Agrobiodiversity for Improving Nutrition, Health and Life Quality

Research Article

OPEN ACCESS

Drought Resistance of *Cerasus vulgaris* Mill. Cultivars Depending on Rootstock in the Right-Bank Part of the Western Forest-Steppe Region

Roman Grynyk

Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine

Roman Grynyk: https://orcid.org/0009-0004-2762-9199

Article Details:
Received: 2024-10-10
Accepted: 2024-11-18
Available online: 2024-11-30

DOI: https://doi.org/10.15414/ainhlq.2024.0023

In the right-bank part of the Western Forest-Steppe, there has been an observed yearly increase in average daily summer temperatures, underscoring the importance of assessing drought tolerance in fruit crops, including cherries. This research aimed to identify the most drought-resistant cherry rootstock-cultivar combinations and the factors enhancing drought tolerance. The study focused on physiological indicators of water balance: water retention capacity, degree of turgor recovery, water deficit, and leaf tissue hydration *Cerasus vulgaris* Mill., which determine resistance to temperature stress. The research was conducted during 2022–2023 using laboratory-field methods at the Institute of Horticulture, NAAS, located in the right-bank area of the Western Forest-Steppe. The research subjects were various cherry cultivars – Igrushka, Lutovka, Balaton, Erdi Botermo, Nochka, Turgenevka, and a promising selection – D 36-25 on various rootstock forms (*Prunus mahaleb* L., Krymsk 5, V-2-180, V-2-230, V-5-88, Rubin), during peak water stress periods. Results indicated that most cherry rootstock-cultivar combinations exhibited high drought tolerance. The water deficit index for studied combinations ranged between 2.2–9.2%, with high and drought-resistant combinations showing values within 2.2–5.6%. Leaf tissue hydration in the studied combinations varied between 60.87–65.93% for cultivars and 60.23–64.19% for rootstocks. The water retention capacity of leaf tissue for most combinations indicated a 10.9% water loss after two hours, while certain cultivars showed an increase of 13.7%. After 4-6 hours, water retention capacity increased by 2.41-3.45% per hour. Turgor recovery in the studied combinations ranged between 40.3–52.7%. Factors influencing drought resistance in these cherry rootstock-cultivar combinations were also identified (weather and climatic factors accounted for 26.0%, cultivar, and rootstock forms for 17.0 and 9.0%, respectively, between climatic conditions and cultivars at 22.0%, and between rootstock forms and cultivars at 18.0%. The results demonstrated that all studied cherry rootstock-cultivar combinations are highly drought-resistant, with drought resistance primarily influenced by the compatibility between cultivar and rootstock and the growing conditions.

Keywords: *cherry*, drought resistance, adaptation, cultivars, clonal rootstocks, rootstock-cultivar combinations

Introduction

Drought is one of the most critical factors of abiotic stress in agricultural production. Fruit crops worldwide often suffer from drought due to climate change, leading to yield loss (Dai 2012; Faghih et al., 2021; Rachappanavar et al., 2022; Joshi et al., 2016; Basu et al., 2022; Xuet al., 2023). Understanding how fruit crops respond to drought and using cultivars with enhanced drought tolerance is crucial (Liu et al., 2023). There are two strategies for mitigating drought stress in fruit crops. One is traditional and molecular breeding (using transgenic technology and genome sequencing). The other includes horticultural methods, such as grafting onto drought-resistant rootstocks, using exogenous plant growth regulators

***Corresponding Author:** Roman Grynyk, Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine, Kyiv-27, 03027, 23, Sadova St., Ukraine
romangrinik609@gmail.com

and biostimulants, and irrigation under water deficit conditions (Liu et al., 2023).

The adaptation of stone fruit crops to drought is associated with their moderate osmotic pressure and the ability of leaves to manage water due to high-polymer compounds with low transpiration intensity (Sedov and Ogoltsova, 1999). Stress at the plant level is generally perceived as a reduction in photosynthesis and growth (Yordanov et al., 2012). It is known that all life processes in plants, as in other organisms, occur in an aqueous environment. Water is needed to maintain the structural integrity of biological molecules and thus of cells, tissues, and the entire organism. Physiologically, water serves as a solvent and medium for substance transport and exchange, and its high heat capacity stabilizes plant temperature (Kryvoshapka, 2012).

