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Creation of *in vivo* and *in vitro* collection of selected forms of endemic wild apricot *Armeniaca vulgaris* (Lam) with economic viability

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ABSTRACT
The wild apricot tree, *Armeniaca vulgaris*, is a special native species that is important for both the natural environment and the economy in farming areas of Kazakhstan. This study focused on developing selected forms of this tree in both natural environments and lab settings to evaluate their economic benefits. Initially, we gathered top-performing samples from different regions, picking them based on how they grow, their resistance to difficult conditions, and the quality of their fruits. Lab techniques, specifically tissue culture, were then used to rapidly grow these samples and preserve their genetic material. We discovered significant differences in their organic contents, such as vitamin C and phenols, and in their physical traits among the various groups. Early findings revealed 15 outstanding types with strong economic advantages. These types produced 20-35% more fruit than the regional average and have excellent potential for establishing sustainable orchards and processing industries. Using both traditional and modern scientific methods, this study provides an approach to preserving and economically utilizing Kazakhstan's native genetic resources.

Keywords: *Armeniaca vulgaris*, Native wild apricot, Economic sustainability, Tissue culture.
Article type: Research Article.

INTRODUCTION
The wild apricot tree, known as *Armeniaca vulgaris*, is a crucial species native to the temperate regions of Central Asia. It plays a significant role in maintaining the balance of ecosystems and offers important genetic material for improving crop varieties. This tree is highly adaptable to harsh conditions such as drought and poor soil, making it a valuable resource for plant breeding programs. However, the expansion of human activities, climate change, and the replacement of these trees with commercial varieties pose a threat to their survival in Kazakhstan. Recent reports indicate that over 30% of these wild apricot populations have declined in the past two decades, highlighting the urgent need for conservation efforts (Nazori *et al.* 2024; Ergashevich *et al.* 2024; Tursinbayeva *et al.* 2024). Despite this decline, the economic benefits of wild apricot trees are not fully recognized, especially in the food, pharmaceutical, and rural tourism sectors. The fruits of these trees are rich in healthy compounds like polyphenols and vitamin C, providing a valuable opportunity to produce health-promoting products. Unfortunately, the lack of organized gene banks and effective growing methods limits their sustainable use. Traditional seed propagation is not ideal for commercial purposes due to genetic variability and long growth periods. Tissue culture technology, which involves growing plants in controlled environments, appears promising for rapid multiplication of superior

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plant types and maintaining genetic diversity, but it has not been extensively explored for the wild apricots of Kazakhstan. This research aims to create the first comprehensive collection of high-quality wild apricot genotypes in both natural and controlled settings, emphasizing both economic and ecological sustainability. By applying various scientific techniques, this study seeks to explore the genetic diversity within the species and identify those that can withstand environmental stresses (Teshaev *et al.* 2024; Violet & Hazarika, 2024). A major innovation of this research is developing effective tissue culture methods for mass production, reducing pressure on natural populations and providing a sustainable supply to local markets. *Armeniaca vulgaris* (Lam), an ancestor of the apricot, is highly interesting to researchers due to its broad genetic variety and ability to thrive in many environments. Studies show that wild populations in Central Asia, especially in Kazakhstan, have unique genes that enable them to withstand drought and salty soils, which are beneficial traits for improving commercial apricot varieties. The diversity of *A. vulgaris* in Kazakhstan is linked to different types of soil and variations in annual rainfall, making it crucial to protect these genetic features. Ecologically, the number of natural *A. vulgaris* plants has dropped significantly in the past twenty years (Puspitasari *et al.* 2022). This decline raises concerns about disruptions in food chains and the loss of ecosystem benefits. A 2022 FAO report revealed that more than 40% of *A. vulgaris* fruit forests in Central Asia have been lost due to industrial agriculture and overgrazing. This reduction not only threatens biodiversity but also limits economic opportunities from products like gum and seeds. Chemically, wild *A. vulgaris* fruits are richer in phenolic compounds and antioxidants than cultivated apricots. They contain about 23 mg g^{-1} dry weight of phenolic compounds and can neutralize up to 85% of free radicals, making them valuable for health foods and pharmaceuticals. However, there are few studies on how to use this potential economically on a local scale (Karatas 2022; Yousefi-Behzadi *et al.* 2023). In terms of propagation, tissue culture techniques are somewhat effective for many *Prunus* species, but they face challenges with *A. vulgaris*. The success rate in lab conditions using MS medium with BAP hormone is only 35%, highlighting the need for better methods. Traditional seed growing is impractical for commercial use due to high genetic variability and long germination times of 140 to 160 days. Despite global initiatives to preserve plant genetic resources, complete programs that combine lab and natural methods haven't been developed in Kazakhstan. Past research has mostly focused on ecological or chemical aspects without addressing sustainable economic models. This gap underscores the need for new research to connect genetic science, biotechnology, and economic strategies to effectively conserve and utilize *A. vulgaris*.

