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Ecological and biological characteristics of introduced clonal rootstocks of stone fruit crops in the conditions of Southeastern Kazakhstan

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ABSTRACT
This article presents the results of a comprehensive ecological and biological assessment of introduced clonal rootstocks of stone fruit crops (*Prunus* spp.) in Southeastern Kazakhstan. The aim of the study was to identify promising rootstock genotypes with high adaptability, productivity, and the ability to vegetatively propagate in a harsh continental climate. The study involved 14 clonal rootstocks of varying ecological and geographical origins, studied in a nursery from 2023 to 2025. A comprehensive set of morphobiological, production, and reproductive traits was assessed using variation statistics. It was found that the rootstocks studied varied significantly in growth vigor, nursery productivity, yield of standard planting material, and rooting ability of green cuttings. The VSV-1 and Druzhba rootstocks were found to have the highest mother plant productivity (up to 224,000 units ha^{-1}), while the Colt and Eureka 99 demonstrated the highest yield of standard shoots (up to 95%). The coefficient of variation for the main traits was found to range from 4.14 to 22.54%, indicating varying degrees of genotypic stability among the rootstocks. VSV-1, Druzhba, VSL-2, and Eureka 99 were found to be the most stable (CV < 10%). It has been shown that the rooting efficiency of green cuttings depends significantly on the substrate composition. The highest rooting rates (up to 78–93%) were obtained using a substrate based on peat, sand, and perlite. Rootstocks were differentiated by rooting ability: easy-, moderately, and difficult-to-root varieties. The scientific novelty of this work lies in establishing patterns of productivity and rooting of clonal rootstocks in the conditions of Southeastern Kazakhstan, taking into account their genotypic specificity and trait variability. Its practical significance lies in substantiating the selection of promising rootstocks (Colt, Eureka 99, Druzhba, VSV-1, and Pumiselect) for commercial nurseries and intensive horticulture. The obtained results can be used in the development of adaptive technologies for growing planting material and increasing the efficiency of fruit plantings in a changing climate.

Key words: Clonal rootstocks, Stone fruit crops, Nursery, Rooting, Rhizogenesis.

INTRODUCTION
Stone fruit crops (apricots, peaches, plums, and cherries) occupy a significant place in the fruit-growing structure of the Republic of Kazakhstan, providing an early supply of high-quality fresh products and valuable raw materials for the processing industry. In the southeastern region of the country, characterized by a favorable temperature regime, a high sum of active temperatures, and a long growing season, these crops possess significant productivity

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and economic potential. However, their share in the structure of fruit orchards remains relatively low, due to a number of factors, including the insufficient implementation of intensive technologies, the limited use of high-quality planting material, and the insufficient adaptability of existing variety-rootstock combinations to local conditions (Whiting *et al.* 2005; Lawrence *et al.* 2025; Lakhiar *et al.* 2025).

In today's horticultural landscape, the transition to intensive and super-intensive cultivation technologies based on the use of high-yielding varieties and specialized clonal rootstocks is particularly important. The use of clonal rootstocks is a key element in intensifying the industry, as they regulate tree growth, accelerate fruiting, increase yields, improve fruit quality, and enhance resource efficiency (Seleznyova *et al.* 2008; Koepke & Dhingra 2013; Mehraj *et al.* 2022). Furthermore, the use of dwarf and medium-sized rootstocks allows for the formation of compact crowns, increased planting density, facilitated agricultural practices, and the introduction of mechanization and automation in production processes (Webster 2001; Kumar *et al.* 2021).

Global experience shows that selecting optimal rootstocks is one of the determining factors for the successful operation of intensive orchards. Rootstocks have a significant impact on plant physiological processes, including water management, mineral nutrition, photosynthetic activity, and resistance to adverse environmental factors (Adnane *et al.* 2015; Osorio-Marín *et al.* 2024). The interaction between rootstock and scion determines not only the growth vigor and productivity of trees, but also their longevity, resistance to disease, and stress, which is especially important in a changing climate (Xu & Ediger 2021).

