
Karate Zeon	0.58 ± 0.07	0.36 ± 0.06	0.23 ± 0.06	0.12 ± 0.04	0.0
Calypso	0.52 ± 0.02	0.32 ± 0.01	0.08 ± 0.06	0.02 ± 0.01	0.0

*Composed by the authors.

Table 3. Effect of Karate Zeon and Calypso on the Key Qualitative Indicators of Carrot Roots*

Variant	Titratable acidity, %	β-Carotene, mg/100g	Ascorbic acid, mg/100g	Soluble sugars, %		
				Mono-	Di-	Total
LSD**	0.03	0.08	0.03	0.19	0.32	
Control	0.17±0.008	3.02±0.06	0.30±0.04	4.2±0.26	5.2±0.32	9.4
Karate Zeon	0.15±0.007	3.63±0.11	0.43±0.03	3.9±0.17	5.8±0.37	9.7
Calipso	0.14±0.004	3.99±0.11	0.35±0.04	4.2±0.26	5.6±0.51	9.8

*Note. LSD** = Least Significant Difference at p ≤ 0.05. Values exceeding the LSD indicate statistically significant differences compared to the control.*

*Composed by the author.

Beyond residue dynamics, both insecticides influenced key biochemical and quality parameters in carrot roots. They induced modest increases in soluble sugars - mainly disaccharides (Table 3) - and more pronounced elevations in antioxidant levels. Among these, ascorbic acid and β-carotene were particularly responsive: relative to control, ascorbic acid rose by approximately 17 % under Calypso and 43 % under Karate Zeon, while β-carotene increased by 32 % and 20 %, respectively ($p = 0.001$ and $p = 0.0013$).

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These antioxidant changes form part of the plant's adaptive defense to oxidative stress, mitigating reactive oxygen species (ROS) generated during pesticide exposure. The accumulation of ascorbic acid and carotenoids indicates activation of secondary metabolite biosynthesis, a phenomenon widely reported in previous studies (Xu, et al., 2023; Wu, P., 2024; Đurić, et al., 2024).

The distinct antioxidant profiles reflect the contrasting physicochemical and physiological properties of the two insecticides. Calypso, a systemic neonicotinoid, distributes throughout plant tissues, producing a mild and transient stress that preferentially enhances β-carotene synthesis - consistent with the role of membrane-bound antioxidants in protecting against systemic perturbations. Supporting this, Dar (2015) observed that low doses of neonicotinoids increased both enzymatic and non-enzymatic antioxidants in mustard.

By contrast, Karate Zeon, a contact pyrethroid, causes more localized oxidative stress at the site of application, leading to a stronger upregulation of ascorbic acid, a rapidly acting, water-soluble ROS scavenger (Wu, 2024). The differential activation of antioxidant systems likely reflects variations in stress intensity, localization, and metabolic distribution between the two compounds.

Although both treatments slightly increased sugar content, these changes were not statistically significant and similar in magnitude. The effect may arise from temporary adjustments in carbohydrate metabolism or compensatory increases in photosynthetic activity under chemical stress conditions.

Conclusion

The comparative assessment of Karate Zeon (lambda-cyhalothrin) and Calypso (thiacloprid) reveals clear differences in their detoxification dynamics and impact on the biochemical quality of carrot roots. While both insecticides initially decline at similar rates, Calypso undergoes faster and more efficient detoxification due to its systemic nature, higher water solubility, and compatibility with plant detoxification enzymes. In contrast, Karate Zeon, being non-systemic and more persistent, detoxifies more slowly and remains in carrot roots longer.

Both insecticides cause mild physiological stress, as evidenced by increased levels of ascorbic acid and β-carotene in treated roots. These antioxidant responses suggest an adaptive defense mechanism that may also improve the nutritional quality of carrots. Calypso is more effective in promoting β-carotene in carrot root crops, while Karate Zeon has a stronger effect on ascorbic acid accumulation. A slight increase in soluble sugars is also observed, mainly due to the content of disaccharides.

These findings highlight the importance of considering both residue dynamics and physiological effects when selecting plant protection against carrot pests.

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Rubus Vulgaris Weihe & Nees and *Rubus Idaeus L.* in the Wild and in Agroecosystems of Lori Region

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ABSTRACT

Rubus vulgaris Weihe & Nees and *Rubus idaeus L.* are valuable berry crops characteristic of both Armenia’s natural ecosystems, including the Lori region, and agroecosystems. Their cultivation plays a significant role in preserving biodiversity in the natural habitat and in promoting sustainable agricultural development in agroecosystems (http://agroecoarm.com). Studying the growth of these plants in natural and agroecological conditions allows for the development of adapted agrotechnologies that ensure high productivity, stability, and efficiency (http://agroecoarm.com). The growth characteristics of *Rubus vulgaris* and *Rubus idaeus* were studied in both wild habitats and agroecosystems in the Lori region. Specifically, biometric indicators of leaves and root pressure were examined, and certain morphological traits of the two species were compared. Understanding the dynamics of root pressure can help regulate the plants water regime, enhancing leaf surface area, which in turn promotes increased photosynthetic activity and higher synthesis of organic compounds.The analysis of biometric data from vegetative organs confirmed that *Rubus vulgaris* develops leaves more slowly, with dense and thorny stems, whereas *Rubus idaeus* grows faster and demonstrates more efficient fruiting in agroecosystems. Phenological studies showed that *Rubus vulgaris* begins its vegetation phase relatively late, while *Rubus idaeus* flowers and fruits earlier. Comparative analysis of physiological processes revealed that raspberry has a more active adaptation to low-water conditions, demonstrated by higher root pressure.

Introduction

Rubus vulgaris Weihe & Nees and *Rubus idaeus L.* are valuable fruit-bearing cultivars characteristic both of natural ecosystems in Armenia, including the Lori region, and of agroecosystems. Cultivating these species is highly significant both for preserving biodiversity in the wild and for developing sustainable agriculture systems. Their fruits are rich in vitamins, antioxidants, and beneficial bioactive compounds, leading to high market demand (Gevrenova, at al., 2024). In Armenia, fruits of these plants are used both fresh and processed (juices, jams, dried fruits), which supports local economy and provides rural employment (Vardanyan, 2005).

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By studying their growth conditions in the wild and in agroecosystems, tailored agro-technologies can be developed to ensure high yields and reliable, sustainable cultivation. Recently, especially since the start of the 21st century, these species have expanded into locations where they previously did not occur. This shift is attributed to climate change, deforestation, and alterations in land use. In Lori region increased distribution of these species has particularly been observed due to changes in forest structure and climate (Gabrielian and Zohary, 2004).

Climate change (CC) refers to long-term alterations in average temperature and precipitation at global or regional scales. It's a natural process. Over the past 50 years such changes have become most tangible. Each of the last three decades has been successively warmer than any preceding decade since 1850 (www.nihcm.org).

Currently, the global temperature is approximately 1 °C above the pre-industrial average and is increasing at about 0.2 °C per decade. Despite uncertainties in climate projections, it is estimated that by the end of the 21st century, the global mean temperature may rise by 1.4–5.8 °C above pre-industrial levels (World Bank Group, November 2024).

Considering these factors, studying the growth of dewberry and raspberry in the Lori region holds not only theoretical but also practical importance - supporting biodiversity conservation, sustainable agricultural development, and activation of local economic potential. Cultivation of these species can also advance organic farming by reducing chemical fertilizers and pesticides. Rubus vulgaris Weihe & Nees and *Rubus idaeus L.* possess naturally high resistance, which makes them tolerant to pests and diseases. Due to this the need for pesticide application during the cultivation of *Rubus vulgaris Weihe & Nees* and *Rubus idaeus L.* is reduced. In addition, these plants have a well-developed root system that enables them to absorb nutrients from the deeper layers of the soil, by decreasing the necessity for chemical fertilizers. These plants can be integrated into permaculture and agroforestry systems, helping maintain soil fertility and ensure sustainable production (https://link.springer.com).

Materials and methods

The Lori region possesses favorable climatic conditions for the growth of studied species; however, climate change may pose serious challenges.

The aim of this study is to investigate the growth characteristics of *Rubus vulgaris Weihe & Nees* and *Rubus idaeus L.* in the wild and agroecosystems of the Lori region (www.fao.org). To assess the growth features of the studied plants, we performed biometric measurements of the leaves and determined the root pressure, which will make it possible to evaluate the absorption of water by plants, while the biometric measurements of the leaves will allow us to asses their growth. These species belong to the Rosaceae family, genus *Rubus L.* The genus includes over 600 perennial species, widespread in Europe, Asia, North and South America, and parts of Africa, growing in both wild and cultivated environments (Vardanyan, 2005; Tutin, et al., 1968). Recent literature notes approximately 700 Rubus species, including blackberry, raspberry, and related hybrids, mostly shrubs or subshrubs (Graham, et al., 2018; Meng, et al., 2022).

Table 1.*

Characteristic	*Rubus vulgaris Weihe & Nees / Rubus fruticosus agg.*	*Rubus idaeus L.*
Life form	Perennial thorny shrub	Shrub with biennial stems
Stems	Thorny, often flexible and semi-arched	Upright, usually without thorns or with few thorns
Leaves	Five-part or three-part, serrated	Three-part, sometimes five-part, serrated
Flowers	White or light pink, 5 petals	White or light pink, 5 petals
Fruits	Black or dark purple, aggregate drupelets	Red or pink, aggregate berries
Plant height	1.0-1.5 m	1.0 - 2 m
Environmental requirements	Undemanding grows in both sunny and shaded areas	Prefers sunny locations, moist soil
Distribution	Europe, Asia, Caucasus	Northern and Central Europe, Asia
Uses	Fresh fruits, jam, syrup, medicines	Fresh, jam, juice, dried fruit, medicinal infusions
Medicinal properties	Anti-inflammatory, diuretic, antioxidant	Tonic, anti-inflammatory, digestive regulator

*Composed by the authors.

In Armenia, 12 natural Rubus species exist, of which the most widespread are *Rubus vulgaris Weihe & Nees* and *Rubus idaeus L.*. Other species e.g., Anatolian (*R. Anatolicus*), Armenian (*R. Armenicus*), Whitish (*R. Candicans*), Kartvelian (*R. Cartalinicus*) are limited to moist habitats in the NE and Zangezur forest zones (Vardanyan, 2005). The most prevalent and economically valuable species in Armenia are *Rubus vulgaris Weihe & Nees* and *Rubus idaeus L.*.

Numerous studies focus on their medicinal and nutritional significance, bioactive compounds in tissues, and fruit uses (Verma, et al., 2014; Zia-Ul-Haq, et al., 2014; Bhatt, et al., 2023; Tao, et al., 2023). Gevrenova and others highlight that leaves of Rubus species are less used than their fruits, but possess anti-inflammatory, antioxidant, wound-healing, and antidiabetic properties (Gevrenova, et al., 2024). Detection of bioactive compounds in plant tissues suggests potential for use as natural medicinal raw materials. Some authors regard Rubus fruits as "superfoods" due to secondary metabolites like hydrolyzable tannins, anthocyanins, polyphenols, flavanols, organic acids, etc. (Foster, et al., 2019; Wang, et al., 2012).

Table 1 compares certain morphological traits of cultivated *Rubus vulgaris Weihe & Nees* and *Rubus idaeus L.* (Torosyan, 1983; Vardanyan, 2005).

The study focused on wild and agroecosystem (greenhouse) samples of common dewberry and raspberry around Hobardzi village, Stepanavan region, Lori. The goal was to investigate leaf sizes and root pressure in these environments.

Results and discussions

The change in biometric indicators of the vegetative organs (leaves) of *Rubus vulgaris Weihe & Nees* and *Rubus idaeus L.* plants has been studied. The individuals regenerated from root offshoots of the mother plant have been examined. The variation in leaf size has been studied both in experimental plants growing in the wild and in agroecosystems.

<u>Sample 1</u> *Rubus vulgaris Weihe & Nees* in the wild

<u>Sample 2</u> *Rubus vulgaris Weihe & Nees* in the agroecosystem (greenhouse)

<u>Sample 3</u> *Rubus idaeus L.* in the wild

<u>Sample 4</u> *Rubus idaeus L.* in the agroecosystem (greenhouse)

Plants growing in the greenhouse have been chosen as agroecosystem samples.

Measurements have been made at stages with 1–3 leaves, 4–8 leaves, and ≥9 leaves. The results of the measurements are presented in table 2.

According to the literature, the average length of *Rubus idaeus L.* leaves is 5–10 cm (Hanelt, 2001), while the average length of *Rubus vulgaris Weihe & Nees* leaves is 4 -12 cm (Clapham, at all., 1962). Biometric measurements reveal that the climatic conditions and soil composition in the Lori region—particularly in the Hobardzi community of Stepanavan - favour the good growth of the studied crops (Manasyan, et al., 2003).

Biometric measurements show that under greenhouse conditions, the *Rubus vulgaris Weihe & Nees* crop grows 2.79 times faster at the 1–3 leaf stage, 3.43 times faster at the 4–8 leaf stage, and 2.18 times faster at the ≥ 9 leaf stage compared to growth in the wild.

The *Rubus idaeus L.* crop under greenhouse conditions grows 2.15 times faster at the 1–3 leaf stage, 1.75 times faster at the 4–8 leaf stage, and 1.18 times faster at the ≥ 9 leaf stage compared to in the wild.