MATERIALS AND METHODS

Study area and sample collection

The authors gathered samples of *Armeniaca vulgaris* from three areas in Kazakhstan: mountains, semi-arid plains, and rivers. This was done over two growing seasons, 2022 and 2023. We chose plants based on when they flower and bear fruit, and how they handle stresses like pests, salty soil, and drought. We focused on trees with good fruit size, weight, and yield. In total, we collected 120 samples from healthy trees aged 10 to 15 years, each located at least 500 meters away from the others.

Morphological and biochemical evaluation

We measured the fruit for length, width, skin thickness, and how much of it can be eaten, using digital tools. For the biochemical part, we checked vitamin C levels through titration and measured total phenolic compounds with the Folin-Ciocalteu method. Spectroscopic tests (UV-Vis) were done three times for each sample.

In vitro propagation

Small samples from healthy bud branches were placed in a special growth medium with the right amount of growth regulators like BAP and NAA. We cleaned them with 70% ethanol and 2% sodium hypochlorite. Conditions were set at 25 ± 1 °C with 60% humidity and periods of 16 hours light followed by 8 hours darkness. We recorded how well they regenerated and how much they grew every four weeks.

Statistical analyses

Data analysed were done using SPSS version 26 software. We applied One-Way ANOVA and Tukey tests with a 95% confidence level. To look into genetic diversity, we used principal component analysis (PCA) and hierarchical clustering with R software version 4.2.1. Average values along with standard deviation are shown in the results tables.

Economic sustainability assessment

We examined the costs and benefits of growing plants *in vivo* (live) and *in vitro* (in the lab) by calculating internal rate of return (IRR) and payback period (PBP). We collected market information like fruit prices, seedling production costs, and local demand by interviewing 50 farmers and 10 processing companies in the study areas.

RESULTS

This study investigated *Armeniaca vulgaris* fruit plants in Kazakhstan, focusing on 120 types from three regions. The research examined the plants in terms of appearance, chemical makeup, and economic potential.

The study found significant differences in fruit weight (Table 1). Fruits from mountain areas weighed more on average (23.5 g) compared to those from flat areas (18.2 g). Beside rivers, fruits had thinner skins (0.85 mm), likely due to higher moisture levels in these areas.

Table 1. Morphological traits of wild apricot fruits across ecological regions.

Region	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Peel thickness (mm)
Mountainous	23.5 ± 3.1*	3.8 ± 0.4	3.2 ± 0.3	1.2 ± 0.2
Semi-arid plains	18.2 ± 2.7	3.1 ± 0.3	2.7 ± 0.2	1.5 ± 0.3
Riverside areas	20.1 ± 2.9	3.5 ± 0.3	2.9 ± 0.2	0.85 ± 0.12*

According to Table 2, wild fruits contained more phenolic compounds (18.9 to 27.4 mg g^{-1}) than domesticated ones (10.5 to 14.3 mg g^{-1}). Fruits from dry regions had the highest vitamin C content at 58.6 mg 100 g^{-1}, which is 35% above the regional average. This increase is related to how plants cope with dry conditions.

Table 2. Biochemical comparison of wild vs. cultivated apricots.

Parameter	Wild *A. vulgaris* (Range)	Cultivated varieties (Range)
Total Phenolics (mg g^{-1} DW)	18.9–27.4	10.5–14.3
Vitamin C (mg 100 g^{-1} FW)	40.2–58.6*	22.5–35.1
Antioxidant Activity (% DPPH inhibition)	78–85%	45–62%

Table 3 shows that a certain propagation method using specific growth substances had a 72% success rate in regrowing plant samples. Shoots grew to 4.3 cm in eight weeks. High levels of NAA caused too much callus formation, which reduced rooting success (15%). Different genotypes responded differently to the growth medium, with ten types showing a regeneration rate above 85%.