The introduction of clonal rootstocks of diverse genetic and geographic origins is particularly relevant in Kazakhstan. Expanding the genetic diversity of rootstocks enhances the adaptive potential of fruit trees and enables the selection of varieties most resilient to extreme environmental conditions. Southeastern Kazakhstan is characterized by a sharply continental climate, significant temperature fluctuations throughout the year, frequent spring frosts, dry summers, and moisture deficits, which significantly impact the growth and development of fruit crops (Gudynaitė-Franckevičienė & Pliūra 2021; Yefremova *et al.* 2023; Ludemann *et al.* 2024). Under these conditions, the resistance of rootstocks to abiotic stress, including frost and drought tolerance, as well as the ability to effectively utilize soil moisture and nutrients, are particularly important.

Modern scientific research indicates that the response of rootstocks to environmental stressors is a key factor determining the performance of fruit orchards. It has been established that different rootstocks vary significantly in their ability to adapt to adverse conditions, which manifests itself in differences in growth, productivity, disease resistance, and plant longevity (Lang 2024; Wang *et al.* 2025; Ling *et al.* 2025). Therefore, a comprehensive ecological and biological assessment of rootstocks, including a study of their growth, development, physiological characteristics, stress resistance, and ability to reproduce vegetatively, is particularly important.

It should be noted that in recent years, research has been actively conducted worldwide to develop and introduce new clonal rootstocks for stone fruit crops with improved adaptive and economically valuable traits. However, the results of this research cannot always be directly transferred to Kazakhstan due to significant differences in climatic and soil conditions. This necessitates local studies aimed at evaluating the introduced rootstocks in the specific agro-ecological conditions of the region.

Despite significant advances in stone fruit rootstock breeding, their adaptability to the conditions of Southeastern Kazakhstan remains poorly understood. The lack of scientifically validated data on the performance of introduced rootstocks in the harsh continental climate limits their effective use in nurseries and commercial horticulture. This, in turn, hinders the development of intensive technologies and reduces the industry's competitiveness.

Therefore, conducting a comprehensive ecological and biological assessment of introduced clonal rootstocks of stone fruit crops is a pressing scientific challenge with both theoretical and practical significance. The results obtained will allow us to identify the most promising varieties adapted to the conditions of Southeastern Kazakhstan and recommend them for widespread use in modern intensive horticulture.

The aim of the study was to conduct a comprehensive ecological and biological assessment of introduced clonal rootstocks of stone fruit crops and to identify promising genotypes with high adaptability and economic value for use in nurseries and intensive orchards in the Southeast Kazakhstan.

MATERIALS AND METHODS

Objects and conditions of research

The objects of the study were 14 introduced clonal rootstocks of stone fruit crops (*Prunus* spp.) of various ecological and geographical origins, differing in growth strength, biological characteristics and adaptive potential.

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The studies were conducted in 2023–2025 in a clonal rootstock nursery located in the Talgar district of the Almaty region (Southeastern Kazakhstan) at an altitude of 1070 m above sea level. The region has a sharply continental climate, with a pronounced temperature range (from −25…−30 °C in winter to +38…+41 °C in summer), uneven precipitation distribution, and frequent droughts during the growing season, which creates stressful conditions for plant growth and development (Iglesias & Echeverria 2022; Chachar *et al.* 2023).
The soil cover of the experimental plot is represented by sierozems of medium loamy mechanical composition with a humus content of 1.5–2.3%, a slightly alkaline reaction of the environment (pH 7.2–7.8) and an average supply of mineral nutrients.

Experimental design and experimental plan

The field experiment was carried out using the Randomized Complete Block Design (RCBD) method with three replicates, which reduces the influence of spatial heterogeneity of the site and increases the accuracy of assessing the studied characteristics (Gomez & Gomez 1984).
The research factor is the rootstock genotype (14 variants).
Experiment structure: repetition - 3; number of plants in repetition - 30 pcs.; number of plants in variant - 90 pcs.; total number of plants - more than 1000.
The placement of variants within each block was carried out using random assignment.
The planting pattern for the mother plant is 1.8 × 0.2 m, which corresponds to standard technologies for growing clonal rootstocks in nurseries (Ollitrault *et al.* 2019).

