Agronomy Research **22**(X), xxx–ccc, 2024
https://doi.org/10.15159/AR.24.014

Adaptability of apricot varieties in the Right-Bank Subzone of the Western Forest-Steppe of Ukraine

O. Ignatenko[1], N. Moiseichenko[1], D. Makarova[1], H. Trokhymchuk[1], V. Vasylenko[1], O. Havryliuk[2,*], O. Kishchak[1], Y. Honcharuk[1] and V. Hrusha[1]

[1]Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine, 23 Sadova Str., UA03027 Novosilky, Kyiv Region, Ukraine
[2]National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony Str., 13, UA03041 Kyiv, Ukraine
[*]Correspondence: o.havryliuk@nubip.edu.ua

Received: October 25th, 2023; Accepted: February 24th, 2024; Published: March 19th, 2024

Abstract. The research reveals the main reasons that prevent the extension of commercial apricot plantations in Ukraine and worldwide. This brief description includes eight cultivars from Ukrainian and foreign breeding programmes. The trials conducted in the Right-Bank subzone of the Western Forest Steppe of Ukraine. The plants from Ukrainian breeding programme ‘Melitopolskyi Rannii’, ‘Botsadivskyi’, ‘Siaivo’, ‘Kumir’, ‘Osoblyvyi Denysiuka’, as well as the foreign one – ‘Robada’, ‘Harogem’, ‘HJA-19’, were distinguished by high adaptability to the complex of adverse overwintering factors in the above-mentioned region. These samples did not lose the acquired level of frost resistance under the influence of provoking thaws. A comprehensive assessment of drought resistance, based on water-holding capacity, turgor recovery degree, water deficiency, and leaves' hydration of the presented varieties, established that all variants of the experiment were not inferior to the best popular cultivars. According to the the biological feature of buds' formation at an early age, the cultivars ‘Robada’ and ‘HJA-19’ were characterized as early-fruiting. The yield and quality indicators for the 2021–2022 years of research were evaluated. Average fruit weight was noted in all samples, with the cultivar ‘Siaivo’ exceeding the average. To improve the assortment and enrich the apricot gene pool collections with the best samples suitable for cultivation in the Forest-Steppe Zone of Ukraine, according to the results of the study, the following researched cultivars were included in the collection of valuable samples of the common apricot gene pool of the Institute of Horticulture of the National Academy of Sciences of Ukraine: ‘Melitopolskyi Rannii,’ ‘Botsadivskyi,’ ‘Siaivo,’ and ‘Osoblyvyi Denysiuka’. These cultivars are sources of productivity and adaptability to abiotic factors of cultivation (winter and frost resistance, drought resistance). They are certified by the National Center of Plant Genetic Resources of Ukraine.

Key words: *Prunus armeniaca,* winter hardiness, abiotic factors, water deficiency, hydration, fruit quality.

INTRODUCTION

Apricot (*Prunus armeniaca* or *Armeniaca vulgaris*) is a valuable stone fruit not only within the territory of Ukraine but also well beyond its borders. The trees are characterized by high yields, short-term fertility, and regenerative ability. This plant has been valued for its taste, nutritious, high-vitamin fruit with a rich mineral composition and excellent medicinal properties (Zhou et al., 2020; Groppi et al., 2021).

According to FAOSTAT (Food and Agriculture Organization of the United Nations. Link), in 2021 the world production of Apricot fruits was 4.2 million tons, mainly from European and Asian countries. The largest plantation areas are situated in China, Turkey, and Iran.

Ukraine is among the countries that have their own industrial areas of apricot plantations but do not significantly impact the international market. In 2021, Ukraine produced 8 thousand tons of fruit. The largest cultivated areas in Ukraine are in Crimea, Odesa, and Mykolaiv regions (Voitovyk et al., 2023).

Tong Zhao et al. (2022) notes that the significant restraint in the extension of industrial apricot plantations area in the world is due to the periodicity of fruiting of this crop. The latter phenomenon is primarily associated with the death of generative buds during sharp temperature variations in the winter-spring period and under adverse weather conditions during flowering (Havryliuk & Kondratenko, 2019; Havryliuk et al., 2022a; 2022b). Such problems in the industrial cultivation of apricots in Ukraine also exist. The main productive orchards of this crop in Ukraine are concentrated in the Steppe zone (Spriazhka et al., 2022). At the same time, the later periods of phenophases in the Forest-Steppe, compared to the Steppe, make it possible to avoid frost damage to flower buds in the early spring period. Therefore, promoting industrial apricot plantations in the forest-steppe zone of Ukraine can significantly increase the productivity of such orchards due to the alignment of morphophysiological development phases with the natural and climatic conditions of the environment (Vasylenko et al., 2021; Ivanova et al., 2022).

Improving the assortment and enriching apricot gene pool collections with the best samples from foreign and Ukrainian breeding programmes, suitable for cultivation in the Forest-Steppe zone of Ukraine, is an extremely urgent task of horticultural science. This will make it possible to establish an industrial apricot fruiting conveyor in the aforementioned growing area. It will also significantly increase the effectiveness of selection by utilizing sources with genetically determined high productivity, excellent commercial and consumer qualities of fruits, resistance to diseases, and significant adaptability to specific pedoclimatic climatic condition. Frost and drought stresses strongly affect the altitudinal and latitudinal fruit plants distribution (Gansert, 2004; Charrier et al., 2013; Litvinova et al., 2023a; 2023b). Among various weather hazards, frost causes the greatest economic losses in agriculture (Snyder & Melo-Abreu, 2005; Vasylenko et al., 2021; Pavlichenko et al., 2023). A frost can cause losses of hundreds of thousands of hryvnias in fruit and plant production. Most fruit crops currently grown in temperate zones originate from warm regions, especially Asia, such as walnut, apple, pear, and plum trees (Fornari et al., 2001). High yield and strong resistance to pathogens, rather than frost or drought tolerance, were the main goals of the breeding process (Fady et al., 2003). Although frost severely limits life forms and causes enormous economic losses, it has not been studied as thoroughly as other biotic or abiotic stresses, such as drought tolerance. The main reason for this may be that damage occurs when trees appear not to be active, but they become visible only in the next growing season (Havryliuk et al., 2022b).

