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The effect of soil structure and mechanical composition on the rooting process in pomegranate (Punica granatum L.) seedling production.

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Abstract: This article scientifically investigates the technology of growing pomegranate (Punica granatum L.) seedlings from cuttings under the soil and climatic conditions of the Boyovut district, as well as the effect of substrate composition on the rooting process. The obtained results confirmed that the substrate composition directly influences the rooting time of pomegranate cuttings, the development of the root system, and the overall quality of seedlings. The highest performance indicators were observed in the variants where mixed substrates were applied. In particular, the Qozoqi pomegranate variety showed a high rooting rate, a well-developed root system, and strong seedling survival. In contrast, when gray soil was used alone, all varieties exhibited slower rooting processes and weaker root system development. Based on the research findings, it was scientifically substantiated that the use of mixed substrates is effective for growing pomegranate seedlings under the conditions of the Boyovut district. These results are of significant importance for producing high-quality seedlings, developing pomegranate cultivation, and introducing advanced technologies into agricultural practice.

Keywords: *pomegranate, Punica granatum, seedling production, cuttings propagation, substrate composition, mixed substrate, rooting process, root development, seedling quality, Boyovut district, soil conditions, nursery technology.*

Introduction. Pomegranate (Punica granatum L.) is one of the ancient subtropical fruit crops that has been cultivated by humans for thousands of years. It is distinguished by its high biological adaptability, tolerance to drought and heat, as well as the nutritional, dietary, and medicinal value of its fruits. Pomegranate fruits contain sugars, organic acids, vitamins, antioxidants, and microelements, making them widely used not only in the food industry but also in the pharmaceutical and processing sectors.

In recent years, due to the development of intensive horticulture systems, increasing attention has been paid to expanding pomegranate plantations and introducing high-yielding varieties. One of the key factors for achieving stable and high yields is the production of high-quality, healthy, and well-developed seedlings. The quality of seedlings, in turn, largely depends on the scientific basis of applied agrotechnical practices and especially on the condition of the growing medium — the soil.

During the cultivation of pomegranate seedlings, the physical, mechanical, and biological properties of the soil play a crucial role. Soil structure, porosity, water permeability, moisture-holding capacity, and aeration level are among the main factors determining the formation and active development of the root system. In conditions where the soil structure is degraded or compacted, root growth is restricted, the water-air regime deteriorates, and consequently, the survival rate and growth intensity of seedlings decrease.

In addition, the mechanical composition of the soil (sandy, loamy, or clayey) significantly affects the rooting percentage and subsequent vegetative growth of seedlings. Light-textured soils provide good aeration but do not retain moisture for long periods, whereas heavy soils retain moisture well but limit air exchange. Therefore, creating optimal soil conditions for pomegranate seedling cultivation, particularly maintaining a balance between water and air regimes, is an important scientific and practical task.

Currently, under conditions of global climate change, water scarcity, and soil degradation, improving cultivation technologies for resilient crops such as pomegranate has become a pressing issue. In particular, developing substrate compositions and agrotechnical methods adapted to local soil and climatic conditions can enhance seedling quality, improve survival rates, and support the establishment of highly productive plantations.

From this perspective, a comprehensive study of the role and influence of soil structure and its main physical properties in the cultivation of pomegranate seedlings, as well as the identification of optimal conditions and development of practical recommendations, is of significant scientific importance.

Relevance of the Study The relevance of this study lies in the fact that improving the technology of efficient pomegranate seedling production under the soil and climatic conditions of the Boyovut district on a scientific basis is currently of great importance. In the context of climate change, water scarcity, and soil-related problems, the development of resource-saving, environmentally friendly, and highly efficient technologies contributes to the sustainable development of pomegranate cultivation, increases farmers' incomes, and strengthens export potential.

Aim of the Study: To scientifically investigate and improve the effective technology of pomegranate seedling production under the soil and climatic conditions of the Boyovut district.

Objectives of the Study: To conduct a comprehensive analysis of the soil and climatic conditions of the Boyovut district in comparison with the biological and ecological requirements of the pomegranate plant.

To adapt technologies for growing pomegranate seedlings from cuttings and other propagation methods to local natural conditions.

To determine nursery preparation methods, optimal substrate compositions, irrigation, fertilization, and care regimes. To develop protection measures against winter cold, wind erosion, and major diseases and pests.

To test the effectiveness of the proposed technology in experimental fields, evaluate it economically, and prepare recommendations for practical implementation.

Subject of the Study: Agrotechnical methods and processes for improving pomegranate seedling production under the soil and climatic conditions of the Boyovut district.

Object of the Study: Pomegranate varieties grown in the Boyovut district and their seedling production technologies.

Scientific Significance: This study provides a comprehensive scientific approach to pomegranate seedling production under the soil and climatic conditions of the Boyovut district for the first time. The results offer new knowledge on maximizing the use of hot summer conditions and loamy-gray soils, as well as reducing the risks of erosion and frost damage. This serves as a basis for developing region-specific technologies in pomegranate cultivation in Uzbekistan and acts as theoretical and practical material for higher education and research institutions.