Table 3. In vitro propagation efficiency under different hormonal treatments.

Hormone combination (mg/L)	Regeneration rate (%)	Shoot length (cm)	Rooting rate (%)	Callus formation
BAP 2.0 + NAA 0.5	72 ± 6.2*	4.3 ± 0.9	65 ± 5.1	Low
BAP 1.5 + NAA 1.0	35 ± 4.8	2.1 ± 0.7	15 ± 3.2*	Excessive
Control (No hormones)	8 ± 2.1	0.9 ± 0.3	0	None

Economic factors

Table 4 highlights that the lab propagation method is more economically viable with a payback period of 3.2 years and a return rate of 24%, compared to traditional methods which have a payback of 5.1 years and a 12% return rate. Each lab-grown plant sells for 1500 tenge (about 3.3 USD), yielding a 40% profit margin.

Table 4. Economic viability of propagation methods.

Parameter	Traditional (*in vivo*)	*In vitro*
Payback Period (PBP)	5.1 years	3.2 years*
Internal Rate of Return (IRR)	12%	24%*
Production Cost per Plant	800 Tenghe (~1.8 USD)	950 Tenghe (~2.1 USD)
Market Price per Plant	1200 Tenghe (~2.6 USD)	1500 Tenghe (~3.3 USD)*
Net Profit Margin	33%	40%*

Genetic analysis also shows separation of plant groups from different regions. The main factors causing this separation are drought tolerance (43.7%) and fruit quality (28.1%). Additional methods grouped the top 15 genotypes into three main categories, helping establish a robust plant collection for ongoing study.

DISCUSSION

This study explores the value of the plant *Armeniaca vulgaris* in Kazakhstan from ecological, biotechnological, and economic viewpoints. The plant grows in different shapes and with different chemicals in various environments (shown in Tables 1 and 2), confirming that environmental changes affect how the plant develops. In mountainous areas, the plant has larger and healthier fruits, likely due to better access to water and nutrients. In contrast, plants in dry areas produce more phenolic compounds and vitamin C to survive harsh conditions, matching findings by Chen *et al.* (2022) about drought's effect on plant chemicals. The study successfully used a lab method called *in vitro* propagation, achieving a success rate of 72% (Table 3). However, different plant types react differently to lab conditions, indicating a need for specific methods for each type, as mentioned by Muratova *et al.* (2023). This study improved the process by optimizing hormones BAP and NAA for better growth. Comparing various growing methods (Table 4) shows *in vitro* propagation as the superior option for both short- and long-term production, supported by Abdullaev *et al.* (2023), who studied its economic benefits. For conservation, identifying the top 15 plant types with high stress resistance and economic performance can guide the creation of gene banks and culture bases. The distribution of these types highlights ecological differences and supports breeding programs to enhance commercial plants with strong traits, following Li *et al.* (2020). A major challenge is integrating these findings with Kazakhstan's agricultural strategies, due to limited production facilities and marketing, which may restrict widespread adoption. This research simultaneously addresses conservation, biotechnology, and economic factors for *A. vulgaris*, offering a broader view than previous studies. However, future research is needed to address the study's limitations, such as its short duration and lack of long-term evaluation of lab-grown plants. Investigating the impact of climate change on these plants using ecological modelling and developing additional products like medicinal extracts could boost project profitability. Overall, this study shows that combining traditional and modern methods not only ensures the survival of native plants but also contributes to local economic growth by creating sustainable rural jobs. The findings offer a potential model for conserving other unique plant species in Kazakhstan.

CONCLUSION

This study examined the top 15 varieties of *Armeniaca vulgaris*, a type of apricot, in Kazakhstan. The research plays a crucial role in protecting these native plants and using them resourcefully. The findings revealed that by using *in vivo* methods, which focus on preserving natural diversity, alongside *in vitro* methods, which boost a 72% plant regrowth and a 24% economic return, we can not only ensure the survival of this species but also open up new business opportunities in the food and medicine sectors. In-depth checks of the plants' genetic makeup and physical traits showed significant differences within the species, which are essential for future plant breeding programs. For the long-term success of this project, it's vital for researchers, farmers, and government leaders to collaborate. They need to work together to build necessary facilities and identify market targets. This study offers a comprehensive plan for conserving and economically utilizing native plants in Central Asia.

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