Moisture deficiency affects water absorption, root pressure, photosynthesis, respiration, transpiration, growth, and development (Skryaga et al., 2005; Skryaga et al., 2006; Lobet and Draye, 2013; Hu and Xiong, 2014; Morris et al., 2017; Lynch, 2019). The impact of water deficiency on metabolic processes depends significantly on its duration. During drought, leaf protein content and sugar levels decrease. Dry weather leads to reduced shoot and root growth, impaired leaf apparatus development, as well as CO_2 assimilation and reduced nutrient accumulation, deteriorating fruit quality and storability (Titarenko et al., 2001; Kumar et al., 2018). Some researchers (Barabash et al., 2000; Taran 2001; Chukhil et al., 2007; Melnichuk et al., 2009) note that soil moisture deficiency and high temperatures inhibit photosynthesis and lead to functional disorders. Leaves, as the main site of photosynthesis and the organ with the largest surface area, are highly exposed to environmental influences. Reduced leaf area and thickening of mesophyll and leaf tissues are among the changes that occur in plants during drought stress (Fang and Xiong, 2015). Furthermore, drought causes stomatal closure, significantly reducing photosynthesis (Daszkowska-Golec and Szarejko, 2013).

The Forest-Steppe's climatic conditions promote cherry cultivation, but in dry years, many domestic and foreign cultivars suffer from drought, leading to significant reductions in orchard productivity (Skryaga, 2007). The recent years, marked by high temperatures and insufficient rainfall, underscore the need to study fruit species' drought response to assess their sensitivity. Consequently, six rootstocks were evaluated for drought tolerance in selected cherry cultivars under the right-bank area of the Western Forest-Steppe in Ukraine to identify those with better physiological drought tolerance.

Materials and methodology

Plant Material and Experimental Setup

The study was conducted at the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (Kyiv) during 2022–2023. The experimental plot soil is dark gray, podzolized, light loam on carbonate loess. A comparative evaluation of drought resistance in six cherry (*Cerasus vulgaris* Mill.) cultivars (Igrushka, Lutovka, Balaton, Erdi Botermo, Nochka, Turgenevka) and a promising selection (D 36-25) on different types of rootstocks (*Prunus mahaleb*, Krymsk 5, V-2-180, V-2-230, V-5-88, Rubin) – totaling 35 experimental options – was carried out using a laboratory-field method. *Prunus mahaleb* (seed rootstock) was taken as a control. The plant spacing scheme in the nursery was 1.4×0.25 m, and the nursery was maintained without irrigation. The samples were taken after the end of intensive growth during the period of high air temperatures (3rd decade of July – 1st decade of August).

Weather Conditions

Evaluating the impact of cherry rootstock-cultivar combinations on tolerance to high air temperatures, it is crucial to consider the weather conditions under which the plants grew. Weather conditions are obtained from the weather station (IT-lynx) of the Institute of Horticulture, Department of Storage, Processing and Analytical Research in Horticulture (https://www.optisys.com.ua/#/dashboard). During the summer of 2022, the average air temperature was 21.0–22.6°C, within the multi-year average range (18.3–20.0°C). Maximum air temperatures reached 34.2–35.9°C, while minimum temperatures fell to 10.3–14.2°C. Relative air humidity was low (36.0–50.0%) due to insufficient rainfall (21.2–24.2 mm), with a three-month total of 68.9 mm, representing 31% of the multi-year average. The hydrothermal coefficient (HTC) was low at 0.30–0.37 (Table 1).

The summer of 2023 was similar in temperature to the previous year, with average air temperatures ranging from 13.8–24.0°C; maximum temperatures were between 32.8– 38.3°C, and minimums between 5.6–

12.5°C. Relative air humidity was low, at 42–46%, although total precipitation was higher than in 2022, amounting to 53.5% of the multi-year average.

Research Methodology

Physiological drought resistance was assessed according to the "Program and Methodology for Variety Testing of Fruit, Berry, and Nut Crops" (Sedov and Ogoltsova, 1999) based on indicators such as water retention capacity, turgor recovery degree, water deficit, and leaf tissue hydration. Leaf sampling was conducted during periods of peak water stress, as cherry cultivars differ in drought resistance.

Water retention capacity is higher when there is less water loss over time. Leaves (3–10, depending on size) were sampled in duplicate, weighed, and placed on racks in a thermostat set to a constant temperature of 23 °C with 50–60% air humidity. Weights were recorded every 2, 4, and 6 hours to assess water retention.

Water deficit was determined by sampling 3–5 leaves with refreshed petiole cuts, weighing them, and placing them in a beaker for saturation in duplicate. After 24 hours, petioles were blotted with filter paper and weighed again.