Phenological stages control the effects of frost on susceptible organs (e.g., bud break, flower, and leaf budding (Lang et al., 1987). Hence, dormancy induction and release occur concurrently with frost acclimation and deacclimation (Charrier et al., 2011). After cessation of growth, frost acclimation and release from endodormancy are regulated by cold temperatures, whereas deacclimation and exit from ecological dormancy are subsequently controlled by warmer, milder temperatures (Bonhomme et al., 2013). For some fruit crop species, photoperiod can also influence dormancy and the timing of bud break. Photoperiod has its greatest effect when chilling requirements have not been met (Basler & Koerner, 2012; Laube et al., 2014). The 'safety margin' (calculated as the difference between damage-inducing and minimum temperatures) is usually wide enough at the end of the ecological dormancy period to avoid bud damage (Lenz et al., 2013). However, frosts may still occur (Cittadini et al., 2006).

The effects of frost on above ground vegetative parts have been less thoroughly investigated than on economically important parts such as flowers and fruits (Winkel et al., 2009; Havryliuk et al., 2022a). However, the architecture of the above-ground part of the tree affects the temperature distribution (microclimate) and, therefore, the potential damage (Karbivska et al., 2022). In all plant parts, the shoot apical meristem plays a key role, as its temperature damage affects survival, ecological distribution, and fruit formation (Nobel, 1980; Rodrigo, 2000). When apical buds are damaged, the loss of apical dominance results in altered growth patterns, especially in columnar apple trees. Thus, subsequent changes in tree architecture will alter local environmental conditions (e.g., light, temperature, and humidity).

The study of frost resistance is detailed in the research of many authors (Honcharuk, 2012; Trokhymchuk, 2012). The investigation of this phenomenon is based on the analysis of various physiological and biochemical indicators or the use of the direct laboratory freezing method. This method allows for the determination of plants' frost resistance based on objective signs of damage when they are exposed to low temperatures using freezers.

One of the significant factors for apricot productivity, especially in dense plantations, is its drought resistance. Apricot is drought-resistant and can withstand a lack of moisture in the air and soil for an extended period without significant dimensional changes. However, unstable temperature and water conditions, especially droughts, significantly affect the quantitative (size, total volume per tree) and qualitative (external attractiveness, taste) characteristics of the crop. Therefore, the field determination of drought resistance provided by the 'Methodology of state cultivar testing...' for apricot plantations of various degrees of intensification is not sufficiently informative. Comprehensive information on drought resistance can be provided by a laboratory assessment (based on a set of methods) with mandatory consideration of weather conditions at the time of the experiment. In the future, such a study will allow for the creation of sufficiently productive apricot plantations in conditions of unstable water supply through the use of more adaptive cultivars, without additional capital investments (Havryliuk et al., 2022a).

The main negative biotic factor for apricot in the conditions of the Western Forest Steppe of Ukraine is brown rot caused by the pathogen *Monilia Cinerea Bonord*. The susceptibility of apricot cultivars to moniliosis varies significantly. Although absolute resistance to the disease does not exist, by selection of appropriate cultivars, it is possible to create apricot plantations with high resistance to Monilia Cinerea Bonord., capable of forming economic productivity and high-quality fruits even in epiphytotic years.

The collection of the common apricot gene pool at the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (IS NAAS) includes 157 specimens at the Melitopol Research Station of Horticulture named after M.F. Sydorenko and 73 cultivars at the Research Station of Pomology L.P. Symyrenko. However, at the beginning of 2023, scientists at the IH of the National Academy of Sciences began to passport and register samples of the working collection of common apricot at the National Center of Plant Genetic Resources of Ukraine (NCPGRU). Based on the results of the initial varietal study presented in this article, valuable samples of common apricot are being registered to obtain the 'Certificate of Registration of Samples of the Gene Pool of Plants in Ukraine'.

MATERIALS AND METHODS

The research was conducted during 2021–2022 in the laboratory of Breeding and Cultivation System of fruit crops and Technologies for growing fruit crops of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (Kyiv region), as well as at the technological base and with the assistance of specialists from the laboratory of Plant Physiology and Microbiology of the same institution. The quality indicators of the fruits were studied using equipment from the laboratory of post-harvest quality processing of fruit and berry products. According to our research, the certification of samples was carried out based on the National Center of Plant Genetic Resources of Ukraine.

Apricot plantations of the 2018 planting year were established in the spring period according to the scheme of 5.0×2.5 m, with one-year seedlings grafted on cherry-plums. The objects of research were 8 new, promising apricot cultivars from Ukrainian and foreign Breeding programmes, based on preliminary varietal studies: 'Melitopolskyi Rannii', 'Kumir', 'Robada', 'HJA-19', 'Harogem', 'Botsadivskyi', 'Osoblyvyi Denysiuka', 'Siaivo'.

Soil profile of the researched area

The soil is dark gray, podzolized, light loam on carbonate loess, typical for the northern part of the Forest Steppe. The humus content in one soil layer is 3.8%, mobile phosphates (according to Kirsanov) - 180.9 mg kg^{-1} (optimal), exchangeable potassium (according to Kirsanov) - 202.8 mg kg^{-1} (high), easily hydrolyzed nitrogen (according to Kornfield) - 98.0 mg kg^{-1} soil (average). At the depth of the main mass of roots (60–80 cm), the content of these substances decreases to 48.1, 68.9, and 35 mg kg^{-1}, respectively. At a meter depth, it is 37.0, 66.0, and 28.7 mg kg^{-1}. The reaction of the soil solution (pH) ranges from slightly acidic (6.1) to slightly alkaline (7.2). Groundwater is at a depth of 2.0–2.5 m.

The **practical value** of the study is the development of recommendations for new cultivars for their use in production and breeding programs. This will make it possible to enhance the assortment of apricots in the Right-Bank subzone of the Western Forest Steppe of Ukraine with samples more adapted to the climatic conditions of the region.

In the process of conducting research, field, laboratory, and comparative methods were used. The main studies on strain investigation conducted according to the Methodology of state testing of plant cultivars for suitability for is in Ukraine (Methodology..., 2005), namely: phenological observations, winter and frost resistance, drought resistance, features of flowering, pollination, and fertilization, time of initiation of fruiting, and fruit quality.