Table 2. Comparison of biometric indicators of leaves of *Rubus vulgaris Weihe & Nees* and *Rubus idaeus L.* plants*

		Rubus vulgaris Weihe & Nees		***Rubus idaeus L.***	
		Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Leaf length (cm) (including petiole)	Stage of 1–3 leaves, March 30	1.9	5.3	2.7	5.8
	Stage of 4–8 leaves	3.5	12	8	14
	≥ 9 leaves	11	24	17	20

*Composed by the authors.

The table clearly shows that *Rubus idaeus L.* grows faster than *Rubus vulgaris Weihe & Nees* during the same periods: In the wild 1.42 times faster at the 1–3 leaf stage, 2.29 times faster at the 4–8 leaf stage, and 1.55 times faster at the ≥9 leaf stage. In the greenhouse: 1.09 times faster at the 1–3 leaf stage, and 1.17 times faster at the 4–8 leaf stage.

However, at the ≥9 leaf stage, the vegetation rate of greenhouse-grown *Rubus vulgaris* begins to accelerate and becomes 1.2 times faster than that of Rubus idaeus.

Determination of Root Pressure Indicators in Common Blackberry (*Rubus vulgaris Weihe & Nees*) and Common Raspberry (*Rubus idaeus L.*) Plants has been carried out.

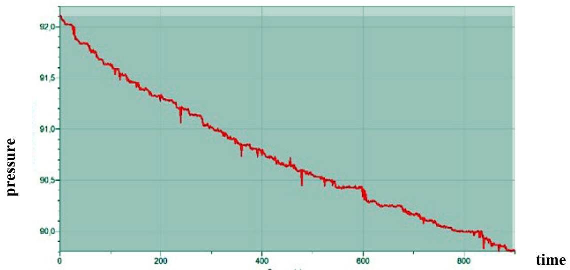
It is known that the normal functioning of terrestrial plants is possible only when a certain amount of water is present in plant tissues. In particular, the rate of leaf growth and their size are directly related to the water content in plant tissues. Water absorption by terrestrial plants from the external environment is an osmotic phenomenon and occurs in accordance with the law of osmosis. The water absorbed by the roots is transported to the aboveground parts of the plant through root pressure (Tangamyan, 2006; Ordog, 2011).

By knowing the dynamics of root pressure indicators in the studied plants, it is possible to improve leaf surface growth by regulating the plant's water regime. This, in turn, will contribute to an increase in the plant's photosynthetic activity and an increase in the amount of synthesized organic substances (Tangamyan, 2006).

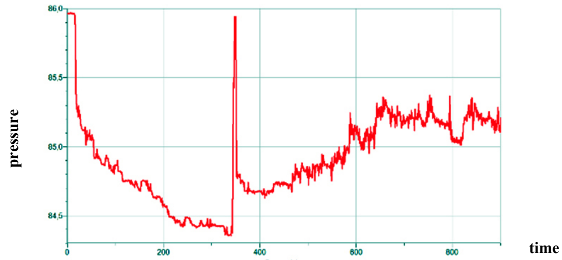
The root pressure of the cultivated plants *Rubus vulgaris Weihe & Nees* and *Rubus idaeus L.* was determined using the LabQuest 2 device (Picture). LabQuest 2 is an automated wireless interface used for collecting sensor data with built-in graphical and analytical applications. Its large, high-resolution touchscreen makes the collection, analysis, and sharing of experimental data easy and intuitive (www.vernier.com).

Graphs 1–4 show the root pressure dynamics: Graph 1 shows the changes in the root pressure index in the wild-growing common raspberry (*Rubus idaeus L.*) plant.

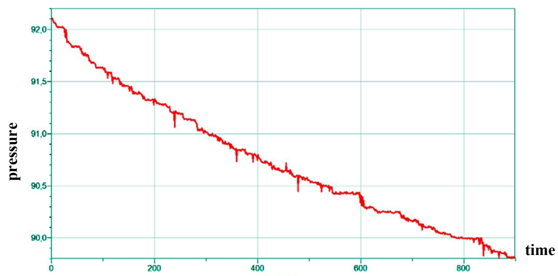
Picture. Equipments for determining root pressure using the LabQuest 2 device.



Graph 1. Root pressure of *Rubus idaeus L.* growing in the wild (*composed by the authors*).



Graph 2. Root pressure of Common Raspberry (*Rubus idaeus L.*) growing in a greenhouse (*composed by the authors*).



Graph 3. Change in root pressure of *Rubus vulgaris Weihe & Nees* growing in the wild over time (*composed by the authors*).

Graph 4. Change in root pressure of *Rubus vulgaris Weihe & Nees* growing in the wild over time (*composed by the authors*).

As can be seen from Graph 1, at the beginning of the experiment the root pressure is about 92.1 kPa.

This can be considered as the initial hydrostatic or baseline root pressure level of the system.

Over time, the pressure steadily decreases, reaching about 89.9 kPa. This trend indicates a decrease in root pressure, which may be due to a reduction in transpiration or a weakening of root activity (Tangamyan, 2006).

The study reveals that in the wild raspberry plant, root pressure decreases slowly but steadily by about 2.2 kPa over ~15 minutes.

Graph 2 shows the change in root pressure in the common raspberry (*Rubus idaeus L.*) plant grown in a greenhouse.

At the beginning of the study, the pressure is about 86.0 kPa. It decreases rapidly and steadily, reaching about 84.4 kPa in about 5 minutes, which is due to the intensive use of water by the plant (e.g., transpiration), and the temporary suppression of the active function of the roots (Pascale, 2020).

On the graph, a sharp increase in root pressure is visible (around 350–400 seconds), a sudden peak—the pressure immediately rises to almost 86.0 kPa. Such a sharp spike is due to mechanical interference (change in sensor position, interference with water supply pipes, or reflex response). If no mechanical interference had occurred, the pressure would have decreased even further, indicating that under greenhouse conditions the plant's root pressure is higher, has a higher hydro-regulatory capacity (restores pressure more quickly), is practically less subject to acute water loss or stress, as can occur in the wild, and has a controlled adaptability to the environment, which is facilitated by the stable temperature, humidity, and lighting in the greenhouse.

Graph 3 shows the change in root pressure in the Rubus vulgaris Weihe & Nees plant growing in the wild. Graph 3 presents the change in root pressure of the Rubus vulgaris Weihe & Nees plant growing in the wild over time. It is clear from the graph that the plant's root pressure shows a steady decreasing trend throughout the experiment, which lasts about 900 seconds.

At the initial stage of the experiment, the root pressure is about 92.1 kPa, and at the end of the experiment about 89.9 kPa. That is, the root pressure decreases by about 2.2 kPa. The root pressure of plants growing in the wild usually depends on the soil moisture content, the plant's transpiration activity, as well as atmospheric conditions. According to the presented data, the root pressure of the blackberry decreases on average by about 0.0024 kPa per second, which indicates quite an active loss of water, probably due to strong transpiration and a gradual decrease in soil moisture.

Graph 4 shows the change in root pressure of the *Rubus vulgaris Weihe & Nees* plant growing in a greenhouse over time.

From Graph 4 it can be seen that at the beginning of the experiment there is a sharp decrease in root pressure from about 86.0 kPa to about 84.6 kPa.Then the pressure drop slows down and reaches its minimum value about 84.45 kPa, after which the pressure begins to increase and return to values close to the initial level in the range of about 85.4–85.6 kPa.

The data from Graph 4 indicate that the root pressure of the Rubus vulgaris Weihe & Nees plant is sensitive to changes in the external environment and responds to them quite quickly. The initial sharp change suggests a sudden change in soil moisture or nutrient flow. The subsequent stabilization and growth phases prove the activity of the plant's adaptive mechanisms. The fluctuations show that the plant has not reached full equilibrium, i.e., physiological adaptation, and that some intracellular or intercellular processes continue to develop.

Conclusion

The results of the studies make it possible to conclude:

- Both species are widespread in both natural landscapes and cultivated systems and exhibit high ecological plasticity.
- *R. vulgaris* n *idaeus* prefers sunny, open areas.
- Biometric analysis confirms that *R. vulgaris* has slower leaf development and thornier, denser stems, whereas *R. idaeus* grows faster and yields more efficiently in agroecosystems.
- Phenological observations indicate that *R. vulgaris* begins vegetating later, while *R. idaeus* flowers and fruits earlier.
- Physiological comparisons show that *R. idaeus* possesses more active drought adaptation, reflected in higher root pressure.

Considering that the studied plants have a well-developed root system, it is recommended to expand the thickets of these plants in order to strengthen the soil layers and improve the soil structure.

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Treatment of Acute Orchitis in Breeding Bulls

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ABSTRACT

The purpose of this research was to diagnose acute orchitis in breeding bulls – an inflammatory condition of the testes occurring in the early stages of its development – and to develop an effective treatment protocol. The treatment scheme was based on the combined use of a broad-spectrum antibiotic and a medication with pronounced anti-inflammatory, antipyretic, analgesic, antispasmodic, and sedative properties. A clinical examination was performed on 23 breeding bulls, among which 7 animals (30.4%) were diagnosed with acute orchitis. To confirm the accuracy of the diagnosis, blood samples were collected twice from the affected animals – before and after treatment – to assess leukocyte parameters. Treatment involved the administration of Cipromag 500 and a 30% solution of Analgin. The results demonstrated that an inflammatory process was indeed present, which was successfully resolved within 5–6 days following treatment.

Introduction

In modern veterinary gynecology, one of the main problems of increasing productivity in bulls is diseases of the reproductive organs, which lead to infertility of animals and, ultimately, to their premature culling. Animals are productive when they are healthy. In this case, their quality of life is higher.

A common form of disease affecting the genital organs of breeding bulls is orchitis – an inflammatory process involving one or both testicles, caused by bacterial or viral infections or by testicular trauma (Koryukov, 2010). Timely and proper treatment of this disease does not allow its transition to chronic form, testicular atrophy and infertility. The disease occurs suddenly and an aggressive inflammatory process begins. The affected testis increases dramatically in volume, thickens, acute pain in the scrotum is observed, the skin of which turns red, and body temperature rises. The causes of the disease can be: injuries (mechanical damage to the testes, wounds with sharp objects, bruises), insect bites, as well as infection of the testes. The causes may also be external effects on the animal body, for example, hypothermia, as a result of which the blood flow of the scrotum worsens (Kozlov, 2022; Foster & Ladds, 2024; Waheed & El-Deeb, 2023).

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The disease has no seasonality and can occur in animals kept in different climatic conditions (Yakovlev, 2022; Ghanem & Tibary, 2023).

Orchitis is usually accompanied by epididymitis (epididimites) - inflammation of the epididymis, or periorchitis (periorchitis) - inflammation of the testis' own membrane. Epididymitis and orchitis are combined into the term epididymo-orchitis (Brito, et al., 2022).

In veterinary practice, a variety of methods of treating animal diseases are used, but there is still a need to improve them, since the tendency to decrease the frequency of manifestations of various diseases is insignificant (Ivanov, 2023; Menon &Senger,2022).

Materials and methods

The purpose of our study was to diagnose orchitis in breeding bulls at an early stage of its development, to develop and apply a new treatment scheme involving the use of a broad-spectrum antibiotic combined with a drug possessing anti-inflammatory, analgesic, antipyretic, antispasmodic, and sedative properties, and to examine the effects of this treatment on the blood leukogram parameters of bulls with acute orchitis.

In 2024, research was conducted on livestock farms in the Kotayk and Armavir regions of the Republic of Armenia, involving breeding bulls of the Caucasian Brown and Simmental breeds aged between 2 and 9 years. The study included 23 bulls, all of which initially underwent clinical examination. The diagnostic process began with the collection of anamnesis, followed by a thorough physical examination and palpation of the scrotum. Through this assessment, the underlying cause of the disease was identified. Palpation revealed tenderness of the testes. It should be noted that the symptoms and progression of the disease were sufficiently pronounced to make the diagnosis of orchitis straightforward, eliminating the need for specialized diagnostic tools. The primary diagnostic indicator was testicular tenderness (Tkachenko, 2023).

Acute orchitis began with a sudden inflammatory process. There was an increase and thickening of the affected testis, a high rise in body temperature, tension and tightness of the scrotum skin, thickening and inflammation of the spermatic cord, general depression of the bull with signs of anxiety, loss of appetite. In the studied farms, the tethered keeping of bulls in individual stall machines was mainly used. The floors in the stalls were mostly concrete with bedding. In winter, the indoor temperature was maintained at 8-12 °C. The organization of active exercise was irregular.

During the experiment, out of 23 breeding bulls under observation, clinical symptoms of acute orchitis were identified in seven animals, representing 30.4% of the total examined population. These affected bulls were assigned to the experimental group, while the control group consisted of seven clinically healthy bulls.

To be more confident in our diagnosis, we took blood samples from these bulls to study the parameters of the leukoformula using the Micro CC – 20 Plus analyzer. The blood test was carried out in the laboratory of the Scientific Research Center of Veterinary Medicine and Veterinary and Sanitary Expertise of the Armenian National Agrarian University.