To determine total water content (leaf tissue hydration), 5–10 leaves were placed in metal crucibles (duplicate) and dried in a thermostat at 105 °C to a constant weight. All data calculations were conducted using the formulas provided in the methodology.

A predictive model for the relationship between leaf tissue hydration and water deficit in cherry plantations:

$V_T = 67.7879 - 0.8214 \times D$,
V_T – leaf tissue hydration, %
D – leaf tissue water deficit, % (1)

Statistical Analysis

For statistical processing of experimental data and determining the reliability and validity of results, dispersion statistical analysis was used with AGROSTAT. Values are presented as the mean ±standard deviation (SD). Data were analyzed for statistical significance using Student's t-test, with an LSD of less than 0.05 considered significant.

Table 1 Weather conditions during the active growth period of cherry plants, 2022–2023

Month	Avg. Temp, °C	Min Temp, °C	Max Temp, °C	Avg Humidity, %	Min Humidity, %	Max Humidity, %	Rainfall, mm	HTC
				2022				
June	22.1	10.3	35.9	35.6	28	58	23.5	0.35
July	21.0	12.8	34.8	44.3	28	77	24.2	0.37
August	22.6	14.2	34.2	50.0	22	77	21.2	0.30
				2023				
June	13.8	5.6	32.8	42.1	23	81	38.1	0.65
July	21.6	11.9	34.2	45.7	31	80	72.7	1.09
August	24.0	12.5	38.3	41.6	33	61	8.6	0.12

Notes: Avg. Temp – average temperature; Min – minimum temperature; Max – maximum temperature; HTC – Sulyaninov hydrothermal coefficient.

Results and discussion

Cherry is generally considered a drought-resistant crop (Skriaha et al., 2005; Skriaha, 2007; Kishchak et al., 2015;) however, climate changes – specifically, sharp fluctuations in daily temperatures, irregular rainfall during the growing season, and severe soil overhydration and drought – have intensified the challenges of plant adaptation to environmental conditions (Dolhova, 2014; Kryvoshapka et al., 2016). Researchers (Stollen and Sharp, 1991; Maurel et al., 2010) note that drought stress initially affects the root system, which continues to develop even when shoot growth is suppressed by atmospheric drought. This highlights the role of rootstock choice and its response to increased air temperatures. Enhanced drought resistance may be closely linked to increased water absorption capacity in various cherry varieties and the rootstock structure due to variations in root system structure (Wu et al., 2013). The rootstock's influence on the scion is crucial and largely determines cherry tree growth and resistance to various environmental stresses, such as drought and salinity (Kucukyumuk et al., 2015).

Grafting fruit crops onto drought-resistant rootstocks to improve water use efficiency has been proposed as a fundamental strategy to combat drought (Berdeja et al., 2015). Understanding the interaction mechanism between rootstock and scion and implementing rootstocks that enhance growth and productivity under drought conditions is thus essential for nurseries. Recently, the use of physiologically active substances (plant growth regulators and biostimulants) to improve drought resistance and sustain yields in fruit crops has become a research frontier (Basile et al., 2020).

Water deficiency in cherry tree leaves occurs when air temperatures rise significantly and drought intensifies. One of the primary indicators underlying the development of models to evaluate rootstock type influence on cherry cultivar drought resistance was leaf tissue water deficit. Research findings on water deficit demonstrated that it varies based on annual weather conditions, ranging from 2.2–7.0% (2022) to 3.7–9.2% (2023), providing a comprehensive assessment of cherry plantation water status (Table 2). The average water deficit, depending on rootstock, was found to be 4.7–5.5%, with a significant difference of 0.37, while the cultivar factor showed a difference of 0.58. It is also noteworthy that all cultivars on the V-2-230 rootstock had the lowest water deficit (4.7%).

To determine the primary factors influencing leaf tissue water deficit in cherries, a multifactorial analysis of variance was conducted, with weather and climate conditions (factor A), rootstock form (factor B), and cultivars (factor C) as the factors. It was found that the water deficit in the studied rootstock-cultivar combinations was determined by weather and climate factors by 26.0%, and by rootstock form and cultivar by 9.0 and 17.0%, respectively. Significant interactions were observed between weather-climate factors and cultivars at 22.0%, and between rootstock form and cultivar at 18.0% (Figure 1). Our research results agree with other scientists (Yaremko, 2015) that the water regime primarily depends on weather and climate factors, then on varietal characteristics and the interaction of these two factors. Shkinder-Barmin's (2014) research also proved that the characteristics of the year had a dominant influence on the adaptability of cherry plants.