Scientific Novelty: The scientific novelty of the study is expressed in the development of new elements of pomegranate seedling production technology adapted to the soil and climatic conditions of the Boyovut district, including optimal substrate compositions, cutting rooting regimes, anti-erosion protective systems, and winter protection schemes.

Soil and Climatic Conditions of the Boyovut District and Research Methodology

Study Site and Natural Conditions

The research was conducted in 2024–2025 at the experimental field of Gulistan State

University as well as in a pomegranate orchard located in the “Anorzor” MFY area of Boyovut district, Syrdarya region. The experimental site covered an area of 0.6 hectares, and the natural conditions are typical for Boyovut district.

The climate is sharply continental, with hot summers and relatively cold winters. The average temperature in July is +26.5…+28 °C, while in January it is –2.5…–3.5 °C. The annual precipitation ranges from 210 to 280 mm, and the vegetation period lasts 195–215 days. The Bekobod wind strongly affects the region, with wind speeds of 15–30 m/s, occasionally reaching up to 40 m/s.

The soil cover mainly consists of gray (serozem) and loamy-gray soils, with a pH range of 7.0–7.8. The mechanical composition of the soil is light to medium loam, which is moderately suitable for agricultural crops, particularly fruit trees. The experiments were carried out under open field conditions.

Research Materials

During the study, three widely distributed and promising varieties of Punica granatum were investigated under the conditions of Boyovut district:

Qizil pomegranate (local variety)

Wonderful (foreign variety)

Qozoqi pomegranate (local variety)

Cuttings were taken from healthy 1–2-year-old fruit-bearing orchards, with a length of 20–25 cm and a diameter of 0.7–1.0 cm. A total of 360 cuttings were selected for each variety.

Experimental Design

The experiment was conducted based on two main factors:

Variety type (3 variants)

Soil (substrate) type (different compositions)

Each treatment was replicated four times. In total, 108 experimental plots were established, and all variants were compared using agrobiological and statistical evaluation methods.

Table 1.

Experimental variants under the conditions of Boyovut district (4 replications)

No.	**Variant**	**Pomegranate variety**	**Soil (substrate)**	**Root emergence (days)**	**Complete rooting (days)**	**Average root length (cm)**
1	V1	Qizil pomegranate	Gray soil (bo‘z tuproq)	22–25	45–50	5–6
2	V2	Qizil pomegranate	Loamy-gray soil	18–21	38–42	7–8
3	V3	Qizil pomegranate	Mixed substrate (sand + peat + gray soil 1:1:1)	15–17	30–35	10–12
4	V4	Wonderful	Gray soil (bo‘z tuproq)	20–22	40–44	6–7
5	V5	Wonderful	Loamy-gray soil	16–18	35–38	9–10
6	V6	Wonderful	Mixed substrate (sand + peat + gray soil 1:1:1)	12–14	28–32	12–14
7	V7	Qozoqi pomegranate	Gray soil (bo‘z tuproq)	18–20	35–40	8–9
8	V8	Qozoqi pomegranate	Loamy-gray soil	14–16	30–33	11–13

9	V9	Qozoqi pomegranate	Mixed substrate (sand + peat + gray soil 1:1:1)	10–12	22–25	15–18
10	Control	Qizil + Wonderful + Qozoqi	Gray soil (bo‘z tuproq)	28–32	55–60	4–5

Based on the climatic conditions of the Boyovut district, the conducted research revealed that both temperature regime and substrate composition have a direct influence on the rooting percentage of pomegranate cuttings and the quality of seedlings.

In variant V1 (Qizil pomegranate + gray soil), the cuttings were studied under gray soil conditions. Root emergence was observed within 22–25 days. It was determined that the physical structure of gray soil is moderate, but its limited moisture retention capacity and poor aeration slowed down root formation. Complete rooting required 45–50 days, while root length reached only 5–6 cm, indicating a weak root system.

In variant V2 (Qizil pomegranate + loamy-gray soil), loamy-gray soil was used. Root emergence occurred within 18–21 days, which was faster compared to V1. Complete rooting took 38–42 days. Root length reached 7–8 cm, and a relatively stable root system was formed.

In variant V3 (Qizil pomegranate + mixed substrate: sand + peat + gray soil 1:1:1), the highest results were recorded. Root emergence occurred within 15–17 days. Complete rooting took 30–35 days, which was one of the shortest periods. Root length reached 10–12 cm, and a strong, well-branched root system was formed.

In variant V4 (Wonderful + gray soil), root emergence was observed within 20–22 days. Complete rooting took 40–44 days. Root length reached 6–7 cm, indicating an average development level.

In variant V5 (Wonderful + loamy-gray soil), root emergence occurred within 16–18 days. Complete rooting took 35–38 days. Root length reached 9–10 cm, and better root development was observed.

In variant V6 (Wonderful + mixed substrate), the best results were obtained. Root emergence occurred within 12–14 days. Complete rooting took 28–32 days. Root length reached 12–14 cm, and a strong root system was formed.

In variant V7 (Qozoqi pomegranate + gray soil), root emergence was observed within 18–20 days. Complete rooting took 35–40 days. Root length reached 8–9 cm, indicating moderate development.