Agrotechnical conditions

During the growing season, uniform agrotechnical measures were applied for all variants: watering as needed (taking into account meteorological conditions); inter-row soil cultivation; application of mineral fertilizers according to agrotechnical recommendations; protection of plants from pests and diseases, if necessary.

Methods of accounting and observation

The survey was carried out systematically throughout the growing season: phenological observations were carried out every 10–14 days; biometric measurements were taken at the end of the growing season; and rooting and standard material yield were assessed after the cuttings were separated.
Phenological phases were recorded in accordance with generally accepted methods for studying fruit crop varieties (Sedov & Ogoltsova 1999).

Evaluation of biometric and productivity indicators

The following parameters were studied during the research: shoot formation capacity (pcs. plant^{-1}); plant height (cm); trunk diameter (mm); total shoot growth (m plant^{-1}); mother plant productivity (number of shoots per plant); yield of standard planting material (%).
The standardization of the cuttings was assessed using morphological criteria (development of the root system, length and thickness of the shoot) in accordance with nursery requirements (Ollitrault *et al.* 2019).

Evaluation of rooting of green cuttings

The rooting of green cuttings was determined using the classical method of vegetative propagation of woody crops, described in the works of Hartmann & Kester (1983), taking into account modern approaches to clonal propagation of fruit plants (Leakey 2004).

Rooting was calculated using the formula: $\mathrm{Y} = \frac{N\text{укор.}}{N\text{общ.}} \times 100\%$

where: Y is the rooting rate (%);

N(rebuke) — the number of rooted cuttings;

N(total) — the total number of planted cuttings.

Rooted cuttings were counted 30–60 days after the experiment was established. Cuttings were considered rooted if they had a formed root system at least 1–2 cm long and at least 3–5 roots.
We also analyzed the dynamics of rhizogenesis (root formation and growth intensity) to more accurately assess the biological characteristics of the rootstocks (Ling *et al.* 2025).

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Statistical data processing

Statistical processing of experimental data was carried out using methods of variation statistics according to the methodology of Boris Aleksandrovich Dospekhov (Dospekhov 1985).

The following parameters were calculated: arithmetic mean (M); standard error (m); standard deviation (σ); coefficient of variation (CV, %).

The coefficient of variation (CV) was calculated using the following formula:

$$CV = (\sigma / M) \times 100\%$$

where:

σ is the standard deviation,

M is the average value of the feature.

The coefficient of variation was interpreted as follows:

up to 10%: low variability of the trait;

10–20%: average variability;

more than 20%: high variability.

The significance of differences between variants was assessed by analysis of variance (ANOVA) using the least significant difference criterion ($LSD_{0.05}$) at a significance level of $p < 0.05$ (Gomez & Gomez 1984).

When necessary, more stringent significance levels ($p < 0.01$ and $p < 0.001$) were applied to identify highly significant differences.

Data processing was performed using Microsoft Excel and Statistica programs. The reliability of the obtained results was ensured by the use of repetitions, randomization and taking into account intra-variant variability.

RESULTS

The effectiveness of clonal rootstocks is largely determined by their ability to undergo vegetative propagation, their adaptability to soil and climate conditions, and their adaptability to various soil and climate conditions. The data obtained during the study demonstrate a pronounced differentiation of the studied rootstocks across a range of agronomic and biological traits, confirming their genotypic determinacy and consistent with modern understanding of rootstock productivity (Jackson 2003).

An analysis of shoot formation capacity revealed that the highest values for this indicator were characteristic of the Kolt and VSV-1 rootstocks, indicating high growth intensity and their potential technological effectiveness in nursery conditions. The established patterns are consistent with the results of studies in which high shoot formation capacity is considered a key criterion for rootstock selection for intensive nursery production (Gudynaitė-Franckevičienė & Pliūra 2021).