Table 2 Water deficit in leaf tissues of various cherry rootstock-cultivar combinations

Year factors (A)	Cultivars (C)	Water deficit, %							
		Rootstocks (B)						LSD05 (C)	LSD05 (A)
		Prunus mahaleb	Krymsk 5	V-2-180	V-2-230	V-5-88	Rubin		
2022	**Igrushka**	3.2	4.0	5.3	3.1	3.9	2.9	0.58	0.21
	Lutovka	5.1	3.9	3.7	2.3	4.0	3.5		
	Balaton	4.0	3.1	5.0	4.2	4.1	2.9		
	Erdi Botermo	3.6	4.0	7.0	3.5	5.2	4.0		
	Nochka	4.6	4.9	5.6	5.2	4.0	2.6		
	Turgenevka	4.5	4.7	5.6	3.2	3.8	3.8		
	D 36-25	4.3	3.4	6.0	4.7	5.0	2.2		
2023	**Igrushka**	3.7	7.9	6.7	4.8	7.8	5.2		
	Lutovka	8.6	5.6	4.5	4.5	6.0	5.6		
	Balaton	5.9	6.1	4.4	7.2	4.4	6.9		
	Erdi Botermo	6.3	6.3	6.1	6.0	5.1	6.1		
	Nochka	4.9	5.2	4.4	3.3	4.1	6.9		
	Turhenevka	9.2	6.8	6.6	9.2	9.0	8.7		
	D 36-25	7.0	5.7	6.1	5.1	5.3	7.5		
Average		5.4	5.1	5.5	4.7	5.2	4.9		
	LSD05 (B)	0.37						-	-

Notes: LSD05 (A) – least significant difference in the factor weather conditions of the year of research; LSD05 (B) – least significant difference in the factor rootstocks; LSD05 (C) – least significant difference in the factor cultivar

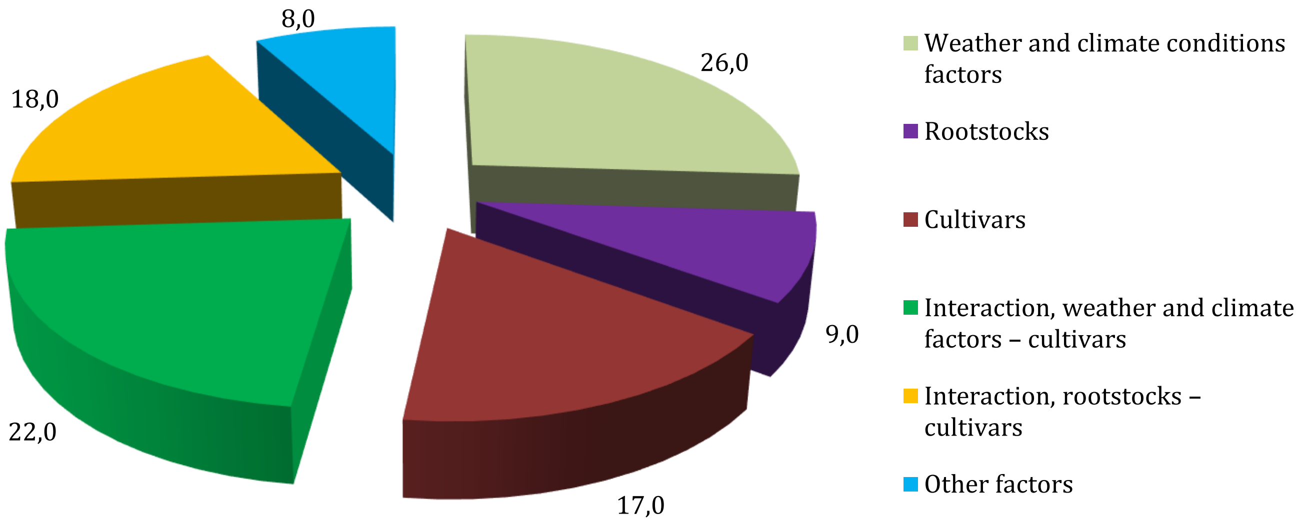

Figure 1 Influence of studied factors on leaf tissue water deficit in cherry, %

Table 3 Leaf tissue hydration in various cherry rootstock-cultivar combinations (average for 2022−2023)