At the next stage of the experiment, a comprehensive treatment protocol was developed and implemented as follows:

1. Ensuring rest for the affected animals.
2. Applying cold compresses to the scrotum during the first two days to reduce swelling, followed by thermal procedures.
3. Providing abundant drinking water to facilitate the elimination of pathogens from the body.
4. Elevating the scrotum to improve circulation and reduce edema.
5. Administering a broad-spectrum antibiotic, Cipromag 500, intramuscularly at a dose of 0.5 mg per 10 kg of body weight once daily for five days, to combat infection.
6. Administering a 30% Analgin solution intramuscularly, 50 ml once daily for three days, to relieve pain and reduce swelling (Kozlov, 2022).

The antibiotic Cipromag 500 used by us contains Ciprofloxacin as an active ingredient – it is a broad-spectrum fluoroquinolone. Its mechanism of action on the microbial cell is fundamentally different from the mechanism of action of other antibiotics, which determines the activity of ciprofloxacin against bacterial strains resistant to other antimicrobial agents. It provides a long-term post-antibiotic effect, causing a violation of the normal function of the microbial cell, which is characterized by intracellular localization in an infected organism. When administered intramuscularly, Ciprofloxacin quickly enters the bloodstream and penetrates into all organs and tissues.

Its maximum concentration is reached within one hour after administration, and ciprofloxacin is excreted primarily through the urine. The drug is used in cattle, pigs, dogs, cats, and rabbits for the treatment of bronchopneumonia, colibacteriosis, salmonellosis, and other infectious diseases.

It is administered intramuscularly or subcutaneously once daily for 3–5 days at a therapeutic dose of 0.3–0.4 ml per 10 kg of body weight in cattle (Ivanov & Petrova, 2023; Ghanem & Tibary, 2023).

The 30% Analgin solution used in this study contains sodium metamizole, which exhibits anti-inflammatory, analgesic, antipyretic, and antispasmodic properties. It effectively reduces inflammatory edema and is well tolerated by the body. The drug may be administered intramuscularly, intravenously, subcutaneously, or intraperitoneally. For cattle, an intramuscular dose of 20–40 ml is recommended. The solution should be stored at a temperature of 8-15 °C (Sidorov & Fedorova, 2024; Pugh & Baird, 2023).

After completing the treatment of breeding bulls for orchitis, blood samples were again collected from the recovered animals to determine leukoprofile parameters. The results are presented in the corresponding table.

Results and discussions

The table below shows the results of the blood leukoprofile indices of breeding bulls with acute orchitis before and after treatment.

From the data of the table it becomes clear that according to the results of the study of the leukoprophile before the start of treatment, the content of lymphocytes in the blood of patients with acute orchitis was reduced (23.7 ± 2.96%). Along with this fact, the content of monocytes (20.63 ± 1.15%), rod-shaped (23.7 ± 2.96%), segmented (40.6 ± 2.13%) neutrophils was increased. This pattern is usually observed in acute bacterial infections, i.e., a sign that the immune system is fighting infection or inflammation (Kovalchuk & Dmitriev 2022; Rinaldi& D'Occhio, 2024; Thrall, et al., 2022). Indicators of the leukoformula of the blood, i.e. lymphocytes (49.3 ± 0.56%), monocytes (6.7 ± 0.47%), segmented neutrophils (28.7 ± 1.34%), rod-shaped neutrophils (7.9 ± 1.16%), were within the normal range after treatment of animals.

Recovery of breeding bulls with acute orchitis, treated with the proposed broad-spectrum antibiotic Cipromag 500 and a 30% Analgin solution – possessing analgesic, anti-inflammatory, antipyretic, antispasmodic, and sedative properties – was achieved within five days of treatment. This is confirmed by the indicators of the leukoformula of the blood of bulls obtained before and after the treatment of animals. After completion of treatment, the affected testicles in bulls returned to their normal shape and volume; swelling subsided, scrotal skin redness and indurations disappeared, acute pain ceased, and body temperature returned to normal (Foster, et al., 2024, Siqueira & Guimaraes, 2022).

Table. Indicators of the leukoformula of the blood of bulls with acute orchitis before and after their treatment*

Indicators	Standards (reference values)	Control group (n=7) healthy bulls (M±m)	Indicators M±m	
			Before treatment n=7	After treatment n=7
White blood cells, total number (thousand/ml)	4.0 – 10.0	6.5 ± 1.8	13.8 ± 2.3	7.3 ± 1.9
Basophils, %	0.0 – 1.5	0.5 ± 0.3	0.47 ± 1.89	0.38 ± 1.14
Eosinophils, %	3.0 – 10.0	4.0 ± 1.5	8.7 ± 1.97	7.3 ± 1.73
Neutrophils				
Young	0	0	0	0
Stick- core, %	3.0 – 10.0	3.5 ± 1.0	23.7 ± 2.96	7.9 ± 1.16
Segmentonuclear,%	12.0 – 30.0	28.5 ± 5.5	40.6 ± 2.13	28.7 ± 1.34
Lymphocytes, %	47.0 – 66.0	58.0 ± 7.0	31.2 ± 1.43	49.3 ± 0.56
Monocytes, %	2.0 – 7.0	5.5 ± 1.5	20.63 ± 1.15	6.7 ± 0.47

$P < 0.05$

*Composed by the authors.

Conclusion

Various diseases of the testes negatively affect the reproductive function of bulls. Therefore, timely detection, referral to specialists, and appropriate treatment are crucial for maintaining animal health. If left untreated or improperly managed, acute orchitis can rapidly progress to a chronic form, leading to suppuration of testicular tissue, infertility, and premature culling of the animal.

Preventing the development of acute orchitis is generally more effective than treating it. Preventive measures include controlling sexually transmitted infections, maintaining the animal's immunity, and vaccinating or treating them against infectious diseases that could later cause orchitis. Scrotal injuries or exposure to hypothermia should be avoided. Additionally, the presence of aggressive animals, such as dogs, in cattle yards should be prevented, and bulls should not be taken for exercise or grazing in areas with hazards such as broken branches, tree stumps, or wetlands (Ali, et al., 2023; Brito, et al., 2022).

The results of our study are consistent with findings from recent international research, underscoring the commonality of challenges and approaches in the treatment of orchitis in breeding bulls across different countries. An integrated approach combining ceftriaxone and anti-inflammatory therapy has demonstrated high efficacy, aligning with data reported from North America. Menon and Senger (2022), in their review, emphasize that the timely use of broad-spectrum antibiotics such as ceftiofur [a ceftriaxone analog], in combination with NSAIDs, is the cornerstone of treating acute bacterial orchitis, allowing preservation of fertility in 70–80% of bulls. Our observation of complete recovery in the treated bulls falls squarely within this international range.

Our conclusion that trauma is one of the causes of orchitis is fully consistent with the findings of British researchers. As noted, despite infectious risks, traumatic scrotal injuries remain the most common trigger of acute orchitis in intensive farming operations (Pugh & Baird, 2023). This underscores the need to prioritize proper housing and management conditions, in addition to infection control.

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Exploring the Untapped Winemaking Potential of the Grape Variety Nrneni (Haghtanaki Quyr)

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ABSTRACT

Research indicates a rising demand for high-quality wines in Armenia. Our objective was to produce premium red and rosé wines using the relatively unexplored Nrneni (Haghtanaki Quyr) grape variety. Throughout the research, we used various winemaking technologies to produce red and rosé wines from the Nrneni (Haghtanaki Quyr) grapes. Concurrently, multiple physicochemical parameters and sensory attributes were investigated in the resulting must and wine. The results highlight the potential to craft unique wines from the Nrneni (Haghtanaki Quyr) grape variety, indicating potential market impact and consumer appreciation.

Introduction

Since the 19th century, our understanding of wine, wine composition and wine transformations has greatly evolved in function of advances in relevant scientific fields i.e. chemistry, biochemistry, microbiology. Each applied development has led to better control of winemaking and aging conditions and of course wine quality. In order to continue this approach, researchers and winemakers must strive to remain up to date with the latest scientific and technical developments in enology. It would be an error to think that the world's greatest wines are exclusively a result of tradition, established by exceptional natural conditions, and that only the most ordinary wines, produced in giant processing facilities, can benefit from scientific and technological progress. Certainly, these facilities do benefit the most from high performance installations and automation of operations. Yet, history has unequivocally shown that the most important enological developments in wine quality have been discovered in ultra-premium wines. The corresponding techniques were then applied to less prestigious products (Ribereu-Gayon & Dubourdieu, 2006).

Red wines are made from red grape varieties, which differ from white wines not only in color but also in fleshiness and astringency. Red wines are richer in substances extracted from the solid parts of grapes and useful microelements (Gabrielyan, 2021).

Red wine should have a brilliant crimson hue, free of any brown undertones. It should possess a harmonious, full-bodied character, delicately velvety texture, and exhibit a subtle balance of acidity and astringency. The careful selection of grape varieties plays a pivotal role in red wine production. Grapes should contain an ample amount of coloring substances (Muradyan & Aghajanyan, 2012).

Rosé wines are made from red grape varieties. Several techniques are available for crafting rosé wines, including the following prominent methods:

• **"Gravity separation of grape must" (Saignée):** The production of top-quality rosé wines often relies on using of this technique. The essence of this method lies in the natural separation of grape juice, typically around 40-50% of the total volume, during grape processing, solely due to the force of gravity. This separated must was then fermented using the technique employed in white wine production. This particular style of winemaking finds significant popularity in France, especially in regions like Provence and Burgundy.

• **Pressing:** The core of the technique involves pressing red grapes, post destemming and crushing, until the must with the desired color and composition is achieved. Subsequently, the obtained must undergoes standard procedures for white wine fermentation.

• **Moderate infusion:** This is regarded as the most popular technique globally; it involves pouring the destemmed and crushed mass into a tank for maceration. The maceration continues until the winemaker determines that the desired amount of phenolic substances has been extracted. Following this process, the mass is pressed and proceeds to fermentation.

• **Separation of liquid mass during fermentation:** In this scenario, the grapes undergo destemming and crushing before being directed to the fermentation tank without immediate pressing. As the fermentation progresses and a satisfactory amount of phenolic substances is extracted, the winemaker decides to separate the liquid part of the fermentation mass. This separated liquid continues to ferment in a distinct tank (Ribereu-Gayon & Dubourdieu, 2006).

Materials and methods

Given the established goal, we have outlined the subsequent primary objectives:

• Investigate the Nrneni (Haghtanaki Quyr) grape variety.

• Evaluate the winemaking capabilities of Nrneni (Haghtanaki Quyr) grape by producing both red and rosé wines from this specific variety.

• Monitor the physicochemical parameters during the winemaking process.

• Assess the sensory characteristics of the finished wines.

This research focuses on the Nrneni (Haghtanaki Quyr) grape variety and the red and rosé wines produced from it. Despite its significance, relatively little information is available about this variety. Presently, ampelographic and genetic studies conducted by our partners are still in progress (https://vivc.de). The main information about the grape variety is presented in picture 1.

During this research, we observed that Nrneni (Haghtanaki Quyr) grape variety features colored flesh, notably thick skin, relatively small berries, and compact clusters. The Nrneni (Haghtanaki Quyr) grapes were harvested from the national grape collection vineyard.

The grapes were harvested at their peak ripeness to ensure the production of high-quality wines. The harvested grapes were meticulously transported in small boxes to the winery to avoid any damage. Once at the facility, the grapes were destemmed and crushed using a horizontal roller crusher-destemmer. Next, using a screw pump, the crushed grape mass was transferred to a fermentation tank, where yeast was added to initiate fermentation. This process lasted for 7 days, followed by a 5-day maceration period with the skins. The fermentation temperature was 20-23 ℃.


Vitis International Variety Catalogue www.vivc.de

Passport data

Prime name	NRNENI
Color of berry skin	NOIR
Variety number VIVC	14065
Country or region of origin of the variety	ARMENIA
Species	VITIS VINIFERA LINNÉ SUBSP. SATIVA (DE CANDOLLE) HEGI
Pedigree as given by breeder/bibliography	1-17-1 (ALICANTE BOUSCHET X CABERNET SAUVIGNON) X SAPERAVI
Pedigree confirmed by markers	SEMENAC 1-17-1 X SAPERAVI
Full pedigree	YES
Prime name of parent 1	SEMENAC 1-17-1
Prime name of parent 2	SAPERAVI
Parent - offspring relationship	
Offspring	
Breeder	Aivazyan, P.K.; Aivazyan, G.P.
Breeder institute code	ARM 02
Breeder contact address	Armenian Scientific Research Institute of Viticulture, Winemaking and Fruit growing
Year of crossing	1979
Year of selection	
Year of protection	
Formation of seeds	COMPLETE
Sex of flowers	HERMAPHRODITE
Taste	NONE
Chlorotype	
Photos of the cultivar	
SSR-marker data	YES
Loci for resistance	
Degree of resistance	
Loci of traits	
Table of accession names	
Table of area	
Registered in the European Catalogue	

Links to:

- Bibliography
- Bibliography to pedigree confirmed by markers
- History of prime name changes
- Remarks to prime names and institute codes

Synonyms: 2	
HAGHTANAKI QUYR	NRKENI

Utilization

WINE GRAPE

May 15, 2025 © Institute for Grapevine Breeding - Geilweilerhof Julius Kühn-Institut 1

Picture 1. Passport data of the grape variety Nrneni (Haghtanaki Quyr).