Seasonal shoot growth dynamics for most rootstocks began in the first ten days of April, which corresponds to the biological growth rhythms of fruit crops in temperate continental and extreme continental climates (Whiting *et al.* 2005). This confirms the adaptation of introduced forms to local agroclimatic conditions; however, the degree of expression of this trait varied depending on the rootstock genotype.

Analysis of the data presented in Fig. 1 revealed significant differentiation among rootstocks in growth vigor. Plant height varied widely—from 1.3 to 4.55 m—indicating a pronounced genotypic dependence of this trait.

Vigorous rootstocks include Fortuna (4.55 m), Eureka 99 (4.40 m), Kuban (4.27 m), and LC-52 (3.9 m), characterized by vigorous growth and the formation of a robust above-ground part. These rootstocks are recommended for conditions requiring vigorous trees with high biomass and productivity potential.

Medium-height rootstocks include Druzhba (3.05 m), VC-13 (3.27 m), and VSL-2 (2.55 m), which provide a balance between vigor and crown manageability. This group is of particular interest for intensive gardening practices, as it allows for controlled planting density and facilitates agronomic management.

Dwarf rootstocks include Pumiselect (1.42 m), VVA-1 (1.5 m), and Zarevo (1.3 m), which are characterized by limited growth. These varieties can be effectively used for establishing high-density plantings and creating compact crowns, which is in line with modern trends in intensive gardening (Fig. 1).

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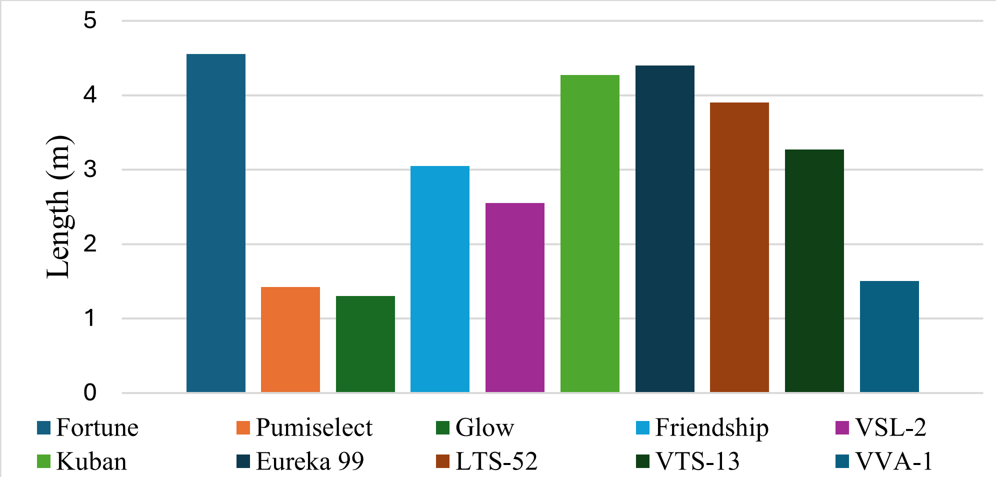

Fig. 1. Biometric measurements of stone fruit trees (average for 2023-2025).

The data obtained confirm the key role of rootstocks in regulating plant growth and shaping the architecture of orchards. The established differentiation of rootstocks by plant height allows for targeted rootstock selection based on the required orchard type (intensive, super-intensive, or traditional), which is an important element in optimizing stone fruit cultivation technologies (Fig. 1).

Evaluation of the parameters of the layers. The study showed that by the end of the growing season, the nominal root collar thickness varied between 0.5 and 1.3 cm, and plant height ranged from 46 to 93 cm, indicating significant differentiation among the studied clonal rootstocks in terms of growth vigor and morphobiological characteristics. Druzhba and VSL-2 demonstrated the highest values for these parameters, producing well-developed plants with a robust above-ground portion and optimal root system parameters. This indicates their high biological productivity and ability to form high-quality standard planting material when grown in rootstock beds using vertical propagation.