Rootstock	Cultivar/Variety							
	Igrushka	Lutovka	Balaton	Erdi Botermo	Nochka	Turgenevka	D 36-25	Average
Prunus mahaleb (control)	62.8	66.5	62.2	61.5	64.9	63.0	65.6	63.79 ±0.71
Krymsk 5	60.9	61.3	60.8	59.7	64.6	63.3	62.5	61.87 ±0.64
B-2-180	62.1	62.6	61.5	59.0	65.3	61.2	61.9	61.94 ±0.71
B-2-230	63.2	63.6	62.7	62.5	62.1	63.1	61.9	62.73 ±0.23
B-5-88	63.3	63.3	62.4	62.9	66.7	63.3	65.2	63.87 ±0.57
Rubin	65.2	66.5	60.0	65.1	67.4	63.0	62.3	64.21 ±0.98
Average	62.92 ±0.58	63.97 ±0.86	61.60 ±0.43	61.78 ±0.91	65.17 ±0.76	62.82 ±0.33	63.23 ±0.69	–

Notes: Data presented as mean ±SE

An important element in assessing physiological drought resistance is tissue hydration, which reflects the crucial role of water balance during the plant growing season (Solovyova, 1983). As previously noted, all metabolic processes in cells occur in aqueous solutions. A reduction in water content below optimum levels for more than 10 days causes irreversible structural and functional changes in organs, tissues, and subcellular components. It is also worth noting that fruit crops maintain optimal intracellular and intratissue water levels even at the cost of reducing reproductive structures, leading to the shedding of flowers, ovaries, and fruits (Trokhymchuk and Makarova, 2012). Thus, in analyzing the water-physical properties of cherry across various rootstock-cultivar combinations, the leaf tissue hydration range was determined, varying across cultivars from 60.87% (Erdi Botermo) to 65.93% (Nochka), and for rootstocks from 60.23% (Krymsk 5, V-2-180) to 64.19% (Rubin) (Table 3).

The study also aimed to establish a relationship between water deficit and leaf tissue hydration in cherry rootstock-cultivar combinations. An inverse linear relationship was identified, with a correlation coefficient of 0.8284, which is significant (Equation 1). This graphically represents a linear inverse function between water deficit and leaf tissue hydration in cherry (Figure 2). The graph shows that an average water deficit value of 5.56% corresponds to cherry leaf tissue hydration at 63.2% (Point A).

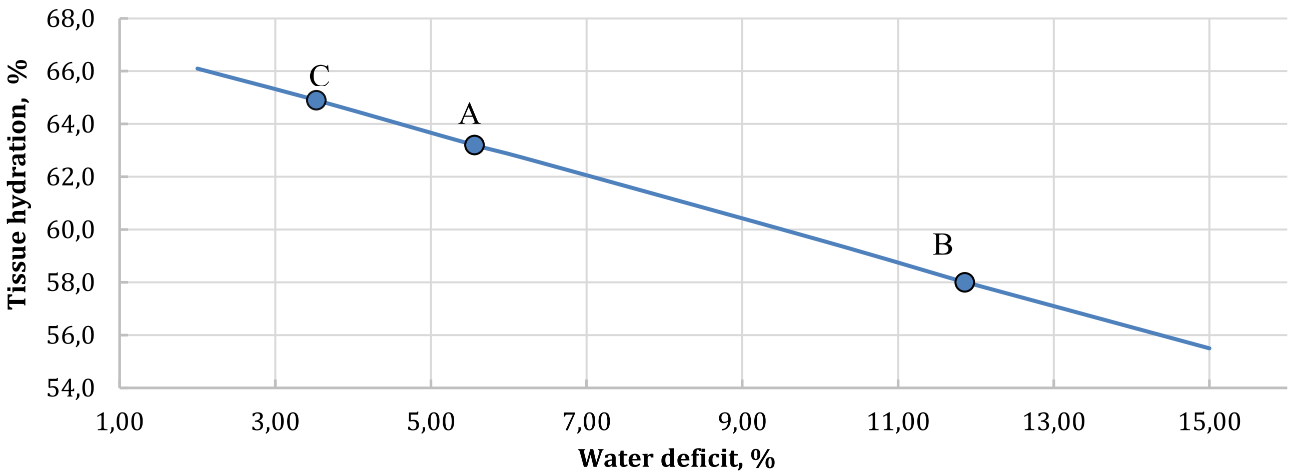

Figure 2 Characteristics of the relationship between leaf tissue hydration and water deficit in various cherry rootstock-cultivar combinations: A – leaf tissue hydration with medium water deficit; B – leaf tissue hydration with the greatest water deficit; C – leaf tissue hydration with the smallest water deficit