The winter and frost resistance of apricot were studied directly in the trial plots according to the 'Methodology of State Cultivar Testing...' (Methodology..., 2005). However, for evaluating the frost resistance of garden crops, including apricot, the laboratory method is considered the main one (Bublyk et al., 2013). Direct freezing was performed under two different temperature regimes with a maximum temperature drop to -25 and -30 °C, and the results were compared with samples taken from the experimental plots without artificial freezing. One-year shoots were selected three times during the period of forced dormancy (second half of winter). One-year shoots were selected three times during the period of forced dormancy (second half of winter). Before freezing, the samples were pre-hardened for 3–5 days in a refrigerating chamber with an adjusted temperature (0...-5 °C), simulating real conditions in the plantation. Direct freezing was performed in a specialized CRO/400/40 freezer with a gradual decrease to the required minimum negative temperature. The latter was held for 4 hours. Thawing of test samples was also gradual, with the use of an additional freezer (Palahecha et al., 2005). This measure is necessary to prevent an artificial increase in the degree of damage to tissue growths, which is not characterise the natural conditions but is observed during laboratory freezing followed by ultra-fast thawing of experimental samples. In this case, gaps in growth tissues increase, and the degree of their damage does not correspond to the reality and real frost resistance of the cultivar (Hrokholskyi, 2003). growths (in triple repetition with triple replication), fixed in glycerin, and an ocular assessment of the condition of the main plant tissues (bark, cambium, wood, pith) was conducted, as well as the degree of frost damage to buds (taking into account the condition of bud tissues and the parenchymal mass beneath it) under a microscope MBI-6 at 90x magnification. The maximum score for frost damage for a particular type of tissue or cut through the bud according to the laboratory freezing method is 5 points. The total score for tissue damage in a cross-sectional anatomical cut of one-year growth is 25 points (four types of tissues and a bud cut). The total score for damage to one-year growth as a whole is 65 points (four types of tissues from the abaxial and adaxial parts of one-year growth, 20 points each; a cut through the internode, 20 points for complete destruction; and a cut through the bud, 5 points for complete destruction).

Drought resistance was studied directly in experimental plantations (Methodology..., 2005), as well as by a complex of laboratory methods (Trokhymchuk & Makarova, 2022). Namely, according to hydration, water deficit, water-holding capacity, and turgor of leaves. The selection of leaves (in 15-fold repetition for each of the drought resistance above parameters) of all cultivars in the orchard was carried out at 10–11 in the morning, at a relative humidity of 30–35%. The method of collecting experimental data was standard for this kind of research (Trokhymchuk & Makarova, 2022).

Developmental stages of bud mutagenesis according to Vytkovskyi (1984) method. Anatomical sections of generative buds of apricot cultivars were made using an OmE freezing microtome, with a fixed thickness of 50–75 µm. Sections were fixed in glycerol and viewed under an MBI-6 microscope at a magnification of 90–180 times (Havryliuk et al., 2022a; 2022b).

The climate is moderately continental and mild, with sufficient humidity. According to the average long-term data (for the last 20 years), the average temperature in January is minus 6.0 °C, in July plus 19.5 °C, and the duration of the growing season is 198–204 days. The sum of active temperatures of 10.0 °C and above gradually increases from north to south and ranges from 3200 to 3,600 °C.

Statistical analysis. Quantitative indicators of the yield and quality of valuable apricot varieties were assessed using a variance analysis. The assessment of frost resistance and flowering intensity was done on a scale, and these calculations currently do not require statistical processing. Factors influence by the correlation re categorized as weak $0 \leq 0.29$, moderate: 0.30–0.49, noticeable: 0.50–0.69, high: 0.70–0.89, very high: 0.9–0.99 (*LSD*: Least significantly difference at $P < 0.05$). Statistical processing was performed in Microsoft Excel 2016 in combination with XLSTAT.

RESULTS AND DISCUSSION

Field and laboratory winter hardiness of promising apricot cultivars

According to frost damage resistance during the winter of 2021/2022, the variants were distributed as follows (in the direction of improvement according to the percentage of tissue and organ damage): 'Osoblyvyi Denysiuka' (39.50) < 'Kumir' (38.25) < 'NJA-19' (33.03) < 'Harogem' (31.07) < 'Robada' (28.85) < 'Melitopolskyi Rannii' (21.45) < 'Siaivo' (20.13) < 'Botsadivskyi' (16.83). It is worth noting that the apricot of the 'Botsadivskyi' cultivar was characterized by consistently high frost resistance in the plantations, regardless of the wintering conditions during the entire period of research.

As a result of laboratory freezing in 2021–2022 at temperatures of -25 °C and -30 °C (the latter is critical for culture), the cultivars 'Botsadivskyi' and 'Melitopolskyi Rannii' turned out to be more resistant. The damage to generative formations in these cultivars ranged from 2.8 to 3.5 points (without indexing the importance of the tissue for the vital activity of the plant; the maximum tissue damage score is 5.0). 'Osoblyvyi Denysiuka', 'Robada', and 'Kumir' were marked as more vulnerable to the stress factors of the cold period of the Forest-Steppe zone of Ukraine, especially to critical temperatures, whose generative formations were damaged from 3.9 to 5.0 points, respectively (on a 20-point scale). The data of direct laboratory freezing confirmed the high frost resistance of tissues of most of the studied cultivars. Even the most susceptible cultivars demonstrated sufficient frost resistance potential for plant preservation and high-yield formation (Table 1).

Negative biotic and abiotic factors of the environment worsen the productive potential and functional state of the apricot, even to the point of complete death. One of the most important goals of modern varietal research is the climatic adaptation of new cultivars. Namely, the selection of cultivars that will have a longer period of generative buds' development. No less important is the selection of intensive-type cultivars: quick-fruiting, self-pollination, high-yielding (Hel, 2015).