After fermentation and maceration, the pulp was pressed to extract the liquid. The resulting wine was then transferred to a tank, where malolactic bacteria were introduced to start malolactic fermentation. Subsequently, the wine was poured into 25-liter glass containers (see picture 2).

Rosé dry wine was produced from the Nrneni (Haghtanaki Quyr) grape variety using specialized equipment and auxiliary materials. The grapes were harvested at their peak technical ripeness and transported from the vineyards to the winery in small boxes. Upon arrival, the grapes were destemmed, crushed and then pressed. Only the free-run juice, or gravity fraction, was collected during pressing. Afterward, the must was transferred to a container where it was clarified using bentonite. The clarification temperature was 14-16 °C. Following this clarification, the must was racked for further processes. A yeast was added to the racked must. Three days into the fermentation, the wine was aerated. Throughout the fermentation process, the sugar content of the must was measured daily, allowing adjustments to the fermentation rate as needed to either accelerate or slow it down. The fermentation temperature was 18-20 °C. Once fermentation was complete, the wine was transferred, and potassium metabisulphite was added. For the rosé wine, the finished wine was also poured into 25-liter glass containers.

All research conducted during the grape ripening process, as well as studies related to must and wines, were performed in the educational laboratory of the EVN Wine Academy. The methodologies used are sanctioned by the International Organization of Vine and Wine (OIV) and adhere to international standards (OIV, 2016; ISO 5495:2005; ISO 4120:2021), as detailed in the "Compendium of International Methods of Wine and Must Analysis" (International Organization of Vine and Wine, 2016, Muradyan, et al., 2017). The results of the conducted research were compared with the provisions of current legislation, including GOST 7208-93, GOST-32030-2013, GOST R 52523-2006, and GOST R 55242-2012. Additionally, they were assessed against the regulatory document set forth by the "International Organization of Vine and Wine" (OIV-MA-C1-01), which specifies the maximum permissible limits (Jackson & Ronald, 2008).

Picture 2. Wine storage containers.

Results and discussions

In the final month of ripening for the Nrneni (Haghtanaki Quyr) grape variety, an analysis was performed to assess the levels and variations of key physicochemical indicators. It is important to mention that samples for each grape variety were collected at consistent 7-day intervals.

During the th0ree-week observation period, the indicators changed as follows: sugar content increased from 130 g/l to 213 g/l, while total acidity decreased from 8.5 g/l to 7.3 g/l, and malic acid content reduced from 2.2 g/l to 1.5 g/l. Additionally, there was a noticeable rise in nitrogen compounds, with ammonium salts ($NH4^{+}$) increasing from 108 mg/l to 143 mg/l, and yeast-assimilable nitrogen (YAN) rising from 220.8 mg/l to 334.5 mg/l.

Anthocyanins are pigments present primarily in the skin of grapes and occasionally in the fruit itself. Their color is highly dependent on pH levels: the lower the pH, the more stable the anthocyanins become, resulting in a deeper red coloration. Phenolic substances emerge during fermentation and undergo continuous changes (Jacobson, 2006; Moreno & Peinado, 2012).

Table 3 summarizes the data on the total phenol and total anthocyanin content of the wines investigated, highlighting their relatively high levels.

Several characteristics of wines produced from the Nrneni (Haghtanaki Quyr) grape variety were evaluated and compared using a numerical assessment method. The results are presented below. Fifteen specialists participated in the tasting process. Initially, the participants identified various features and descriptors using a descriptive approach, then grouped these features to highlight the most prominent ones. Subsequently, the intensity of these features was rated on a scale of 1 to 10. After consolidating the results, aromatic wheels for the organoleptic indicators of the wine were created, as detailed below (Gabrielyan, et al., 2024; Wang & Spence, 2019).

Table 1. The levels of various chemical indicators and their changes over time in the grape variety Nrneni (Haghtanaki Quyr)*

	Indicators					
Samples	**Sugar content, g/l**	**Total acidity, g/l**	**pH**	**$NH4^{+}$, mg/l**	**YAN, mg/l**	**Malic acid, mg/l**
1st sampling 12.09.2020	130	8.5	2.85	108	220.8	2.2
2nd sampling 18.09.2020	169	7.9	2.99	125	280	1.9
3rd sampling 25.09.2020	213	7.3	3.3	143	334.5	1.5

Table 2. The content of some chemical indicators in wines made of the studied Nrneni (Haghtanaki Quyr) grape variety*

Physicochemical indications	**Alc.**	**Totaal acidity**	**Volatile acidity**	**Residual sugar**	**pH**	**Free SO_2**	**Total SO_2**	**Reductones**
Unit of measurement	Vol.%	g/l	g/l	g/l	-	mg/l	mg/l	mg/l
Red wine	12.8	5.3	0.51	0.2	3.4	20.5	85.3	1.69
Rosé wine	12.5	5.7	0.43	0.1	3.3	25.4	90.2	1.41

Table 3. Total phenols and anthocyanins content in the examined wines*

Samples	**Indicators**	
	Total phenols, mg/l	**Total anthocyanins, mg/l**
Red wine	2960	610
Rosé wine	2090	129,7

*Composed by the authors.

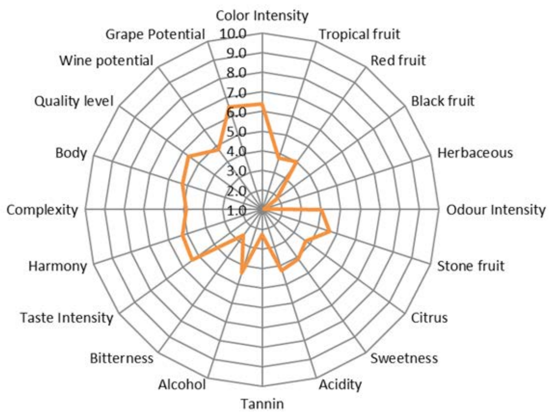

Diagram 1. The aroma wheel of Nrneni (Haghtanaki Quyr) rosé dry wine (*composed by the authors*).

Based on the sensory characteristics, the wines made from the Nrneni (Haghtanaki Quyr) grape variety can be described as follows: The rosé wine exhibits an intense color and presents fruity aromas, predominantly of red fruits, with medium to low tropical notes. Herbal or green aromas are nearly absent. The overall intensity of the aromas is above average, with red berry notes also rated as above average in intensity. The wine's sweetness is considered very low, while its acidity is assessed as medium. The tannin content in the rosé wine made of the Nrneni (Haghtanaki Quyr) grape variety was assessed as low, which is ideal for a light rosé. The overall flavor intensity of the wine received a high rating. Based on the evaluations, it can be concluded that the rosé wine from the Nrneni (Haghtanaki Quyr) grape variety is notably harmonious and features an above-average complexity in its bouquet (see Diagram 1).

The color intensity of the red wine was rated as notably high. The wine exhibits pronounced fruity aromas, predominantly featuring black fruit characteristics, with a significant presence of red fruit notes. Tropical fruit aromas are almost negligible. A moderate to low vegetal aroma is also present. The overall intensity of the wine's aromatic profile was assessed as above average. In terms of sweetness, the wine was rated very low, while acidity levels were found to be quite high. The tannins in the wine were rated as relatively high, alcohol sensitivity was assessed as medium, and bitterness was rated as low. The overall flavor intensity of the red wine made from the Nrneni (Haghtanaki Quyr) grape variety was rated above average. This wine was generally evaluated as having medium harmony and above-average aromatic diversity. Based on these evaluations, the wine is classified as having medium potential. The potential of the Nrneni (Haghtanaki Quyr) grape variety was assessed as high (see Diagram 2).

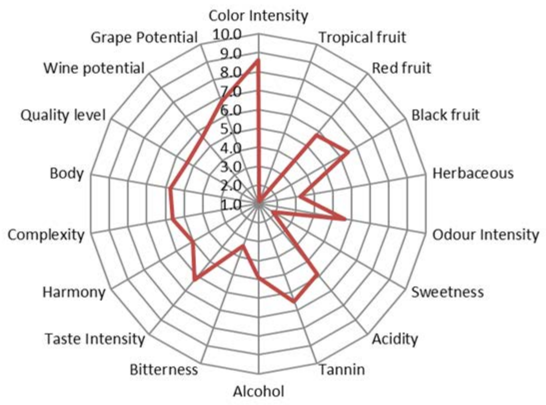

Diagram 2: The aroma wheel of Nrneni (Haghtanaki Quyr) red dry wine (*composed by the authors)*.

Conclusion

The potential of the Nrneni (Haghtanaki Quyr) grape variety for production of rosé and red dry wines has been studied. The findings indicate that wines produced from this grape variety can meet international standards. The overall quality of both rosé and red wines was rated as above average, with their potential, based on sensory characteristics, also assessed as high. The research provides valuable insights into the winemaking potential of the Nrneni (Haghtanaki Quyr) grape variety. However, it is recommended that future studies be conducted on a more comprehensive and large-scale basis to further explore this potential.

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Comparative Study of the Mechanical Composition and Physicochemical Parameters of the "Areni Sev" Grape Variety and its Clones

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Conflict of Interest
The authors declare no conflict of interest concerning the research, authorship, and/or publication of this article.

ABSTRACT

Within the scope of this study, a comparative analysis was conducted on the mechanical composition and physicochemical properties of the Vitis vinifera cultivar "Areni Sev" and its three distinct clones - "Nosr Areni", "Areni Sev Clone №9", and "Areni Sev Clone №15". The objective of the research was to assess the technological suitability and production efficiency of these clones for winemaking applications. The results demonstrated that the "Nosr Areni" clone, with the highest juice content (82.78%) and rachis composition index (4.8), is the most efficient in terms of sugar yield, contributing to higher wine production efficiency and a reduction in product cost. "Areni Sev Clone №. 9", in turn, is characterized by well-developed pulp, firm berry mass, and a high structural index, ensuring strong technological and breeding potential. Overall, the clonal variants, particularly "Nosr Areni" and "Clone №9", exhibited superior production and technological characteristics, enhancing the applied value of this grape cultivar in the winemaking industry.

Introduction

Since ancient times, viticulture practices have recognized cases of distinct traits and heritable variability in perennial crops (Zarmaev, 2013). Due to the variability of perennial plant cultivars, their vegetatively propagated progeny are commonly regarded as groups of clones, unified by a set of economically valuable and biological characteristics, while differing in various morphological or physiological traits such as color, shape, size, ripening period, and phenophase (Zarmaev, 2014).

The purpose of clone selection may include increasing the yield of specific cultivars, improving fruit quality, identifying early-ripening clones, and other objectives (Zhukovsky, et al., 1972). Thanks to clonal selection, vineyard productivity has generally increased 2–5 times across countries and regions, including Germany, Italy, France, and California (Zarmaev, 2015).

Only in the last decade has research on the effectiveness of clonal selection received significant attention, as it contributes to cultivar improvement and productivity

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enhancement (Zarmaev, 2017). Determining the suitability and intended use of a cultivar relies heavily on oenological research. Oenology primarily involves studying the structural components of the rachis and fruit according to their mechanical composition. During clonal selection, attention is focused on improving cultivar traits such as rachis and berry dimensions, the weight of 100 berries, and the number of berries per cluster.

It should be noted that in winemaking, the ratio of the rachis, berries, berry skin, pulp, seeds, juice, and pedicel is determined through mechanical analysis. Notably, this ratio can vary depending on the grape cultivar, soil and climatic conditions of cultivation, berry ripeness, and applied agrotechnical practices (Troshin, et al., 2018).

Analysis of the mechanical composition of grapes allows the determination of the characteristic structure of the cluster for a given cultivar, as well as the proportional relationships among its various components, which is crucial from a technological standpoint (Grigoryan, et al., 2024).

The aim of this study is to conduct a comparative investigation of the mechanical composition and physicochemical parameters of the "Areni Sev" cultivar and its clones. This approach enables the identification of their production potential and the selection of clones that ensure optimal yield and quality for implementation in winemaking production.

Materials and methods

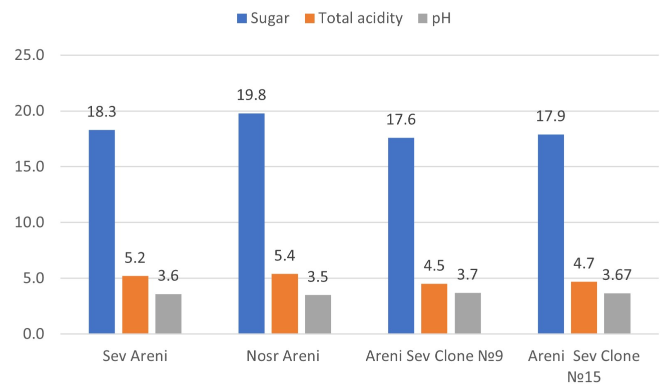
A comparative study was conducted on the mechanical composition and physicochemical parameters of the "Areni Sev" grape cultivar and its clones: "Nosr Areni", "Areni Sev clone №9", and "Areni Sev clone №15". For each clone and the cultivar, five clusters were analyzed in three replicates. The study was carried out in 2023–2024 at the National Grape Collection Vineyard located in the Ejmiatsin province of Armavir region, Armenia.