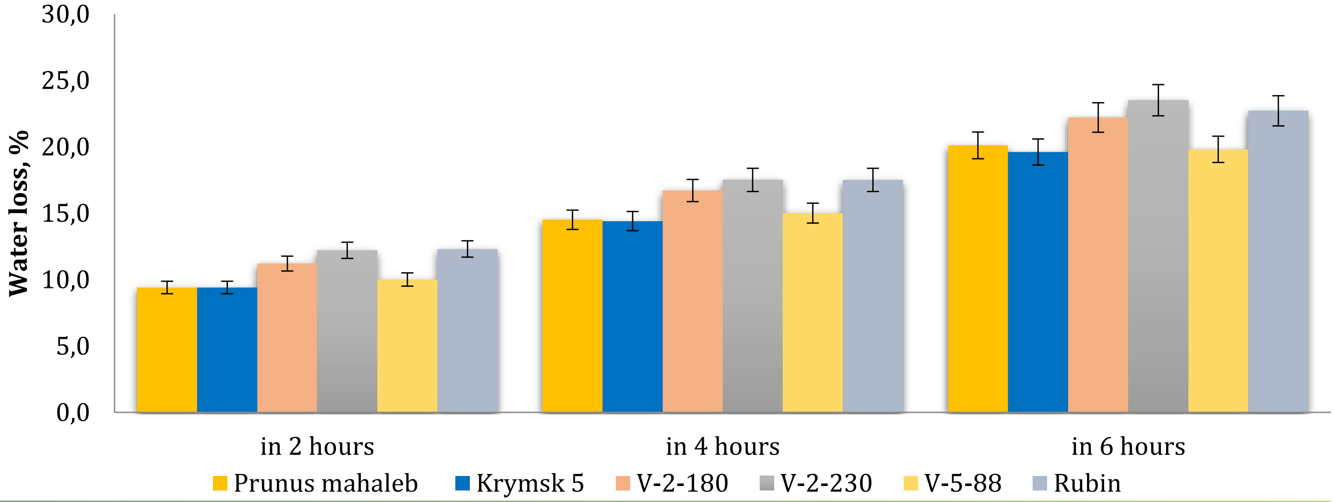

Figure 3 Water retention capacity of cherry leaf tissues in studied rootstocks (average for 2022−2023), %

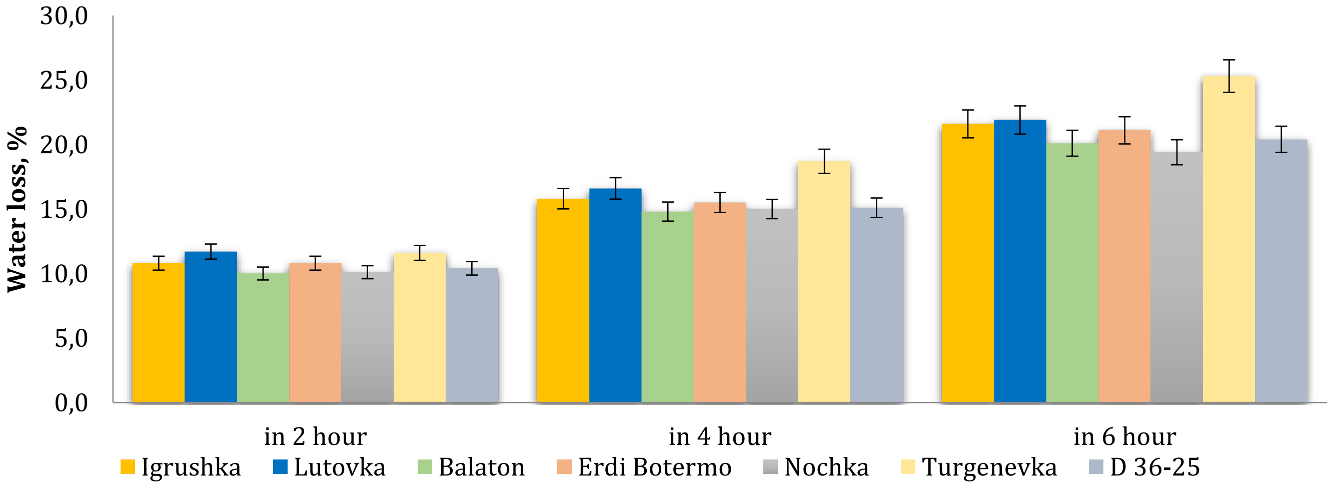

Figure 4 Water retention capacity of cherry leaf tissues in studied cultivars (average for 2022–2023), %