Table 1. Damage to one-year growths of apricot in the winter periods of 2021–2022, Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine*

Cultivar	Control (with no freezing)		-25		-30	
	2020–2021	2021–2022	2020–2021	2021–2022	2020–2021	2021–2022
Melitopolskyi Rannii	3.2	14.0	8.5	32.9	52.0	52.0
Siaivo	10.8	13.1	15.3	28.1	28.9	48.6
Botsadivskyi	6.4	10.9	20.7	21.7	43.6	56.1
Kumir	5.1	24.9	16.3	29.6	44.7	52.7
Harogem	7.0	20.2	28.6	43.6	48.2	53.7
NJA-19	5.2	21.5	17.3	41.2	37.2	52.7
Robada	16.5	18.8	16.6	41.0	43.0	50.2
Osoblyvyi Denysiuka	7.7	25.7	16.6	27.2	44.7	51.5

Note to the Table 1 – * A maximum score of organ damage (complete tissue death of growths and generative buds) is 65 points.

Winter hardiness of apricot plants, the main deterrent factor for the spread of this culture, depends on external and internal factors - temperature changes in the cold season, and the degree of generative sphere development during wintering. Which collectively determine one or another level of spring frost resistance. Generative buds during the rest period from October to January, which coincides with the formation of sporogenous tissue in anthers, are the most resistant to low temperatures (Yablonsky & Elmanova, 1986). Winter-hardy cultivars are characterized by slowed physiological rhythms in the autumn-winter period, as well as at the beginning of spring. To get out of the rest state, they require longer exposure to positive temperatures - from 0 to 7 °C. Their spring development takes place at a greater sum of effective temperatures (from 5 °C and higher) than in non-winter-hardy apricot cultivars (Yablonsky & Elmanova, 1983).

A decrease in temperature in cold-resistant apricot plants does not cause visible damage, let alone the death of cells. At the same time, it stimulates the launch of intracellular processes to prevent ice formation and reduce the harmfulness of this phenomenon at the cellular and subcellular levels. The low-temperature resistance of apricot trees during spring frosts depends on the ability of photosynthesis to function and the suppression of other metabolic processes. At low temperatures, changes in the chemical composition of cell membranes occur, where the lipid layer acquires the ability to retain liquid properties, which causes the cell to retain a complex of membrane-bound functions (Klimov, 1997).

Szalay et al. (2021) note that apricot plants have a short period of rest, bloom early, and are quite often damaged by spring frosts. Therefore, it is very important to study the flowering characteristics and to select genotypes with later flowering. Generative buds in apricots are formed in the years preceding flowering, and their differentiation begins after the active spring-summer growth and development of the plants. Differentiation of generative buds begins after active spring and summer growth and plant development. The bud formation depends to a greater extent on the biological characteristics of the cultivar and on the natural growth conditions (Bulatović & Bulatović, 1981; Kaya & Kose, 2019). In the future, apricot cultivars adapted to local conditions at the stage of buds morphophysiological development in the phyllosperm stage practically do not lose their resistance to frost after thawing. They react to environmental temperature fluctuations to a lesser extent and less actively irrigate tissues during thaws. In their experiments, Salazar-Gutierrez & Chaves-Cordoba (2020) observed the maximum saturation of apricot tissues with water during the thaw period at +15...+20 °C. The same authors and others emphasized that the degree of apricot plants' resistance depended on the speed and direction of related processes: accumulation of dry mass and water in buds, changes in the overall hydration of functionally related generative and vegetative organs at various stages of morphogenesis (Salazar-Gutierrez & Chaves-Cordoba, 2020).

The gradual decrease in temperature before wintering in 2020–2021 contributed to the acquisition of winter and frost resistance by experimental apricot trees and the smooth entry into deep rest. No sharp temperature fluctuations were observed during the specified winter period (from 30.11.20 to 24.02.21). During the three winter months of 2020–2021, precipitation was sufficient (123.2 mm of precipitation was recorded, while the average long-term data is 103 mm). The minimum air temperature in mid-January (January 17, 2021) reached -20 °C. Thaws lasting 5...7 days (2.0–7.1 °C) did not provoke a significant loss of the frost resistance acquired level by the experimental trees, which was confirmed by field studies. We noted minor damage to one-year growths - up to 12.9% (minor damage to bark and cambium from 0.1 to 0.5 points, heartwood from 0.3 to 1.8 points, generative formations from 0.3 to 1.0 points; with a maximum tissue damage score of 5.0 points). In promising apricot cultivars that are more sensitive to cold, there was a freezing of the growths tops (‘Kumir’, ‘Harogem’ up to 3.3 points), bark and cambium damage was from 0.3 to 1.2 points, generative formations from 0.3 to 2.5 points (5.0 points - the maximum damage score). The total percentage of damage to one-year growths ranged from 4.0 (‘Siaivo’) to 43.4% (‘Harogem’). In general, according to the resistance to frost damage during the winter of 2020–2021, the studied variants were distributed as follows (in the direction of improvement of the characteristic, according to the percentage of tissues and organs damage): ‘Robada’ (25.35) < ‘Siaivo’ (16.60) < ‘Osoblyvyi Denysiuka’ (11.85) < ‘Harogem’ (10.75) < ‘Botsadivskyi’ (9.90) < ‘NJA-19’ (7.95) < ‘Kumir’ (7.85) < ‘Melitopolskyi Rannii’ (4.90).

The winter period 2021/2022 was mild, with little snow, and short-lived. The maximum decrease in air temperature was observed on December 23 -13.5 °C, January 13 at -15.4, and February 5 at -10.1 °C. The greatest temperature drop to minus 16.8 °C (13.01.22) led to minor damage to one-year growth in apricot cultivars ranging from 16.83% to 39.50%. A prolonged thaw was recorded in mid-February, with positive air temperatures during the day (up to 10.3 °C on February 22) and slight frosts at night (-0.5...-4.1 °C). During the winter months, 89.8 mm of precipitation fell, with the majority (68.7 mm) occurring in December, and 12.4 mm and 8.7 mm in January and February, respectively.

In general, the weather conditions during the 2021–2022 research years for apricot wintering were satisfactory. Before the onset of cold weather, the generative buds of most apricot cultivars were in the phase of phyllosperm formation. In this state, cultivars of this crop have a high risk of damage from low temperatures. Field studies indicated sufficient winter hardiness of the most promising cultivars (except for the more vulnerable ‘Kumir’ and ‘Harogem’). They were well adapted to wintering conditions in the right-bank subzone of the Western Forest-Steppe of Ukraine, without a tendency to lose the level of frost resistance during forced dormancy under the influence of provoking thaws.