In contrast, Saint-Julien, VVA-1, and Zarevo demonstrated restrained growth, resulting in shorter plant heights (46–52 cm) with relatively stable root collar diameters. These varieties may be of interest for use in intensive and super-intensive plantings where limiting tree vigor and creating a compact crown are required.

A detailed analysis of the data presented in Table 1 revealed that the studied rootstocks differed significantly in a range of economically valuable traits. The highest yield of standard shoots was observed for the Kolt rootstock (95%), demonstrating its high reproductive capacity and technological effectiveness in nursery conditions. Eureka 99 and VSL-2 also demonstrated high yields of standard material (83% and 75%, respectively), confirming their potential for commercial nursery production.

Average values of standard shoot yield (50–57%) were observed for VVA-1, Zarevo, and VSV-1, which may be due to their moderate shoot-forming ability or sensitivity to growing conditions. The minimum values of this indicator were recorded for Saint-Julien (43%), which indicates its limited suitability for mass propagation in the conditions of the study region (Table 1).

Table 1. Economic and biological indicators of clonal rootstocks of cotton crops in the mother plantation (average 2023-25).

Rootstocks	**Bush height (cm)**	**Diameter of the nominal root collar (cm)**	**Output of standard layers (%)**
VVA-1	51	0.6	50
VSV-1	77	0.5	57
VSL-2	92	1.0	75
Friendship	93	1.0	75
Glow	52	0.5	50
Colt	81	1.3	95
Eureka 99	68	0.5	83
Saint-Julien	46	1.0	43
NSR $_{0.05}$	20	0.4	-

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It's worth noting that Kolt achieved the largest nominal root collar diameter (1.3 cm), which, combined with the high yield of standard shoots, demonstrates its vigorous growth and potential plant resilience. Druzhba and VSL-2 (1.0 cm) also demonstrated optimal values for this parameter, ensuring the formation of standard planting material.
The established least significant difference (LSD) for plant height was 20 cm, indicating that differences between extreme values (e.g., between Saint-Julien and Druzhba) are statistically significant, while differences between similarly sized variants (e.g., VSL-2 and Druzhba) are statistically insignificant. For the nominal root collar diameter, the LSD was 0.4 cm, indicating less differentiation between rootstocks for this trait.
Overall, the results indicate that the most practical rootstocks are Kolt, VSL-2, and Druzhba, which combine high biometric performance with a high yield of standard planting material. Eureka 99 is also characterized by high productivity, but has a smaller root collar diameter.
Thus, the evaluation revealed that the studied clonal rootstocks differ significantly in morphological, biological, and economically valuable traits, confirming the need for differentiated use depending on production objectives. The identified highly productive and stable varieties can be recommended for further introduction into the intensive nursery and horticultural systems of Southeastern Kazakhstan.
An analysis of bush height variability revealed that the coefficient of variation (CV) ranged from 4.14 to 22.54%, indicating varying degrees of trait stability among the rootstocks studied. The most stable rootstocks were VSV-1 (CV = 4.14%), Druzhba (CV = 4.25%), VSL-2 (CV = 6.96%), and Eureka (CV = 6.99%), indicating their high genotypic uniformity and adaptive resistance.
Average variability was characteristic of Kolt (CV = 19.18%) and VVA-1 (CV = 13.60%), while the greatest variability was noted in Zarevo (CV = 22.54%), which may indicate its increased sensitivity to growing conditions (Table 2).

Table 2. Variability in bush height of stone fruit rootstocks (average for 2023-2025).