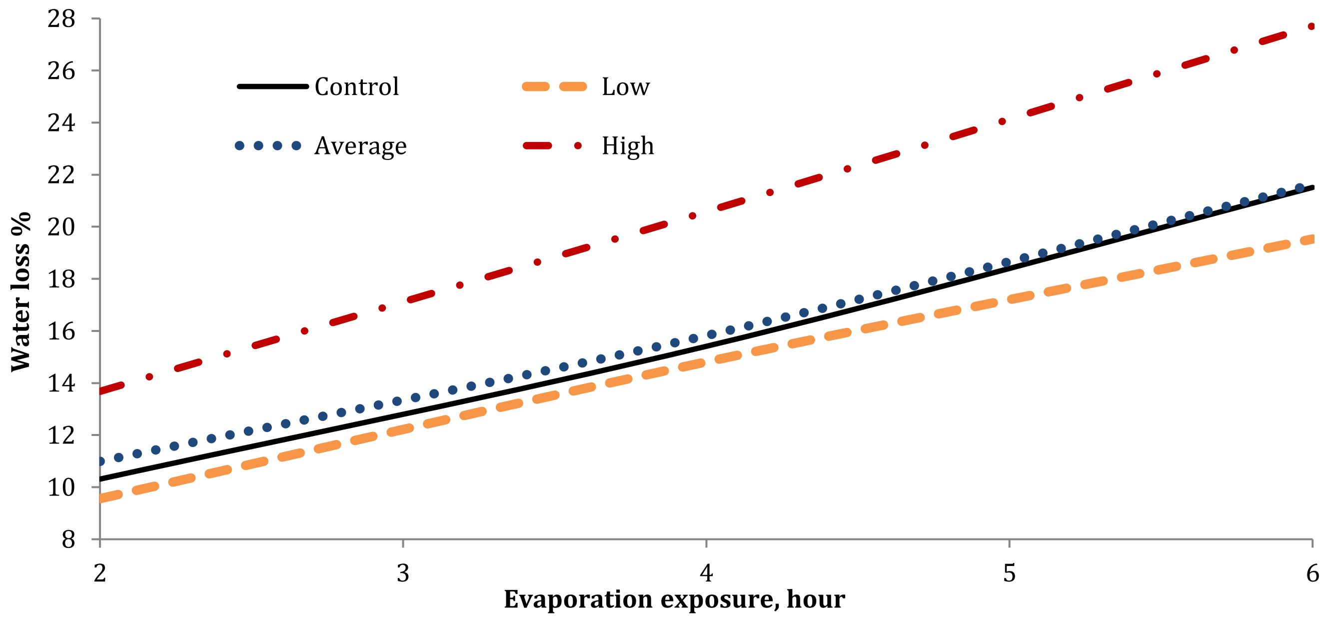

Figure 5 Water retention capacity of cherry leaf tissues under water deficit in studied cherry rootstock- cultivar combinations, %

Table 4 Turgor recovery in cherry leaf tissues in various rootstock-cultivar combinations (average 2022–2023)

Rootstock (B)	Cultivar/Variety (A)							
	Igrushka	Lutovka	Balaton	Erdi Botermo	Nochka	Turgenevka	D 36-25	LSD05 (A)
Prunus mahaleb (control)	39.2	43.3	47.3	36.9	51.2	59.8	51.5	4.04
Krymsk 5	39.2	37.8	38.8	34.9	36.4	45.8	43.5	3.80
V-2-180	30.0	33.5	36.7	41.3	37.4	37.7	36.9	3.68
V-2-230	41.1	40.1	34.1	38.5	41.0	48.2	43.4	3.70
V-5-88	45.6	46.4	34.5	50.0	36.4	48.7	40.2	3.21
Rubin	31.6	47.7	39.3	39.7	35.5	41.3	38.7	2.97
LSD_{05} (B)	3.35	3.77	2.68	3.39	3.30	3.63	3.98	–

Notes: LSD_{05} (A) – least significant difference in the factor variety; LSD_{05} (B) – least significant difference in the factor rootstocks.

A reduction to 3.53% (Point B) increases hydration to 64.9%, while an increase in water deficit to 11.9% (Point C) decreases leaf tissue hydration to 58.0%.