Areni is classified among late-ripening wine grape cultivars (Ayvazyan, et al., 2015). The mechanical composition of the cultivars was assessed according to the methodology developed by N.N. Prostoserdov (1935). Specifically, the weight of the cluster, berry skin, and pedicel, as well as the number of berries per cluster and the weight of seeds, were determined. The berry skin was weighed immediately after separation from the berries. Based on the obtained data, the structure and composition of the clusters of the studied cultivar and clones were compared.

The sugar content of the grape juice was determined using a refractometric method with a laboratory refractometer, and the results were expressed in °Brix. Titratable acidity was measured by titration with a 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator, and the results were expressed as grams per liter of tartaric acid equivalent (g/L). The pH of the grape juice was measured using an electronic pH meter in accordance with ISO 10523 standard (International Organisation of Vine and Wine, 2022).

Results and discussions

The improvement of the agrobiological characteristics of locally cultivated grape varieties through clonal selection plays a crucial role in the production of high-quality wines. Key primary indicators characterizing the grapes include sugar content, titratable acidity, and pH. These parameters significantly influence the future wine's aroma, flavor, and overall quality. The physicochemical parameters of the studied "Areni Sev" variety and its clones are presented in Figure 1.



Picture 1. Physicochemical characteristics of the Sev Areni Sev variety and its clones (composed by the authors).

Table 1. Mechanical composition of the “Areni Sev” and its clones*

Grape variety and clones	Bunch length, cm	Bunch width, cm	Bunch mass G	Number of berries in the bunch, n	Berries mass, g	Stem mass, g	Skin mass, g	Seed mass, g	Hard residue mass, g	Berries pulp+juice, g
Areni Sev	18	10,4	316,7	161	304,7	12	53,9	13,9	79,8	236,9
Nosr Areni	11,6	7,5	118,1	50	113,3	4,8	10,8	4,7	20,3	97,8
Areni Sev Clone №9	19,8	13,9	502,3	194	485,8	16,5	51,4	23,3	91,2	411,1
Areni Sev Clone №15	18,1	11,7	406,7	144	392,9	13,8	43,2	20,1	77,1	329,6

Table 2. Bunch structure of the “Areni Sev” grape variety and its clones*

Grape variety and clones	Average bunch mass, g	Number of berries in the bunch, n	Berries mass, g	Berries ratio to the bunch, %	Stem mass, g	Stem ratio to the bunch, %	Bunch structure index	Berries index
Areni Sev	316,7	161	304,7	96,2	12	3,78	25,4	50,8
Nosr Areni	118,1	50	113,3	95,9	4,8	4,06	23,6	42,3
Areni Sev Clone №9	502,3	194	485,8	96,7	16,5	3,28	29,4	38,6
Areni Sev clone №15	406,7	144	392,9	96,6	13,8	3,39	28,4	35,4

*Composed by the authors.

It was observed that the highest sugar content was recorded in the “Nosr Areni” clone, while the lowest was found in “Areni Sev Clone №9”. Titratable acidity and pH did not differ significantly among the studied clones and the main variety; however, “Areni Sev Clone №9” exhibited the lowest acidity and the highest pH, making it particularly suitable for producing light red and rosé wines.

The results of the mechanical composition analysis of the “Areni Sev” variety and its clones (“Nosr Areni”, “Areni Sev Clone №9”, and “Areni Sev Clone №15”) are presented in Table 1. The lengths of the grape clusters were 18.0 cm, 11.6 cm, 19.8 cm, and 18.1 cm, respectively, while the widths measured 10.4 cm, 7.5 cm, 13.9 cm, and 11.7 cm, respectively. The cluster weights were 316.7 g, 118.1 g, 502.3 g, and 406.7 g, respectively, with the corresponding fruit weights being 304.7 g, 113.3 g, 485.8 g, and 392.9 g. The highest stem weight was recorded in “Areni Sev Clone №9” (16.5 g), followed by “Areni Sev Clone №15” (13.8 g), the main “Areni Sev” variety (12.0 g), and “Nosr Areni” (4.8 g). The greatest seed weight was observed in “Areni Sev Clone №9” (23.3 g), “Areni Sev Clone №15” (20.1 g), the main “Areni Sev” variety (13.9 g), and “Nosr Areni” (4.7 g).

The structure of a grape cluster is characterized by its average weight, the number of berries, the weight of the berries and stem, their percentage composition within the cluster, as well as by the cluster structural index. A higher structural index indicates more efficient utilization of the cluster and results in increased juice yield.

The cluster structural index is determined as the ratio of the combined berry weight to the stem weight (Table 2).

The grape variety “Areni Sev” and its clones — “Nosr Areni”, “Areni Sev Clone №9”, and “Areni Sev Clone №15” — differ significantly in terms of cluster and berry weight. Compared to the “Areni Sev” variety, “Areni Sev Clone №9” produces a higher number of berries. Specifically, the “Areni Sev” variety had 161 berries per cluster, “Nosr Areni” had 50 berries, “Areni Sev Clone №15” had 144 berries, and the highest berry count was recorded in “Areni Sev Clone №9”, with 194 berries per cluster.

The maximum stem weight was observed in “Areni Sev Clone №9” (16.5 g), followed by “Areni Sev Clone №15” (13.8 g), the “Areni Sev” variety (12 g), and “Nosr Areni” (4.8 g). No significant differences were observed in the ratio of berry to stem weight among the “Areni Sev” variety and its clones. The cluster structural index, calculated as the ratio of berry weight to stem weight, was 25.4 for the “Areni Sev” variety, 29.4 - for “Areni Sev

Clone №9", 23.6 - for "Nosr Areni", and 28.4 - for "Areni Sev Clone №15".

According to the study, the berry index of the "Areni Sev" grape and its clones, defined as the number of berries per 100 g of cluster, was as follows: 50.8 for "Areni Sev", 38.6 for "Areni Sev Clone №9", 42.3 for "Nosr Areni", and 35.4 for "Areni Sev Clone №15".

The results of the berry composition analysis — including the weight of 100 berries and 100 seeds, the number and weight of seeds per 100 berries, and the weights of berry skin and pulp plus juice — are presented in Table 3. Of particular importance is the berry composition index, calculated as the ratio of pulp plus juice weight to berry skin weight.

In the "Areni Sev" grape variety, the number of seeds per 100 berries was 168, while in the clones it was 104 in "Nosr Areni", 182 in "Areni Sev Clone №9", and 215 in "Areni Sev Clone №15". The weight of seeds per 100 berries was highest in "Areni Sev Clone №15" (29.9 g), followed by "Areni Sev Clone №9" (21.8 g), the "Areni Sev" variety (14.5 g), and "Nosr Areni" (9.8 g).

Notably, the maximum weights for both 100 berries and 100 seeds were recorded in "Areni Sev Clone №15", with 276 g and 29.9 g, respectively; in "Areni Sev Clone №9", 262.5 g and 21.8 g; in the "Areni Sev" variety, 247.6 g and 14.5 g; and in "Nosr Areni", 241.2 g and 9.8 g.

For technical grape varieties, the berry composition index is also of significant importance. The highest value was observed in "Nosr Areni" (9.75), followed by "Areni Sev Clone №9" (8.1), "Areni Sev Clone №15" (7.2), and the lowest in the "Areni Sev" variety (5.96).

During grape processing, particular attention is also paid to the ratio of berries to the rachis.

The structure of the grape cluster is characterized by the composition of its constituent parts—rachis, skin, seeds, stem, pulp, juice—and their percentage ratios, which vary depending on the grape variety, ripeness stage, ecological factors, and climatic conditions.

The parameters of the individual components of the "Areni Sev" grape variety and its clones are presented in Table 4.

According to the research results, in the clusters of the "Areni Sev" grape variety, the stem content was 3.8% and the skin content 17%. In the "Nosr Areni" clone, these values were 4.1% and 9.14%, in "Areni Sev Clone №9"—3.3% and 10.23%, and in "Areni Sev Clone №15"—3.4% and 10.6%, respectively. Table 4 shows that the highest skin content was observed in the "Areni Sev" variety, while the stem content was highest in the "Nosr Areni" clone.

Table 3. Berry composition of the "Areni Sev" grape variety and its clones*

Grape variety and clones	Mass, g		Number of seeds in 100 berries, n	Weight of 100 berries, G			Berry composition index
	100 berries	100 seeds		Seed	Skin	Pulp+juice	
Areni Sev	247,6	8,65	168	14,5	33,5	199,6	5,96
Nosr Areni	241,2	9,4	104	9,8	21,52	209,9	9,75
Areni Sev Clone №9	262,5	12	182	21,8	26,5	214,2	8,1
Areni Sev Clone №15	276	13,9	215	29,9	30	216,1	7,2

Table 4. Bunch composition indicators*

Grape variety and clones	Composition of individual parts in the bunch, %					Bunch composition index
	Stem	Skin	Seed	Hard residue	Pulp+juice	
Areni Sev	3,8	17	4,39	25,19	74,81	2,97
Nosr Areni	4,1	9,14	3,98	17,22	82,78	4,8
Areni Sev clone №9	3,3	10,23	4,64	18,17	81,83	4,5
Areni Sev clone №15	3,4	10,6	4,94	18,94	81,06	4,3

*Composed by the authors.

The seed content was highest in “Areni Sev Clone №15” (4.94%), followed by the “Areni Sev” variety (4.39%), “Nosr Areni” (3.98%), and “Areni Sev Clone №9” (4.64%).

For technical grape varieties, the percentage of pulp plus juice is a particularly important indicator. This value was highest in the “Nosr Areni” clone (82.78%), followed by “Areni Sev Clone №9” (81.83%), “Areni Sev Clone №15” (81.06%), and the “Areni Sev” variety (74.81%). All clones exceeded the parent variety in this respect. The mass of the cluster skeleton was highest in the “Areni Sev” variety (25.19%), followed by “Areni Sev Clone №15” (18.94%), “Areni Sev Clone №9” (18.17%), and “Nosr Areni” (17.22%). Notably, the lower the skeleton mass, the higher the proportion of pulp.

The cluster composition index is determined as the ratio of pulp plus juice to the skeleton mass. For the “Areni Sev” grape variety, the cluster composition index was 2.97; in “Nosr Areni”, it was nearly 1.6 times higher at 4.8; in “Areni Sev Clone №9”, it was 4.5, and in “Areni Sev Clone №15” - 4.3. This index varies depending on the grape variety. The higher the cluster composition index—that is, the ratio of pulp plus juice to skeleton mass—the juicier the grape, resulting in a higher yield.

Conclusion

According to the research, the cluster composition index of the “Areni Sev” grape variety and its clones is determined by the content of pulp and juice. The higher the ratio of pulp plus juice to skeleton mass, the greater the cluster composition index and, consequently, the higher the juice yield. The highest cluster composition index was recorded in the “Nosr Areni” clone (4.8), followed by “Areni Sev Clone №9” (4.5) and “Areni Sev Clone №15” (4.3), while the lowest index was observed in the parent “Areni Sev” variety (2.97).

Based on these results, the clones of “Areni Sev” can be successfully utilized in winemaking. The studied clones are promising for the production of high-quality wines, and further research is ongoing to fully explore their potential.

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Dietary Exposure Assessment of Potentially Toxic Elements in Armenian Honey

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ABSTRACT

The study aimed to assess the contents of potentially toxic elements (Cu, Mo, Pb, As) in honey and associated health risks in Armenia. To assess dietary exposure and characterize potential health risks, the estimated daily intake (EDI) and margin of exposure (MOE) of these elements were calculated. The assessment was carried out considering honey consumption patterns among the Armenian adult population. The outcomes of the health risk assessment reveal that the EDI of the investigated elements were notably lower in comparison to the health-based guidance values. Overall, the study findings suggest that the levels of potentially toxic elements in Armenian honey are within acceptable limits, and there are no health risks to consumers. However, future research could expand to include a larger number and variety of honey samples, as well as additional elements.

Introduction

Honey remains a staple in diets worldwide, valued not only for its organoleptic properties but also for its potential health benefits, including immune support and its role as a natural alternative to refined sugars. However, with increasing environmental pressures from industrialization, urbanization and intensive agricultural practices, this seemingly pure and wholesome product may contain various chemical hazards. Among these are environmental contaminants such as potentially toxic elements (PTEs), raising concerns for food safety and public health (Godebo, et al., 2025; Fakhri, et al., 2025; Mititelu, et al., 2023).

PTEs, commonly known as heavy metals or trace elements, include both essential and non- essential elements that can accumulate in biological systems, potentially causing adverse health effects (Fakhri, et al., 2025, Morariu, et al., 2024). These elements enter the honey production chain through various pathways, primarily via environmental contamination and agricultural practices. Major sources of possible contamination include industrial emissions and agricultural practices involving pesticides, fertilizers, and herbicides containing metal impurities. Additionally, the geographic origin of honey significantly influences PTE levels, with samples from industrialize or intensively farmed regions typically showing higher concentrations than those from non-polluted areas (Godebo, et al., 2025; Ligor, et al., 2022; Pipoyan, et al., 2020, Thrasyvoulou, et al., 2018).