Rootstock	Average (cm)	SD	CV (%)	Level of variability
VVA-1	55.5	7.55	13.6	average
VSV-1	49.75	2.06	4.14	low
VSL-2	85.2	5.93	6.96	low
Friendship	93.2	3.96	4.25	low
Glow	47.2	10.64	22.54	high
Colt	84.6	16.23	19.18	average
Eureka 99	44.5	3.11	6.99	low
LC52	67	5.03	7.51	low

The obtained results are consistent with data from foreign studies indicating that a low level of variability is an important indicator of the stability of clonal rootstocks and their suitability for industrial use.
The yield of standard shoots ranged from 43 to 95%. The highest values for this indicator were observed for the Colt and Eureka 99 rootstocks. This indicates their high reproductive capacity and technological suitability for industrial nursery production. The obtained results are consistent with data from international studies, which emphasize the importance of rootstock genotype in the formation of a high yield of standard planting material (Gudynaitė-Franckevičienė & Pliūra 2021).
Mother rootstock productivity ranged from 84,000 to 224,000 units ha^{-1}. The most productive rootstocks were VSV-1 and Druzhba, which may be due to their high shoot formation capacity and good adaptation to arid conditions. These results are consistent with research showing that tolerance to water stress directly impacts the productivity of clonal rootstocks (Yefremova *et al.* 2023).
The results revealed significant intraspecific variability in the studied parameters, confirming the high genotypic dependence of the adaptive and production characteristics of clonal rootstocks. The coefficient of variation (CV) for the main biometric parameters ranged from 8.5 to 22.3%, indicating a moderate to high degree of variability in traits depending on genotype and growing conditions.
The most stable values were observed for the diameter of the conventional root collar (CV = 8.5–12.4%), while higher variability was observed for the yield of standard shoots (CV = 15.8–22.3%). This indicates a significant influence of agronomic and microclimatic factors on the processes of rhizogenesis and the formation of planting material.

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A comparative analysis revealed that Kolt and VSV-1 are characterized not only by high productivity but also by relatively low variability in key traits, making them more stable in continental climates. Similar patterns were previously noted in research by G. Reig *et al.* (2015), which emphasized that genotypes with low phenotypic variability exhibit greater adaptive resilience under stressful conditions (Reig *et al.* 2015).

The yield of standard shoots varied from 43 to 95% (CV = 18.6%), with the highest values observed for Colt and Eureka 99. The data obtained are consistent with the results of Lordan *et al.* (2019), who found that the efficiency of shoot formation is closely related to the physiological state of the mother plants and their genetic characteristics (Lordan *et al.* 2019).

Rootstock productivity ranged from 84,000 to 224,000 units ha^{-1}, with a coefficient of variation of approximately 20.1%. The most productive rootstocks (VSV-1 and Druzhba) demonstrated both high productivity and moderate variability, indicating their stability under various environmental conditions. Similar findings are presented in the work of AD Webster, who emphasizes that highly productive rootstocks typically exhibit a stable physiological response to stress factors.

Thus, the obtained results confirm that variability indicators are an important criterion for assessing the stability and adaptability of clonal rootstocks. The most promising genotypes for practical use are those that combine high productivity with low or moderate variability, which ensures the stability of their economically valuable traits in continental climates.

The study focuses on the rooting of green cuttings, a key method for accelerated rootstock propagation. It was found that rooting efficiency depends significantly on the substrate composition. The highest rooting rates (up to 78% on average) were achieved using a substrate containing peat, sand, and perlite (Table 3).

Table 3. The influence of soil on the rooting of green cuttings of stone fruit rootstocks (%; average for 2023-2025).

Rootstock	Soil and ground			Average rooting rate of rootstocks
	Sand + peat (St)	Coconut flakes + perlite	peat + sand + perlite	
VSL-2	60	55	82	66
Colt	61	28	78	56
LC-52	51	20	79	50
Pumiselect	62	30	80	57
VC-13	40	19	65	41
Average by options	55	20	78	51
NSR $_{0.5}$	18	24	11	

At the same time, when using alternative substrates (coconut coir + perlite), a decrease in rooting was noted, which may be due to insufficient water-holding capacity and changes in the physicochemical properties of the medium. These patterns are confirmed by research findings indicating a significant influence of the substrate on rhizogenesis processes in woody crops (Leakey 2004; Nakamura 2015).