In variant V8 (Qozoqi pomegranate + loamy-gray soil), root emergence occurred within 14–16 days. Complete rooting took 30–33 days. Root length reached 11–13 cm, and a strong root system was formed.

In variant V9 (Qozoqi pomegranate + mixed substrate), the highest indicators were recorded. Root emergence occurred within 10–12 days. Complete rooting took 22–25 days, which was the shortest period. Root length reached 15–18 cm, and a very strong root system was formed.

In the control variant (all varieties + gray soil), the lowest results were observed. Root emergence took 28–32 days, while complete rooting required 55–60 days. Root length reached only 4–5 cm, and a weak root system was formed, confirming that gray soil alone is not optimal for pomegranate cutting propagation..

Seedling Production Technology

Cuttings were prepared in October and planted on March 15–25. Planting was carried out at a 45° angle with a depth of 15–18 cm.

The humidity level was maintained at 80–90%. Irrigation was performed using a drip irrigation system every 3–5 days, depending on soil moisture conditions.

After root formation, the seedlings were transplanted into polyethylene bags, and the hardening stage was carried out under open field conditions during April–May. For winter protection, in November the seedlings were buried in soil at a depth of 20–25 cm**.**

Table.2.

Main observed indicators

№	**Stage / Activity**	**Observation indicator**	**Duration (days)**	**Notes**
1	Planting of cuttings	Initial condition after planting	–	Start of experiment
2	Root emergence process	Appearance of first roots	10–25 days	Varies depending on substrate and variety
3	Active rooting stage	Rapid root growth	15–35 days	Most intensive development period
4	Formation of complete root system	Stabilization of seedlings	22–60 days	Most important stage
5	Root length growth	Maximum root development	4–18 cm (up to 60 days)	Varies depending on substrate
6	Seedling survival	Survived cuttings	30–60 days	Overall result evaluation
7	Adaptation period	Adaptation to soil conditions	7–20 days	Initial stress decreases
8	Start of	Appearance of new	25–50	Depends on root

	vegetative growth	buds	days	strength
9	Substrate effect observation	Growth differences	10–60 days	Comparison of all variants
10	Final evaluation	Identification of best variant	60th day	End of experiment

The experimental process began with the planting of pomegranate cuttings. Initially, the prepared cuttings were placed into the selected substrates, and this stage was recorded as the beginning of the experiment. During this period, the seedlings had not yet entered active vegetative growth, and the initial experimental conditions were established.

In the next stage, the process of root emergence was observed. Within 10–25 days after planting, the appearance of the first roots was recorded. This process varied depending on the substrate type and varietal characteristics, with some variants showing earlier and others later root formation.

After that, the active rooting stage was recorded. During 15–35 days, the roots entered a rapid growth phase, during which the development and expansion of the root system intensified. This period was considered the most important stage of vegetative development in the experiment.

In the following stage, the formation of a complete root system was observed. Within 22–60 days, the seedlings developed a stable root system and became firmly established in the soil. This stage served as a key biological foundation for further plant development.

In parallel, root length growth was monitored. Over a period of up to 60 days, root length varied between 4–18 cm, with significant differences depending on substrate composition. The best results were observed in substrates rich in organic matter and with a loose structure. Seedling survival was also analyzed during the experiment. Between

30–60 days, the proportion of successfully established cuttings was determined, and overall performance was evaluated. This indicator reflects the ability of seedlings to adapt to new conditions.

In addition, the adaptation period was observed within 7–20 days. During this stage, cuttings adapted to environmental conditions, and initial stress gradually decreased. Humidity and temperature regimes had a significant influence on this process.

The onset of vegetative growth was recorded between 25–50 days. In this period, seedlings with sufficiently developed root systems began forming new buds, and upward growth became active.

Throughout the experiment, substrate effects were continuously monitored between 10–60 days. Each variant was compared separately, and soil composition was analyzed in relation to growth rate and root quality.

In the final stage, a final evaluation was conducted on day 60. The results obtained for each variant were compared, and the most effective substrate and best-developed seedlings were identified.

Conclusion

Based on the conducted research and obtained results, the following conclusions were made regarding the improvement of pomegranate seedling production and their quality under the conditions of the Boyovut district:

1. The results of the experiments confirmed that the rooting process of pomegranate cuttings is strongly dependent on substrate composition, varietal characteristics, and agroecological conditions.

2. Among the studied varieties, the Qozoqi pomegranate showed the highest adaptation capacity and fastest rooting during vegetative propagation.

3. The Qizil and Wonderful varieties demonstrated moderate biological activity, with significant improvement under favorable substrate conditions (loamy-gray and

mixed substrates). However, under pure gray soil conditions, rooting was slower and the root system developed weakly.

4. The use of gray soil alone produced the lowest results across all varieties. This was explained by soil compaction, insufficient aeration, and low moisture retention, resulting in root length not exceeding 4–6 cm.

5. Overall observations showed that the rooting process of pomegranate cuttings develops in stages over 10–60 days: initial root emergence (10–25 days), active rooting (15–35 days), and full root system formation (22–60 days). Vegetative growth began from 25–50 days and was directly associated with root system strength.

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