Recent studies have reported varying levels of PTEs

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in honey originated from different countries, reflecting differences in environmental contamination, agricultural activities and regulatory control (Bartha, et al., 2020; Casula, et al., 2024; Mititelu, et al., 2023). Regulatory bodies in different countries set maximum allowable levels for elements in food, including honey, to mitigate risks (European Commission, 2023; Morariu, et al., 2024; Thrasyvoulou, et al., 2018; TR CU 021/2011). Monitoring and controlling these elements is crucial to ensure the safety of honey for human consumption. At the same time, it is important to conduct risk assessments that consider not only contamination levels but also population-specific consumption patterns and the toxicological characteristics of the elements, including relevant health-based guidance values (HBGVs).

A recent study conducted in Armenia on locally produced honey of two regions (Shirak and Syunik) highlighted the importance of monitoring trace element levels and assessing dietary exposure via honey consumption (Pipoyan, et al., 2020). Therefore, the present study aimed to assess the contents of potentially toxic elements (Cu, Mo, Pb, As) in honey and associated health risks in Armenia. Given the rising global demand for honey as a natural and healthy product, a better understanding of the occurrence and possible health risks due to PTE contamination is essential.

Materials and methods

Sampling and analysis

60 samples of Armenian multifloral honey were collected in the frame of the state residue monitoring program on honey. Preparation and further chemical analysis of honey samples was carried out at the Republican Center for Veterinary and Sanitary and Phytosanitary Laboratory Services, accredited according to ISO 17025 standard. The contents of potentially toxic elements: copper (Cu), molybdenum (Mo), lead (Pb) and arsenic (As) were determined using atomic absorption spectrometry (AAS, Thermo Fisher iCE-3500).

Dietary exposure assessment

To assess dietary exposure and characterize potential health risks, the estimated daily intake (EDI) and margin of exposure (MOE) of the potentially toxic elements were calculated. The EDI of potentially toxic elements through Armenian multifloral honey consumption was calculated using the following equation:

$$EDI = \frac{C * IR}{BW},$$

where, EDI (mg/kg/day) is the estimated daily intake of the potentially toxic element through honey consumption, C is the content (mg/kg) of the investigated element in honey, and BW is the average body weight (kg) for the Armenian adult population (Pipoyan, et al., 2023b). IR is the average daily consumption of honey (kg/day).

Honey consumption data (Figure 1) were obtained through a food frequency questionnaire (FFQ), administered via in-person, interview-based surveys designed and conducted by the Informational-Analytical Center for Risk Assessment of Food Chain at the Center for Ecological-Noosphere Studies (CENS), NAS RA. Prior to implementation, the FFQ was pre-tested in a pilot phase (n=20) to assess its reliability and respondent understanding. The survey was conducted anonymously and included 1040 participants aged 18-65, selected using a stratified random sampling approach (with a 95% confidence level and a margin of error of ±3%) to ensure proportional representation of gender and age groups within each administrative district of Yerevan, the capital city of Armenia. Since Yerevan accounts for about 30% of the national population, the study sample was considered representative of Armenian adult consumers. Further details on the FFQ methodology are described by Pipoyan et al. (Pipoyan, et al., 2023a; 2023b).

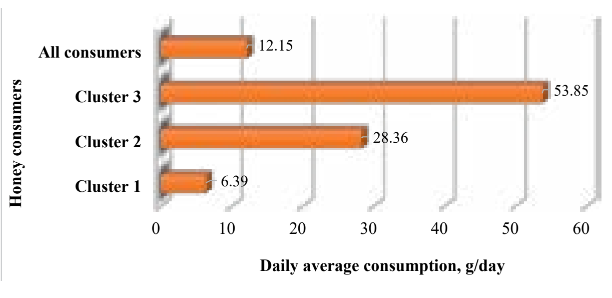

Figure 1. Daily average consumption of honey by the adult population in Armenia *(Pipoyan, et al., 2023b).*

The margin of exposure (MOE) for each detected element was calculated using the following equation:

$$MOE = \frac{HBGV}{EDI},$$

where, $HBGV$ is the health-based guidance values of each investigated potentially toxic elements. For risk characterization, *HBGV*s set by the European Food Safety Authority were applied (EFSA, 2010; EFSA Scientific Committee, et al., 2023).

Results and discussions

Contents of potentially toxic elements in honey

Among the analyzed potentially toxic elements, molybdenum (*Mo*) was not detected (i.e., below the limit of detection of 0.008 mg/kg) in any of the investigated multifloral honey samples produced in Armenia. In contrast, copper (*Cu*) was detected in all samples, with contents ranging from 0.059 to 0.312 mg/kg, and an average content of 0.138 mg/kg (Figure 2).

Toxic element lead (Pb) was detected in 86.7% of the investigated multifloral honey samples, ranging from 0.021 to 0.046 mg/kg, with a mean content of 0.03 mg/kg (Figure 2). Importantly, all detected Pb contents were below the national (TR CU 021/2011) and EU (European Commission, 2023) maximum levels of 1 mg/kg and 0.1 mg/kg, respectively. Arsenic (As) was found in only one sample at a content of 0.025 mg/kg, which remains within the national maximum level of 0.5 mg/kg set by the Technical Regulation (TR CU 021/2011).

A comprehensive review on physicochemical properties, minerals, trace elements, and heavy metals in honey of different origins reported that chemical elements in honey samples throughout the world vary in terms of concentrations (Solayman, et al., 2016). A recent global systematic review conducted by Fakhri et al., reported pooled concentration of potentially toxic elements in honey as follows: *Cu* at 0.11 mg/kg, *Pb* at 0.0026 mg/kg and As at 0.00048 mg/kg. Notable, the higher concentrations were observed in honey from Brazil (*Cu*), Jordan (*Pb*) and Ethiopia (*As*) compared to the other countries (Fakhri, et al., 2025). Théolier et al. reported a regional pooled mean *Pb* concentration of 0.12 mg/kg in honey samples from Arab countries, based on a meta-analysis of 57 studies (Théolier, et al., 2024). Another study conducted by Mititelu et al. on heavy metals in various types of honey from different areas in Romania revealed that polyfloral (or multifloral) honey contained the highest level of *Pb* (0.52 mg/kg) compared to linden, acacia and rapeseed honey (Mititelu, et al., 2023). The mean concentrations of *Cu* in the studied polyfloral honey from three Romania areas were 0.47 mg/kg, 0.38 mg/kg and 0.46 mg/kg (Mititelu, et al., 2023).

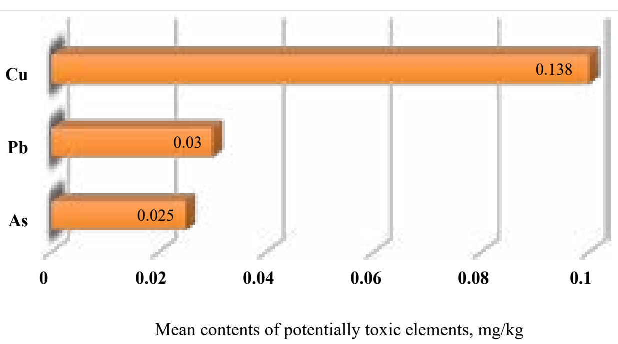

Figure 2. Mean contents of potentially toxic elements detected in Armenian multifloral honey.

A study on toxic and essential elements in Serbian multifloral honey reported mean concentration of *As* at 0.00168 mg/kg (ranged from 0.001 to 0.0054 mg/kg), *Pb* at 0.0064 mg/kg (ranged from 0.002 to 0.0176 mg/kg), and *Cu* at 0.1939 mg/kg (ranged from 0.06535 to 0.407 mg/kg) (Spirić, et al., 2019).

A comparative study by Ligor et al. on potentially toxic elements in honey produced in Poland reported *Pb* levels below the background equivalent concentrations in all tested samples, while the mean contents of *As*, *Mo* and *Cu* were 0.00006 mg/kg, 0.00042 mg/kg and 0.136 mg/kg, respectively (Ligor, et al., 2022). It is important to note, that compared to other studied elements, *Mo* has not been as extensively investigated in honey, however, the study by Ligor et al. included Mo and detected its presence (Ligor, et al., 2022), in contrast to the finding of the present study in Armenia, where *Mo* was not detected.

Exposure assessment and risk characterization

Since copper (*Cu*) was detected in all honey samples and lead (*Pb*) in the majority of them, dietary exposure assessments were performed for these elements. The estimated daily intake (*EDI*) and margin of exposure (*MOE*) were calculated both for the overall population of honey consumers and for three clusters (Figure 1), which were defined according to consumption rates and reflect honey consumption patterns among the Armenian adult population. Moreover, a conservative worst-case scenario approach was applied, whereby the maximum detected concentration of each element in honey was assumed as its mean content. In this case, for estimating daily intake, consumption data of high consumers (i.e., Cluster 3), representing individuals with the highest honey consumption, were used. The calculated *EDI* values for *Cu* and Pb are shown in Figure 3.

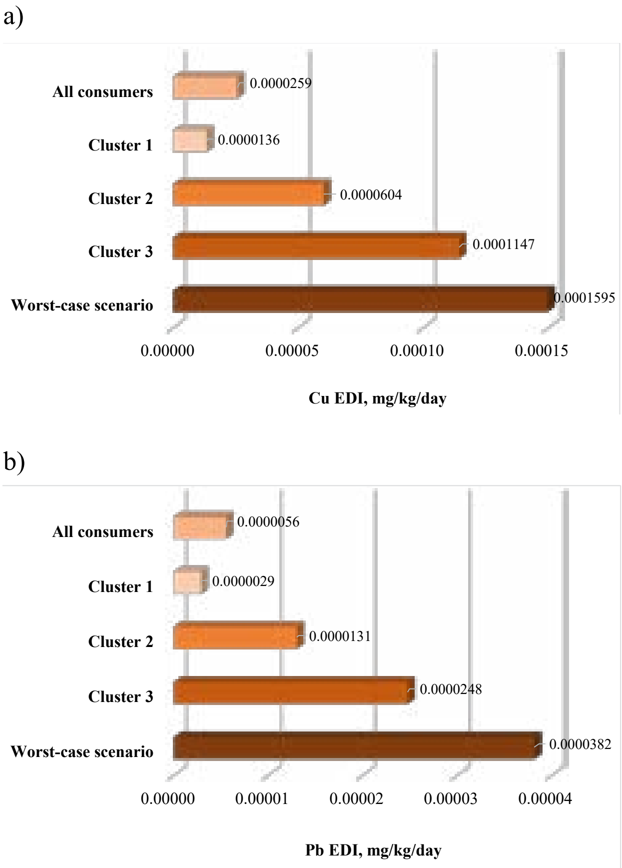

Figure 3. Estimated daily intake (*EDI*) of *Cu* (a) and *Pb* (b) through honey consumption (*composed by the authors*).

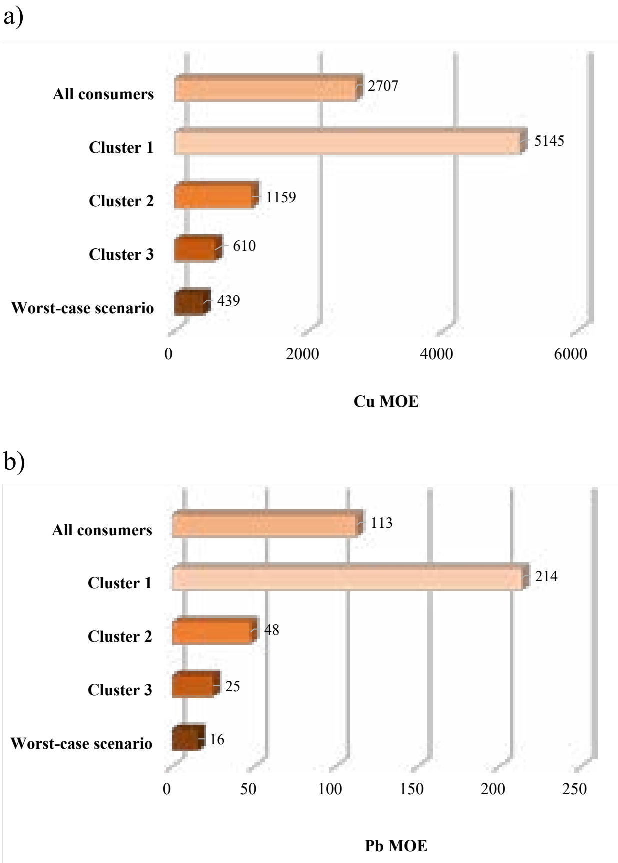

Figure 4. Margin of Exposure (*MOE*) of *Cu* (a) and *Pb* (b) through honey consumption (*composed by the authors*).

The obtained *EDI* values of *Cu* and *Pb* (Figure 3) were compared with the *HBGV*s established by *EFSA* (EFSA, 2010; EFSA Scientific Committee, et al., 2023). Specifically, *Cu EDI* values were compared with the Acceptable Daily Intake (ADI) of 0.07 mg/kg/day (EFSA Scientific Committee, et al., 2023), while *Pb EDI* values were compared with the benchmark dose level (BMDL10) of 0.00063 mg/kg/day (EFSA, 2010). In both cases, the *EDI* values from honey consumption were considerably lower than the established HBGVs.

For *Cu* and *Pb* risk characterization, the margin of exposure (*MOE*) was calculated based on the *HBGV*s (Figure 4). According to *EFSA* methodology, *MOE* values greater than 10 (*MOE>10*) indicate no risk to public health.