The influence of abiotic factors of the vegetative period on the growth and development of promising apricot cultivars.

Apricot is a drought-resistant crop with low transpiration intensity and low osmotic pressure. The effect of dehydration on the change in the chemical composition of leaves is less pronounced than in grain crops. At the same time, during fruit ripening, moisture is of great importance for the normal formation of the apricot crop. The laboratory method, and not the field method, of determining drought resistance is methodologically correct for an accurate assessment of orchard crops' drought tolerance, including apricot, especially in denser plantings.

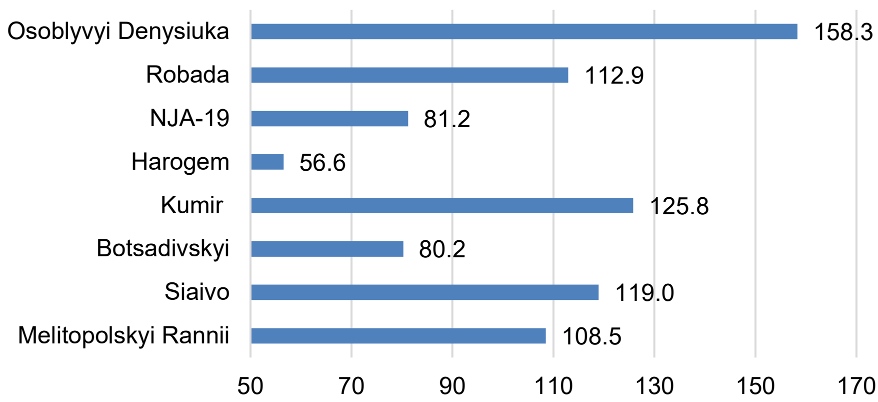

Figure 1. The ability of apricot cultivars to retain water in tree leaves after 24 hours of exposure, % (average for 2021–2022).

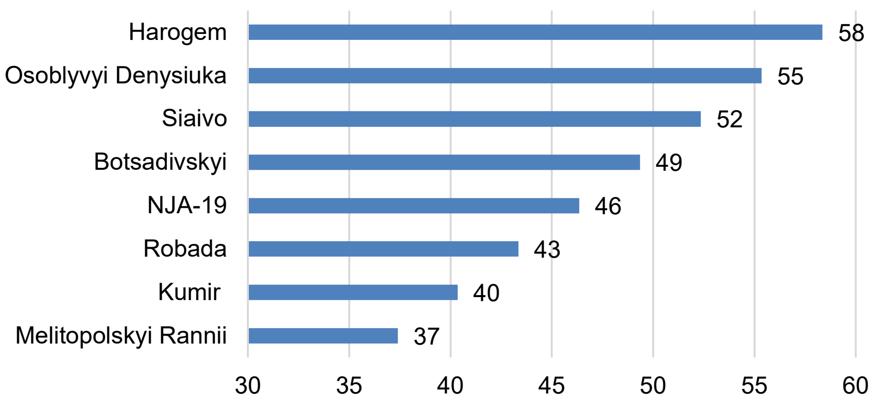

Figure 2. The ability of apricot cultivars to restore water in leaf tissues, % (average for 2021–2022).

In 2021–2022, a comprehensive study was carried out to determine the drought resistance of valuable apricot cultivars of Ukrainian and foreign selection, namely: water-holding capacity (Fig. 1) and turgorescence (Fig. 2), water deficit, and hydration of leaf tissues. The first two of these studies confirmed the sufficient and high drought resistance of all test cultivars under the weather conditions of the research period. Plants of the cultivars ‘Botsadivskyi’, ‘NJA-19’, and, especially, ‘Harogem’, retained water better during wilting followed the restoration of turgor in laboratory conditions.

The laboratory study results of the experimental apricot plants' reaction to water stress in terms of **hydration** and water deficit were indicative.

The hydration of apricot tissues of all studied variants in 2021 and 2022 was within the normal range. Plants, in the second half of the growing season during significant dry periods, maintained their water balance at an appropriate level of 60–70%. Univariate variance analysis showed that in 2021 and 2022, all variants of the experiment did not differ from the control in terms of tissue hydration.

Apricot **water deficiency** in 2021 and 2022 was within the norm and did not exceed 30% even 24 hours after the start of the experiment in all variants. This proves the absence of significant stress due to the lack or excess of moisture and the good functioning of experimental apricot trees during the experiment (the second half of the growing season).

Individual variants significantly outperformed control trees in terms of adaptability and water stress, as indicated by lower values of water deficit. Plants of the early-ripening cultivar ‘Robada’ (17.00) showed better drought resistance throughout the experiment. The water deficit of these apricot leaves did not exceed 19.00% even 24 hours after the start of the experiment. The plants of other cultivars from the group of mid- and late-ripening groups were better than the control in terms of drought resistance to water deficit and were distributed as follows (in the direction of the trait improvement): ‘Siaivo’ (28.65%) < ‘Osoblyvyi Denysiuka’ (18.62%) < ‘Harogem’ (17.29) < ‘NJA-19’ (17.16%) < ‘Botsadivskyi’ (13.97%).

In general, the weather conditions of 2021–2022 were favorable for the water regime, but periods of drought were also noted, allowing the assessment of the resistance of experimental apricot trees to water stress. In laboratory conditions, experimental trees were not inferior to control cultivars in terms of drought resistance. According to turgorescence, water-holding capacity, water deficit, and hydration of leaf tissues, apricot trees from the group of early-ripening cultivars - ‘Robada’ showed a tendency towards higher drought resistance; from the group of medium and late-ripening - ‘Harogem’, ‘Botsadivskyi’, ‘NJA-19’.

Compliance with growing conditions in terms of drought resistance in 2021–2022 was high in almost all cultivars. The most adapted foreign cultivars, such as ‘Harogem,’ ‘Robada,’ and ‘NJA-19,’ which can be used in breeding programs to strengthen the above-mentioned economic trait, have been identified.