Based on the obtained data, all studied rootstocks were differentiated according to their rooting ability: easy-to-root (Pumiselect, and Colt), moderately rooting (LC-52), and difficult-to-root (VSL-2, and VC-13). This classification is of great practical importance, as it allows for the optimization of propagation technology and increases the efficiency of nursery production (Gudynaitė-Franckevičienė & Pliūra 2021).

Of particular interest are the results on the rooting rate of green cuttings. Depending on the substrate composition, the coefficient of variation for this parameter reached 12.7–24.5%, indicating the high sensitivity of the rhizogenesis process to environmental conditions. The highest rooting rate (up to 93%) and the lowest variability (CV ≈ 12.7%) were observed with a peat + sand + perlite substrate.

The obtained results are consistent with the data of RRB Leakey (2014), who demonstrated that optimizing the physicochemical properties of the substrate (aeration, and water holding capacity) is a key factor in the successful development of the root system in woody plants. Similar conclusions are presented in the research of Boughalleb *et al.* (2015), which emphasizes the influence of water regime and substrate structure on the rooting ability and adaptability of rootstocks.

Differentiating rootstocks by rooting ability (easily, moderately, and difficultly rooted) also demonstrates their genotypic determinacy. In particular, Pumiselect and Colt demonstrated high rooting ability with relatively low

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variability, making them promising for industrial propagation. Meanwhile, VSL-2 and VC-13 were characterized by higher variability, which may limit their use in intensive production systems.

In general, a comparative analysis with foreign studies confirms that the identified patterns correspond to global trends in the field of nursery production, where special attention is paid to the combination of high productivity, stability of traits and adaptability of rootstocks to stressful conditions (Webster 2001; Gudynaitė-Franckevičienė & Pliūra 2021).

Thus, a comprehensive assessment of introduced clonal rootstocks revealed that their adaptive, morphobiological, and reproductive characteristics vary significantly, which must be taken into account when selecting rootstocks for specific soil and climatic conditions. The identified promising varieties possess high potential for use in intensive horticulture in southeastern Kazakhstan.

CONCLUSION

The conducted research made it possible to obtain new scientifically substantiated data on the ecological and biological characteristics of introduced clonal rootstocks of stone fruit crops in the conditions of the sharply continental climate of Southeastern Kazakhstan.

The scientific novelty of this study lies in the comprehensive comparative evaluation of 14 clonal rootstocks across a range of morphobiological, production, and adaptive traits using variability indices. For the first time, patterns in shoot formation, mother plant productivity, and rooting of green cuttings were established for the region, depending on rootstock genotype and substrate composition.

It was found that the VSV-1 and Druzhba rootstocks exhibit the highest mother plant productivity (up to 224,000 units ha^{-1}), while the Colt and Eureka 99 provide the highest yield of standard planting material (up to 95%) and are distinguished by high trait stability. Pumiselect, Colt, and LC-52 demonstrated high rooting capacity, confirming their potential for accelerated vegetative propagation.

It was found that optimal rooting conditions are achieved using a peat + sand + perlite substrate, which ensures high rooting rates (up to 78–93%) and low rooting variability. Rhizogenesis processes are highly dependent on the physicochemical properties of the substrate.

The practical significance of the work lies in substantiating the choice of promising clonal rootstocks (Colt, Eureka 99, Druzhba, VSV-1, and Pumiselect) for industrial nursery and intensive gardening, as well as in developing recommendations for optimizing vegetative propagation technologies.

The theoretical significance of the study lies in expanding the understanding of the genotypic determination of adaptive and production traits of rootstocks and their response to environmental stress factors.

The obtained results can be used in the development of adaptive technologies for intensive horticulture aimed at increasing the productivity, sustainability and competitiveness of the industry in a changing climate.

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