In the case of *Cu* and *Pb* detected in Armenian honey samples, the estimated *MOE* values (Figure 4) were significantly above 10, suggesting that the detected contents of these elements do not pose a health risk to the adult population in Armenia. Only in the worst-case scenario, which combines the highest honey consumption rate with the highest detected concentration of the element, the MOE of Pb (Figure 4, b) was the lowest and slightly above the threshold of 10, suggesting that continuous monitoring and control are essential to ensure consumer safety and minimize potential risks in the future.

Conclusion

In conclusion, this study provides important insights into the levels of potentially toxic elements (*Pb, As, Mo, Cu*) in Armenian multifloral honey and their possible risk to public health. The analytical results reveal that the levels of these elements are generally low and well below the available regulatory thresholds. The dietary exposure and associated risk assessment further showed with *EDI* values are significantly lower compared to the health-based guidance values. Furthermore, the estimated *MOE* values were above the threshold of 10, indicating no significant public health concern associated with chronic exposure to studied elements through honey consumption. Overall, the study findings suggest that the levels of potentially toxic elements in Armenian honey are within acceptable limits, and there are no health risks to consumers.

While the current research data suggest no immediate public health concerns from dietary exposure to potentially toxic elements via honey consumption, the potential for variability due to factors such as agricultural practices and industrial activities highlights the need for continuous monitoring. Ongoing controls and compliance to best practices in honey production will be essential to safeguard the quality of Armenian honey and protect consumer health in the long term. Future research could expand to include a larger number and variety of honey samples, as well as additional elements.

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Assessment of Dietary Fiber Intake from Fruit and Vegetable Consumption: Case Study of Yerevan, Armenia

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ABSTRACT

Fruits and vegetables are staple component of a healthy diet. They are rich sources of macronutrients (proteins, fats, carbohydrates), including dietary fiber, which is associated with a reduced risk of noncommunicable diseases. In Armenia recent population-level assessments of dietary fiber intake are lacking. Therefore, this case study aimed to estimate daily dietary fiber intake from fruits and vegetables consumed by the adult population (18-65 years old) residing in Yerevan, Armenia. By integrating data on fruit and vegetable consumption collected through a food frequency questionnaire (FFQ) with data on the dietary fiber content of these products, the daily dietary fiber intake (DI) was calculated for males and females, and the overall adult population in Yerevan. These estimates were then compared with the available international recommendations. The results showed that the overall mean daily dietary fiber intake from the studied fruit and vegetable species was 24,64 g/day, with males consuming slightly more fiber (26,59 g/day) than females (23,19 g/day), overall remaining below the generally recommended minimum requirements. However, the estimates reflect only 12 fruit and vegetable species and seasonal consumption patterns, while other dietary sources may also contribute. Therefore, broader research including a wider variety of fiber sources seasonal variations is needed in Armenia.

Introduction

Fruits and vegetables are important component of a healthy diet due to their high content of nutrients (macronutrients such as proteins, fats and carbohydrates, as well as vitamins and minerals). Regular consumption of a variety of fruits and vegetables can ensure adequate intake of essential nutrients that contribute to the prevention of noncommunicable disease and the maintenance of overall health (WHO, 2023). Among the nutrients, the dietary fiber is of high importance in this context (Suresh, et al., 2024; World Cancer Research Fund, 2018). It's a complex of carbohydrates and their derivatives. The term "dietary fiber" was originally defined by Trowell (1972) as "that portion of food which is derived from the cellular walls of plants and digested very poorly by human beings". Traditionally, the terms "soluble" and "insoluble" dietary

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fiber were used in the literature to distinguish between types of fiber. However, this classification is method-dependent and solubility does not always accurately predict physiological effects (EFSA, 2010).

Adequate dietary fiber intake has been associated with reduced risk of obesity, type 2 diabetes, cardiovascular disease, colorectal cancer and other chronic conditions (Aune, et al., 2011; Reynolds, et al., 2019; Zhang, et al., 2025, World Cancer Research Fund, 2018). Higher intake of dietary fiber from various sources were associated with lower risk of mortality (Yao, et al., 2023). Dietary fiber participates in human metabolism, prevents the development of the mentioned diseases, also boosts the production of gastric digestive juice and enhances gastrointestinal (GI) motility (Li and Zhang, 2021; Zhang, et al., 2025). Specifically, the fiber from fruits and vegetables provides protective effects against inflammatory bowel disease (Deng, et al., Milajerdi, et al., 2021).

Despite its known health benefits, global estimates indicate that dietary fiber intake remains below recommended levels (for example 25 mg per day) in many populations (EUFIC, 2023; Ioniță-Mîndrican, et al., 2022; Stephen, et al., 2017). In Armenia, where fruits and vegetables are dietary staples, population-level data on dietary fiber intake from these sources are lacking. Considering the essential role of fruits and vegetables in the Armenian diet (Stepanyan, et al., 2022), assessing dietary fiber intake from these sources is important for public health and nutrition, as well as for identifying opportunities for dietary improvement. Therefore, this case study aims to estimate daily dietary fiber intake from fruits and vegetables consumed by the adult population (18-65 years old) in Yerevan, the capital with the largest population in Armenia.

The research was supported by the Higher Education and Science Committee of MESCS RA (Research project N24LCG-4A011).

Materials and methods

The daily dietary fiber intake (DI) from fruits and vegetables was calculated for males and females, and the overall adult population (18-65 years old) in Yerevan using the following equation:

$$DI=C\times IR,$$

where C represents the dietary fiber content in each fruit and vegetable (g/100g, converted to mg/kg), and DI is the daily consumption of fruits and vegetables (g/day, converted to kg/day) by the adult population in Yerevan.

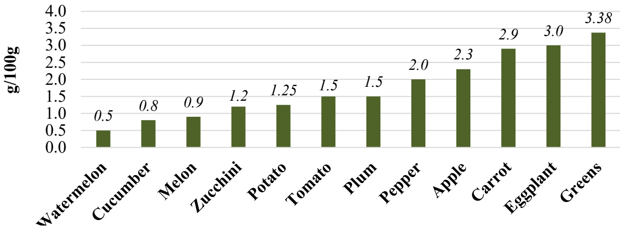

Figure 1. Mean dietary fiber content (g/100g) in fruits and vegetables (*FAO, 2010).*

The data (Figure 1) on dietary fiber content in 12 species of fruits (apple, plum, watermelon, melon) and vegetables (tomato, cucumber, eggplant, carrot, greens, zucchini, pepper, potato) were obtained from the FAO's food composition table for Armenia (FAO, 2010).

Data on the consumption of the aforementioned 12 fruits and vegetables were taken from the database created by the Informational-Analytical Center for Risk Assessment of Food Chain at the Center for Ecological-Noosphere Studies (CENS). Consumption data were collected through an interviewer-administered, semi-quantitative, 12-item food frequency questionnaire (FFQ), developed to assess the dietary intake of the Yerevan population during summer 2017. Although some fruits and most vegetables are available year-round in Yerevan, their intake varies by season. Consumption of fruits and vegetables has noticeable seasonal fluctuations, which depend not only on seasonal production but also on changes in the socio-economic conditions. Therefore, the FFQ questionnaire focused on fruit and vegetable consumption by season.

The FFQ is a checklist in which each participant is asked about the frequency and portion size of foods consumed over a specific period. In general, FFQs are reliable, valid, and cost-effective tool for assessing usual dietary intake within a population over a defined period. The questionnaire included questions about consuming frequency and portion size, as well as demographic characteristics (such as age, gender). A detailed description of the FFQ is provided by Beglaryan et al. (Beglaryan, et al., 2025).

A total of 1329 individuals (563 males and 766 females), aged 18-65 years and residing in Yerevan, voluntarily participated in face-to-face surveys. The representative sample size was calculated and selected to represent the entire Yerevan population, with participants enrolled from all 12 districts of the city.

Data entry and statistical analysis were performed using SPSS Software (version 22.0).

Results and discussions

The estimated mean daily dietary fiber intakes (DI) from 12 commonly consumed fruits and vegetables among the adult population in Yerevan are summarized in Table.

Table. Estimated daily dietary fiber intake (DI) from fruit and vegetable consumption by the adult population in Yerevan*

Fruits and vegetables	**Estimated daily dietary fiber intake *(DI)*, *Mean* ± *SD* (g/day)**		
	DI for all consumers	**DI for males**	**DI for females**
Apple	4.52 ± 3.60	4.55 ± 3.57	4.50 ± 3.63
Plum	1.00 ± 0.94	1.08 ± 0.98	0.94 ± 0.89
Watermelon	3.03 ± 2.25	3.44 ± 2.33	2.71 ± 2.13
Melon	1.15 ± 0.94	1.28 ± 0.99	1.05 ± 0.89
All fruits (excluding watermelon and melon)	5.52 ± 3.84	5.63 ± 3.85	4.77 ± 3.84
All fruits (including watermelon and melon)	9.70 ± 5.11	10.34 ± 5.20	9.21 ± 4.97
Tomato	4.52 ± 2.74	5.10 ± 2.87	4.09 ± 2.57
Cucumber	1.33 ± 0.90	1.50 ± 0.95	1.21 ± 0.84
Eggplant	2.61 ± 2.23	2.69 ± 2.19	2.56 ± 2.26
Carrot	1.02 ± 0.91	1.07 ± 0.92	0.98 ± 0.91
Greens	0.86 ± 1.06	0.83 ± 1.05	0.89 ± 1.06
Zucchini	0.82 ± 0.73	0.85 ± 0.73	0.80 ± 0.73
Pepper	1.78 ± 1.46	1.98 ± 1.53	1.63 ± 1.38
Potato	1.99 ± 1.54	2.22 ± 1.68	1.82 ± 1.41
All vegetables (excluding potato)	12.95 ± 7.05	14.02 ± 7.17	12.16 ± 6.89
All vegetables (including potato)	14.94 ± 7.48	16.24 ± 7.61	13.98 ± 7.27
Overall *DI* (∑*DI*)	24.64 ± 10.28	26.59 ± 10.51	23.19 ± 9.88

Note: SD - standard deviation.

*Composed by the authors.

The obtained data (Table) indicate daily dietary fiber intakes from individual food items, aggregated categories for fruits and vegetables, and overall total (∑*DI*), for all consumers, males and females. All values are reported as mean ± standard deviation (*SD*) in grams per day (g/day).

The overall *DI (∑DI)* from all assessed fruits and vegetables was 24.64 ± 10.28 g/day. When analyzing separately by gender, males had a higher intake of fiber (26.59 ± 10.51 g/day) compared to females (23.19 ± 9.88 g/day).

Fruits contributed approximately 39.4% (9.7 g/day) of the total fiber intake, while vegetables had the major share of around 60.6% (14.94 g/day). The highest fiber intake from fruits was observed for apples (4.52 ± 3.6 g/day), followed by watermelon (3.30 ± 0.25 g/day) and melon (1.15 ± 0.94 g/day). Combined fruit intake, excluding watermelon and melon, was 5.82 ± 3.85 g/day, increasing to 9.70 ± 5.20 g/day when including these items, indicating their notable seasonal impact. Among vegetables, tomatoes contributed the most fiber (4.52 ± 2.74 g/day), followed by eggplant (2.61 ± 2.23 g/day) and potato (1.99 ± 1.54 g/day). Daily fiber intake from vegetables in case of excluding potato was 12.95 ± 7.05 g/day, reaching to 14.94 ± 7.48 g/day when potato was included.

The contributions of each studied fruits and vegetables in the estimated daily dietary fiber intake *(DI)* for all consumers, males and females are shown in Figure 2, Figure 3 and Figure 4, respectively.