Resistance of promising apricot cultivars to moniliosis

One of the most important tasks in the initial varietal study of apricots is to determine their resistance to diseases, especially in the Forest-Steppe zone, such as brown rot. In the research plantation of the Institute of Horticulture (IH) of the National Academy of Sciences during 2021–2022, susceptibility to the pathogen *Monilia Cinerea* Bonord varied significantly depending on the cultivar. In 2021, during apricot blossoming (April 21–May 7), wet and moderately warm weather (the average monthly temperature reached 4.6–11.2 °C, and atmospheric humidity was 70–86%) contributed to the spread of the causative agent of the disease and damage to inflorescences. The outbreak of the disease in the orchard planting was estimated at 0.5–5.0 points, depending on the cultivar (Table 2). More susceptible to moniliosis in 2021 were ‘Botsadivskyi’, ‘Kumir’, ‘NJA-19’ (4.0–5.0 points each, average level of damage). Trees of the ‘Siaivo’ cultivar were distinguished by their high field resistance this year.

In 2022, we recorded slight precipitation only at the beginning of the apricot flowering (April 18). In general, the weather was cool and rainless, with air frosts at the beginning of flowering (-0.9...-1.6 °C, April 19–20). Such conditions extended the flowering period by 13 days, but the lack of moisture significantly reduced the damage risk to trees. Susceptibility to moniliosis in 2022, despite a fairly long period of potential plant damage, ranged from very low (0.1 points) to medium (4.5 points). Apricot 'Robada' and 'Siaivo' in the experimental plantation differed in very low susceptibility to the disease causative agent (0.8 and 0.1 points, respectively), as well as 'Osoblyvyi Denysiuka' (1.4 points). 'Botsadivskyi' was characterized by average susceptibility (4.5 points), NJA-19, the second most susceptible to moniliosis in 2022, was affected by 3.4 points.

Table 2. The degree of damage to apricot cultivars for 2021 and 2022

Cultivar	Affection by moniliosis, score *	
	2021	2022
Melitopolskyi Rannii	3.1	2.2
Harogem	2.5	2.2
Kumir	4.0	3.1
Robada	2.3	0.8
NJA-19	4.0	3.4
Botsadivskyi	5.0	4.5
Siaivo	0.5	0.1
Osoblyvyi Denysiuka	2.9	1.4

Note: *9.0 – maximum damage score.

Phenological phases of development of valuable apricot cultivars in 2021–2022

The spring period of 2021 was cool and rainy. Apricot flowering in 2021 began at the end of April, with the early ripening cultivars 'Melitopolskyi Ranniii' and 'Kumir' (April 23). Cultivars 'Robada', 'Bodsadivsky' bloomed on April 24. The duration of flowering in these cultivars was 9 calendar days and ended at the beginning of May (May 12). Such cultivars as 'Bodsadivskyi' and 'Robada' began to bloom on April 24 and ended at the same time (May 3), and the duration of flowering was 9 days. The mid-late maturing cultivars, namely 'NJA-19', 'Harogem', 'Osoblyvyi Denysiuka', and 'Siaivo', flowered on April 25–29, within 8–10 days. The degree of flowering varied significantly depending on the cultivar (1.0 to 7.5 points). During apricot flowering in 2021, air frosts of up to -0.4 °C were recorded (from 04/08/2021 to 04/09/2021). This worsened the process of pollination and fertilization and led to the falling of flowers and fruits. At the same time, during the fruit-setting phase (May), significant precipitation (71.4 mm) was recorded, which caused oxidative stress in plants and provoked further falling of flowers and fruits. The temperature and water regime during the spring period of 2021 led to a dropping of 75% in the initial number of flowers and fruits. The trees of the 'NJA-19', 'Robada' cultivars kept the maximum number of useful ovaries (pollinated flowers). It is worth noting that in 2021, the experimental apricot plantation began to bear fruit even under the influence of a complex of adverse weather factors in the spring period. The above-mentioned two cultivars formed a certain crop already in the first year of fruiting (at the age of four). The spring period of 2022 was marked by rainy weather at the beginning of flowering and air frosts on April 19–20 (-0.9–1.6 °C). Due to the weather conditions, apricot blossoming was extended for 18 days (from April 18). The first to bloom were 'Melitopolskyi Ranniii' and 'Kumir', within 8 days. 'NJA-19', 'Harogem' (April 22), 'Osoblyvyi Denysiuka' (April 23), and, especially, 'Siaivo' (April 25) had the latest onset of the flowering phase in 2022. Flowering within the cultivar lasted 8–10 days, the intensity of which was very high (8.0–9.0 points, on a nine-point scale). The degree of flowering of the 'Robada' and 'Kumir'.

The study of phenological features makes it possible to determine the adaptability of apricot cultivars to specific soil and climatic conditions. The duration of the growing season, the pace of growth and development, and adaptability to certain conditions are determined by the peculiarities of the ontogenesis of cultivars (Havryliuk et al., 2022a; 2022b).

Growth, differentiation, and formation of flower organs in apricot occur after passing the annual temperature maximum. When the average daily air temperature drops below +10–15 °C, sporogenous tissue begins to form in the anthers. Between the duration of the sporogenous tissue formation period and the sums of average daily temperatures in the range of 0–10 °C, there is a direct correlation from $r = 0.70 \pm 0.21$ to $r = 0.80 \pm 0.15$, depending on the considered cultivar. Knowing the dependence of the rest period and the duration of the phases of generative buds' development on the characteristics of the temperature regimes of apricot orchard cultivation regions allows for their more rational placement on the territory.

Yield and quality of apricot fruits

In 2021, at the age of four, the first crop of cultivars was formed: 'Melitopolskyi Rannii', 'Osoblyvyi Denysiuka', 'Harogem', 'Botsadivskyi', 'Siaivo', 'Robada' and 'NJA-19'. Trees of the last two cultivars entered the fruiting season earlier, their productivity immediately reached 5.0 kg/tree (Table 3).

Table 3. Apricot yield and fruit quality, 2021–2022

Cultivar	Yield and quality indicators						Overall tasting score, points, average for 2021–2022
	kg per tree		t ha^{-1}		Fruit weigh, g		
	2021	2022	2021	2022	2021	2022	
Melitopolskyi Rannii	0.5	7.3	0.3	4.9	35.7	64.6	8.9
Harogem	single fruits	4.0	-	2.6	40.2	38.8	8.4
Botsadivskyi	single fruits	4.5	-	3.0	55.4	56.2	8.8
Robada	5.0	2.2	3.4	1.5	42.1	44.9	8.4
Kumir	-	3.0	-	2.0	-	36.6	8.5
NJA-19	5.0	4.1	3.3	2.7	59.6	42.3	8.6
Osoblyvyi Denysiuka	0.5	4.5	0.3	3.0	43.2	37.0	8.8
Siaivo	single fruits	4.5	-	3.0	61.8	68.5	8.8
LSD_{05}	0.1	1.6	0.19	0.86	2.60	3.09	

In 2021, the trees formed fruits of medium size, ranging from 42.1 to 59.6 g. In the next year, 2022, all studied cultivars started fruiting. Apricot trees are considered precocious if they form a yield of 2.0 kg/tree or more at the age of three to four years. 'Robada' and 'NJA-19' were distinguished as precocious (in the 4th year). Some reduction in the yield of 'NJA-19' in 2022 is attributed to the trees being overloaded in the previous period combined with their significant stunting (Havryliuk et al., 2022b). The 'Robada' cultivar in 2022 bloomed with average intensity (5.5 points), and the beginning of the phase coincided with spring frosts. The combination of adverse weather conditions with a phase of morphophysiological development vulnerable to them led to a significant decrease in the yield of the above-mentioned variant in comparison with last year's data. All experimental samples, except for the cultivar ‘Siaivo’, formed fruits of medium size (35.7–56.2 g), with the latter cultivar having above-average fruit size (68.5 g).

A varietal study of promising apricot cultivars in the right-bank subzone of the Western Forest Steppe of Ukraine showed that all studied cultivars exhibited a tendency to rapidly increase productivity. In the second year after the beginning of fruiting, the productivity ranged from 1.5 to 4.9 t ha^{-1}. The ‘NJA-19’ cultivar stood out as precocious (bearing fruit at the age of 4 years) and productive (yielding 2.7 t ha^{-1} and above) for the mentioned growing region.

According to the results of the apricot varietal study conducted by the Institute of Horticulture of the National Academy of Sciences, some valuable samples were certified by the National Center of Plant Genetic Resources of Ukraine. Specifically:

– ‘Melitopolskyi Rannii’ (national catalog number UN0500557) - utilized in breeding as a source of early ripening fruits with high taste, marketability, and transportability.

– ‘Botsadivskyi’ (national catalog no. UN0500723) - a source of early fertility, winter hardiness, and high productivity.

– ‘Siaivo’ (national catalog number UN0500905) - a source of transportability, productivity, and winter hardiness.

– ‘Osoblyvyi Denysiuka’ (national catalog number UN0501199) - a source of prematurity and a long ripening period.

Description of cultivars

‘Melitopolskyi Rannii’ is an early ripening cultivar bred in the Melitopol Horticulture Experimental Station named after M.F. Sydorenko in Melitopol. It was obtained as a result of crossing the ‘Chervonoshchokyi’ × ‘Ahrori’ cultivars. The tree is medium-sized and forms an inverted pyramidal crown of medium density. Fruiting typically commences in the 5th to 6th year after planting, and the yield is annual. This cultivar is self-fertile.

Winter hardiness is high. It is also resistant to bacterial gummosis and shows moderate resistance to moniliosis.

Fruits are medium to above-medium size, weighing 35–55 g, with a wide oval shape, beveled along the dorsal seam, and slightly compressed on the sides. The skin is thin, delicate, yellowish-orange, with a slight crimson-red blush on the sunny side of the fruit. Pubescence is weak and velvety. The flesh is orange, juicy, of medium density, fiberless, offering a pleasant wine-sweet taste with a well-defined apricot aroma, and a dessert-like flavor (8.0–8.5 points). The pit is medium-sized and oval, not always separating freely from the pulp. The seeds taste sweet.

The fruits contain dry matter - 12.14%, sugars - 7.8–8.18%, organic acids - 0.94–1.11%, and vitamin C - 6.98–9.53 mg per 100 g of raw mass. It is a dessert cultivar with fruiting concentrated on one-year growth and shortened shoots. The fruits ripen from June 20 to July 10, and the transportability is good, making it different destination variety. Since 1980, the cultivar has been included in the Register of Plant Cultivars of Ukraine. Trees of this cultivar do not require special care; timely pruning to thin out the crown is essential.

'Botsadivskyi' is a medium-ripening cultivar developed by Ukrainian breeder of the National Botanical Garden named after M.M. Hryshko (Kyiv). It is a result of crossing of form of 'Kashchenko 84' with 'Lytovchenko'. The tree is medium-sized, with a spherical, spreading, and medium-thickened crown. The cultivar is quick fruiting, entering the fruiting season in the 3rd to 4th year after planting, and the yield is annual. 'Botsadivskyi' exhibits very high winter hardiness and its resistant to fungal diseases.

The fruits of 'Botsadivskyi' are large, weighing 40–50 g, with a maximum weight of 80–120 g. They have a spherical-oval shape and are flattened on the sides. The skin is medium hairy, delicate, thin, smooth, and yellow, with a blurred blush covering 40–50% of the fruit's surface. The flesh is yellowish-orange, tender, juicy, and sweet, with a dessert taste (8.5–9.0 points). The stone is medium size and well separated from the pulp. Fruits ripen on July 15. 'Botsadivskyi' is a cultivar of different destination and is recommended for cultivation in the Steppe and Forest Steppe regions of Ukraine.

'Siaivo' is a late-ripening apricot cultivar developed by the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (Kyiv). The tree is vigorous and forms a spherical, thin, slightly thickened crown with thick red-brown shoots. It exhibits very high winter hardiness, although occasional damage by moniliosis (brown rot) is observed in some years, necessitating chemical treatment against fungal diseases. It is a self-pollinate cultivar and enters the fruiting season in the 4–5th year after planting.