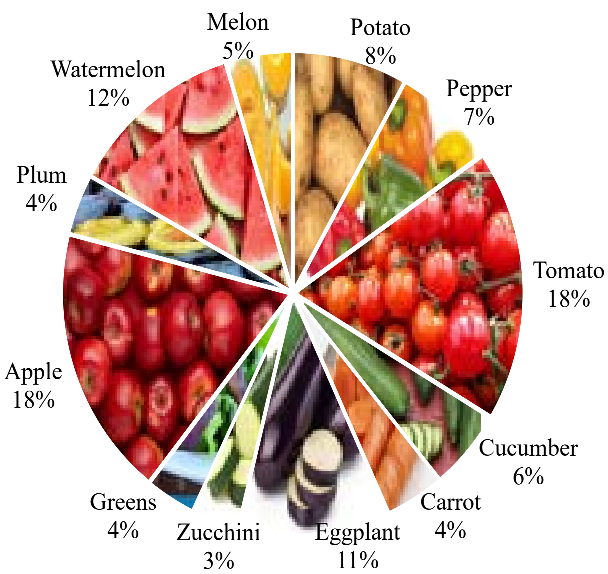

Figure 2. Contribution of fruits and vegetables in dietary fiber intake (DI) for all consumers *(composed by the authors).*

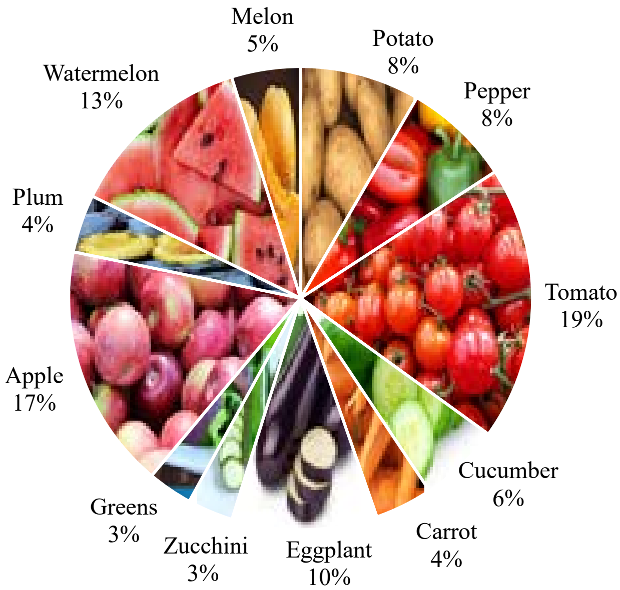

Figure 3. Contribution of fruits and vegetables in dietary fiber intake *(DI)* for males *(composed by the authors).*

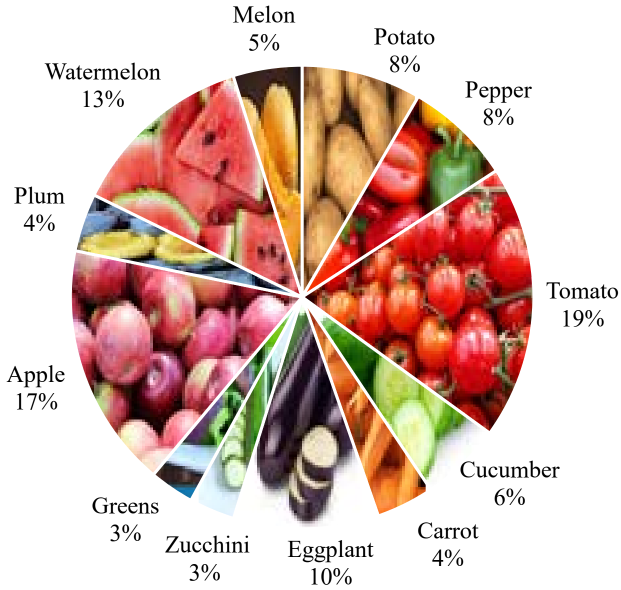

Figure 4. Contribution of fruits and vegetables in dietary fiber intake *(DI)* for females *(composed by the authors).*

Differences in contributions to the overall *DI* were observed for most of the studied fruits and vegetables consumed by males and females (Figure 3 and Figure 4). Notably, tomato consumption contributed the most to overall fiber intake among males, while apple consumption had the highest contribution among females.

International agencies and organizations recommend average minimum daily intake values for dietary fiber, which generally range from 25 to 35 g/day for adults, depending on gender, age and energy intake (EFSA, 2010; EUFIC, 2023; Marconi, et al., 2025; South, 2025). The European Food Safety Authority set the dietary reference value (DRV) for an adequate intake (AI) of fiber at 25 g/day for adults to support normal bowel function (EFSA, 2025). However, in most European countries, daily dietary fiber intake remains below this recommended value. For example, average intakes of fiber were around 20 g/day in Germany and Norway, followed in decreasing order, by Denmark, the Netherlands, Sweden, Belgium, Ireland, the UK, Spain and France (EUFIC, 2023). In the Nutritional Recommendations for the French population, a fiber intake above 25 g/day is suggested for maintaining a healthy colon, with 30 g/day as the preferred level to decrease the risk of colon cancer (EFSA, 2010). In the Nordic Nutrition Recommendations, fiber intake is set at 25 g/day for women and 35 g/day for men (Nordic Nutrition Recommendations, 2023). The UK government guidelines state that dietary fiber intake should increase to 30 g/day as part of a healthy, balanced diet (NHS, 2025). The US Food and Drug Administration (FDA) recommends 28 g/day for a 2000 kcal/day diet, while the American Dietetic Association specifies 14 g/day per 1000 kcal/day diet (Marconi, et al., 2025). The Food and Nutrition Development Guideline in China (2025-2030) recommends increasing daily dietary fiber intake to 25-30 g/day (WFP, 2025).

When drawing a comparison between the obtained results and international recommendations, the overall mean daily dietary fiber intake of 24,64 g/day among adults in Yerevan is slightly below the adequate intake (AI) of 25 g/day set by EFSA, and remains lower than the higher recommended levels of 28-35 g/day suggested by other international guidelines.

Conclusion

The findings of this study provide important insights into the daily dietary fiber intake derived specifically from fruits and vegetables among the adult population in Yerevan, Armenia. The overall mean intake of dietary fiber was 24,64 g/day (SD=10,28 g/day), with variations observed between male and female consumers. Individual differences are also reflected in the estimated standard deviations. Notable, male consumers had slightly higher intake of dietary fiber (26,59 g/day) compared to females (23,19 g/day), reflecting differences in consumption patterns.

Although the overall mean daily intake of dietary fiber for the Yerevan adult population is below the generally recommended value of 25-35g/day, it should be noted that these intake estimates are based only on 12 species of fruits and vegetables, while other dietary sources of fiber may also contribute. In addition, the observed consumption patterns primarily reflect the season when these particular fruits and vegetables are commonly and frequently consumed.

Overall, study emphasizes the need for broader research that includes a wider range of fiber sources and covers different seasons to provide more comprehensive assessment of dietary fiber intake among the Armenia population.

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ՊԱՐԲԵՐԱԿԱՆԸ ՆԵՐԱՌՎԱԾ Է ԴՈԿՏՈՐԱԿԱՆ ԵՎ ԹԵԿՆԱԾՈՒԱԿԱՆ ԱՏԵՆԱԽՈՍՈՒԹՅՈՒՆՆԵՐԻ ԱՐԴՅՈՒՆՔՆԵՐԻ ԵՎ ԴՐՈՒՅԹՆԵՐԻ ՀՐԱՊԱՐԱԿՄԱՆ ՀԱՄԱՐ ՀՀ ԿԳՄՍՆ ԲՈԿ-Ի ԿՈՂՄԻՑ ԸՆԴՈՒՆԵԼԻ ԳԻՏԱԿԱՆ ՀԱՆԴԵՍՆԵՐԻ ՑԱՆԿՈՒՄ:

ИЗДАНИЕ ВКЛЮЧЕНО В ПЕРЕЧЕНЬ ВЕДУЩИХ НАУЧНЫХ ЖУРНАЛОВ ВАК МНОКС РА, В КОТОРЫХ ДОЛЖНЫ БЫТЬ ОПУБЛИКОВАНЫ ОСНОВНЫЕ РЕЗУЛЬТАТЫ И ПОЛОЖЕНИЯ ДИССЕРТАЦИЙ НА СОИСКАНИЕ УЧЕНОЙ СТЕПЕНИ ДОКТОРА И КАНДИДАТА НАУК.

THE JOURNAL IS INVOLVED IN THE LIST OF SCIENTIFIC PERIODICALS RELEVANT FOR PUBLICATIONS OF THE RESULTS AND PROVISIONS OF DOCTORAL AND PHD THESES AND APPROVED BY THE HIGHER EDUCATION QUALIFICATION COMMITTEE OF THE RA MoESCS.

ՀՈԴՎԱԾՆԵՐԻ ԸՆԴՈՒՆՄԱՆ ԿԱՐԳԸ

1. Հոդվածներն ընդունվում են հայերեն, ռուսերեն և անգլերեն լեզուներով:
2. Հոդվածի առավելագույն ծավալը չպետք է գերազանցի 15 համակարգչային էջը (ներառյալ ամփոփագրերը):
3. Հեղինակների թիվը չպետք է գերազանցի չորսը:
4. Հեղինակների տվյալներում պետք է ներառվեն հեղինակ(ներ)ի անունը, ազգանունը, հայրանունը, գիտական աստիճանը, աշխատավայրը, էլ. հասցեն:
5. Հոդվածը ներկայացվում է տպագիր և էլեկտրոնային (WORD ձևաչափով) տարբերակներով:
6. **Հոդվածը շարադրվում է հետևյալ կառուցվածքով.** վերնագիր, 5 բանալի բառ, «Նախաբան», «Նյութը և մեթոդները», «Արդյունքները և վերլուծությունը», «Եզրակացություն», «Գրականություն»:
7. Գրականության հղումները կատարվում են տեքստում՝ փակագծում նշվում են հեղինակը և հրատարակման տարեթիվը:
8. Հոդվածները պետք է ունենան ամփոփագրեր. հայերենով և ռուսերենով ներկայացված հոդվածների դեպքում՝ հայերեն (առնվազն 60 բառ), ռուսերեն (առնվազն 60 բառ) և անգլերեն (150-250 բառ), անգլերենի դեպքում՝ անգլերեն լեզվով (առնվազն 60 բառ):
9. Հայերեն և ռուսերեն հոդվածների վերնագրերը, հեղինակ(ներ)ի տվյալները և բանալի բառերը ներկայացվում են հայերեն, ռուսերեն և անգլերեն լեզուներով:
10. Գրականության ցանկը ներկայացվում է առնվազն 10 անուն, շարադրվում է այբբենական կարգով:
11. Մեջբերված գրականության աղբյուրների առնվազն 30%-ը պետք է հրատարակված լինի վերջին տասը տարիներին:
12. Էլեկտրոնային հղումը որպես աղբյուր մեջբերելիս գրականության ցանկում նշվում է դիտման ամսաթիվը:

Հոդվածներին ներկայացվող տեխնիկական պահանջներն են. անգլերեն և ռուսերեն հոդվածների տառատեսակը՝ Times New Roman, հայերեն հոդվածներինը՝ GHEA Grapalat, տառաչափը՝ 12, միջտողային տարածությունը՝ 1.5, վերնագիրը՝ մեծատառերով, գծապատկերները՝ Word, Excel ծրագրերով, աղյուսակները՝ ուղղահայաց դիրքով (Portrait), բանաձևերը՝ Microsoft Equation 3.0 ձևաչափով:

Կարգին չհամապատասխանող հոդվածները չեն ընդունվում: Հոդվածներն ուղարկվում են գրախոսման: Մերժված հոդվածները չեն վերադարձվում հեղինակին: Հոդվածները չեն հրատարակվի, եթե ամբողջությամբ կամ համառոտ տպագրված լինեն այլ պարբերականում:

ПОРЯДОК ПРИЁМА СТАТЕЙ

1. Статьи принимаются на армянском, русском и английском языках.
2. Объём статьи не должен превышать 15 компьютерных страниц (включая аннотации).
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4. В сведениях об авторах должны быть включены имя (имена), фамилия, отчество, научная степень, место работы, эл.адрес.
5. Статья представляется в печатном и электронном (в формате WORD) вариантах.
6. **Статья должна быть изложена следующим образом:** заглавие, 5 ключевых слов, “Введение”, “Материал и методы”, “Результаты и анализ”, “Заключение”, “Литература”.
7. Библиографические ссылки указываются в тексте (в скобках пишутся фамилия автора и год издания).
8. Статьи должны иметь аннотации: статьи, представленные на армянском и русском языках – на армянском (не менее 60 слов), на русском (не менее 60 слов) и на английском (150-250 слов). В случае статей, написанных на английском, аннотация должна быть на английском языке (не менее 60 слов).
9. Заглавия, данные автора (авторов) и ключевые слова статей на армянском и русском языках представляются на армянском, русском и английском языках.
10. Список литературы должен содержать не менее 10 наименований источников, указанных в алфавитном порядке.
11. Не менее 30% цитируемых литературных источников должны быть опубликованы в течение последних десяти лет.
12. При ссылке на интернет-ресурс как на источник информации в библиографическом списке необходимо указать дату просмотра.

Технические требования к статьям: для статей на английском и русском языках – шрифт Times New Roman, для армянского – GHEA Grapalat; размер букв – 12; межстрочное расстояние – 1.5; заголовок – прописными буквами; графические изображения – программой Word, Excel; таблицы – вертикально (Portrait); формулы – в формате Microsoft Equation 3.0;

Статьи, не отвечающие требованиям, не будут приняты. Статьи передаются на рецензирование. Статьи, не принятые к печати, не возвращаются автору. Статьи не будут опубликованы, если ранее были полностью или частично опубликованы в других периодических изданиях.

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1. The articles are accepted in Armenian, Russian and English languages.
2. The size of the article shouldn’t exceed 15 PC pages (including summaries).
3. The number of authors should not exceed four.
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5. The article is submitted in a hard copy and electronically (WORD format).
6. **The article should have the following structure:** title, 5 keywords, “Introduction”, “Materials and Methods”, “Results and Discussions”, “Conclusion”, “References”.
7. References to the literature should be indicated in the text (the author and the date of publication in the parentheses).
8. The articles should have abstracts: in case of Armenian and Russian articles, abstracts in Armenian (minimum 60 words), Russian (minimum 60 words) and English (150-250 words) languages should be submitted, while in case of English articles, abstracts in English (minimum 60 words) language should be submitted.
9. The titles, information about the author(s) and keywords should be presented in Armenian, Russian and English languages.
10. The list of literature should be presented with at least 10 names, arranged in alphabetical order.
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