The fruits of 'Siaivo' are large, weighing 55–73 g, with a maximum weight of 150 g, and have a wide-oval shape. The skin is intensely yellow, covered with a thick blurred red blush on the sunny side of the fruit. The pulp is very dense, intensely yellow, sweet, and sour, with excellent taste (8.5 points). The stone is of medium size and easily separated from the pulp. The fruits have different destination suitable for fresh consumption, making high-quality jams, candied fruits, juices with pulp, compotes, and are excellent for obtaining dried apricots.

'Siaivo' ripens from July 20 to August 10, and the fruits do not crack during ripening. They exhibit excellent transportability and good marketability. This cultivar is promising for cultivation in industrial and amateur horticulture in the Forest-Steppe and Southern Polissia regions of Ukraine.

'Osoblyvyi Denysiuka' is a medium-late ripening apricot cultivar developed by the Ukrainian Institute of Horticulture of the National Academy of Agrarian Sciences (Kyiv). The tree is medium-sized, fast-growing, and forms a spherical, slightly spreading, powerful, slightly thickened crown. It exhibits very high winter hardiness and is highly resistant to fungal diseases. Early fruiting begins in the 3–4th year after planting, and the yield is very high. However, it is prone to crop overload, leading to a decrease in fruit size. Strong, regulatory pruning for fruit rationing is recommended.

The fruits of 'Osoblyvyi Denysiuka' are large, weighing 50–60 g, and have an oval shape. The peel is yellow, covered with a thick, bright carmine blush on most of the fruit surface. The flesh is yellow, medium-density, fleshy, juicy, aromatic, and sweet, with excellent taste (8.9–9.0 points). The stone is of medium size but poorly separated from the pulp. The fruits have Different destination, suitable for fresh consumption, as well as for technical processing.

‘Osoblyvyi Denysiuka’ ripens from July 15 to 30. The fruits do not crumble, do not rot, and hang on the crown for a long time. Overripe fruits on the tree shrivel and acquire a honey taste. Maturation is non-simultaneous and extended over 1–1.5 months, allowing consumption until the end of September. They are typically harvested 2–3 times. This cultivar is intended for private gardening.

‘Kumir’ is an early cultivar, a progeny seedling of Melitopolskyi 4/150 x Melitopolskyi Rannii. The tree is medium-sized, with a spreading, flat-rounded crown of medium density. Fruiting begins in the 4th-5th year of planting. ‘Kumir’ is resistant to moniliosis, winter- and frost-resistant, and productive.

The fruits of ‘Kumir’ are large, weighing 57–67 g, with an elongated-rounded shape, and a light golden color with a blush in the form of dots on the sunny side. The flesh is yellow, tender, very juicy, not fibrous, and has a sour-sweet taste (8.5–8.8 points). It separates well from the stone.

The chemical composition of the pulp, %: dry soluble substances - 11.80–15.20, sugars - 7.70–8.30, acids - 0.41–0.65, as well as 5.70–8.00 mg of vitamin C and 190–203 mg of phenolic compounds per 100 g of raw mass.

‘Kumir’ ripens at the end of the second decade of June.

The presented brief description of the varieties is based on the results of collection cultivar studies, which precede the initial evaluation, according to the ‘Methodology of the state testing of plant varieties for suitability for distribution in Ukraine’ (Methodology..., 2005). Collective varietal research was conducted through the network of scientific institutions and farms of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (the main scientific institution of fruit growing in Ukraine) in various growing zones. The study of the collection revealed sufficient economic and biological potential for the promotion of the described varieties in the northern growing regions.

CONCLUSIONS

A comprehensive study of apricot cultivars from Ukrainian and foreign breeding programmes according to the influence of abiotic factors of the environment confirmed their compliance with the pedo-climatic conditions of the right-bank subzone of the Western Forest Steppe of Ukraine. The morphophysiological phases of the domestic breeding programme cultivars ‘Melitopolskyi Rannii’, ‘Botsadivskyi’, ‘Siaivo’, ‘Osoblyvyi Denysiuka’, as well as the foreign - ‘HJA-19’, coincided with the meteorological conditions of the above-mentioned growing region for all years of the study. These cultivars did not lose the level of acquired frost resistance under the influence of provoking thaws. In terms of drought resistance, the investigated cultivars were not inferior to the control trees, which are confirmed by a comprehensive assessment of water-holding capacity, the degree of turgor recovery, water deficiency, and leaf hydration.

Due to the biological feature of buds' formation at an early age, ‘Robada’ and ‘HJA-19’ cultivars were characterized as precocious. In 2021–2022, there was a propensity of domestic bred cultivars ‘Melitopolskyi Rannii’, ‘Botsadivskyi’, ‘Osoblyvyi Denysiuka’ and ‘Siaivo’ to gradually increase the yield and form fruits with high taste qualities. The ‘HJA-19’ cultivar was selected for both yield and fruit quality.

Most cultivars in the experiment formed fruits of medium size, while 'Siaivo' produced above-average size fruits.

According to the preliminary data of the primary cultivar study, the 'HJA-19' cultivar from foreign breeding programme is promising for commercial cultivation in the right-bank subzone of the Western Forest-Steppe of Ukraine in terms of early fruiting and yield in the first years of fruiting.

A comprehensive assessment of domestically bred apricots confirmed their high adaptability to adverse abiotic factors of the environment, a tendency to quickly increase productivity in the first years of fruiting, and a dessert fruit taste for the cultivars 'Botsadivskyi' and 'Osoblyvyi Denysiuka'. The latter, along with the 'Siaivo' cultivar, exhibited high and very high resistance to moniliosis (the main apricot disease in Ukraine) throughout the entire study period in the experimental plot at the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine.

According to our research results, several cultivars can be involved in to thebreeding programs as sources of valuable breeding traits, namely: 'Melitopolskyi Rannii', 'Botsadivskyi', 'Siaivo', and 'Osoblyvyi Denysiuka'. Presently, they have been certified by the National Center of Plant Genetic Resources of Ukraine and deposited in the collection of valuable samples of the apricot gene pool at the Institute of Horticulture of the National Academy of Agrarian Sciences. These cultivars serve as sources of early fruiting, productivity, and adaptability to abiotic cultivation factors.

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