During drought, a key element in assessing the physiological state of plants is their ability to maintain water balance in leaf tissues at an optimal level. Researchers (Kryvoshapka, 2012; Vasylenko, 2016) note that cherry leaves, compared to other crops, are characterized by an enhanced ability to regulate water due to high-polymer compounds, low transpiration intensity, and low osmotic pressure. The conducted research revealed that water retention capacity in cherry leaf tissues depends on both the cultivar and the rootstock. On average, across cultivars, the lowest water losses were recorded on the rootstocks *Prunus mahaleb* (control), Krymsk 5, and V-5-88, ranging from 9.6 ±0.2% % in the first 2 hours of the experiment (Figure 3). On the V-2-180 rootstock, water losses were 11.2%, while the highest losses were recorded on V-2-230 and Rubin rootstocks, at 12.3 ±0.04%, respectively, which significantly differed from the control. This pattern continued in subsequent hours, with water losses at 15.9 ±0.6% after 4 hours and 21.3 ±0.7% after 6 hours. It should be noted that the greatest water loss occurred within the first two hours of the study, with subsequent losses every two hours decreasing by around 5%, indicating that this crop can adapt to drought conditions to some extent (by moderating water loss). This regularity of water loss by leaf tissues is observed in the experiments of other scientists (Vasylenko, 2014; Yaremko, 2015; Viljevac et al., 2022;), which confirms the fact that this indicator is formed due to less bound water, the content of which is higher in leaves with optimal water supply.

When examining these indicators by cultivar, it was found that by the end of the experiment, the lowest water losses were recorded in the cultivars Nochka, Balaton, and D 36-25 – 20.0 ±0.3%. Other studied cultivars Erdi Botermo, Igrushka, Lutovka showed water losses ranging from 21.5 ±0.2%, and Turgenevka 25.3% (Figure 4). Similar results were obtained in the studies of Kryvoshapka (2012) on Nochka and Turgenevka cultivars. Based on the experiment evaluating the impact of rootstock-cultivar combinations on drought resistance in cherries, assessed by water retention capacity, the cultivar Nochka on Krymsk 5, V-5-88, and Rubin rootstocks was identified as highly drought-resistant. The cultivars Igrushka, Lutovka, Balaton, Erdi Botermo, Turgenevka, and D 36-25 were categorized as moderately drought-resistant and are recommended for cultivation on all studied rootstocks. Other scientists (Nemeskeri, 2007; Viljevac et al., 2013; Kryvoshapka et al., 2014; Vasylenko, 2014; Tereshchenko et al., 2019; Wan et al., 2021) have established that the water retention capacity of the leaves of fruit crops depends on the genetic characteristics of the cultivar and rootstocks.

An analysis of leaf tissue water retention capacity under various water deficit levels showed that it remained close to the control level for low and moderate deficit levels, with an average of 10.9% water loss after two hours, while for high deficit levels, it was 13.7% (Figure 5). It is also worth noting that the increase in water retention capacity was 2.41% per hour for control, low, and moderate deficit levels, while it was 3.45% for high deficit levels.

An important characteristic of drought resistance is the ability to recover turgor after wilting. The highest turgor recovery was observed in the *Prunus mahaleb*, with the cultivars Turgenevka (59.8%), Nochka (51.2%), Balaton (47.3%), and the elite form D 36-25 (51.5%). For the cultivar Igrushka, the best indicators were seen on V-5-88 (45.6%) and V-2-230 (41.4%) rootstocks, which significantly exceeded the control (39.2%). For the cultivar Lutovka, the best rootstocks were Rubin (47.7%) and V-5-88 (45.6%), significantly higher than the widely used Krymsk 5 (37.8%). For the cultivar Erdi Botermo, the best combinations were with V-5-88 (50.0%) and V-2-180 (41.3%) rootstocks. Thus, when assessing rootstock-cultivar combinations by turgor recovery in leaf tissues, the best clonal rootstocks were V-5-88, V-2-230, and Rubin (Table 4).

A graphical model was also constructed to show the relationship between turgor recovery in leaf tissues (Table 4) and water deficit in various cherry rootstock-cultivar combinations (Table 2). It was established that the turgor recovery level for the majority of the studied rootstock-cultivar combinations ranged from 40.3 to 52.7% against the background of a water deficit of 2.2–6.5% (r = 0.860) (Figure 6, A-B). The same results were obtained by other researchers (Vasylenko, 2016; Khodakivska, 2018). Notably, for each percentage increase in water deficit, the turgor recovery indicator increased by 5.68%. Our results contradict the research of Vasylenko (2016), who claims that the smaller the water deficit, the faster the turgor recovery rate, in our opinion, this can be explained by various cultivar-rootstock combinations, which proves the influence of the rootstock on the cultivar.

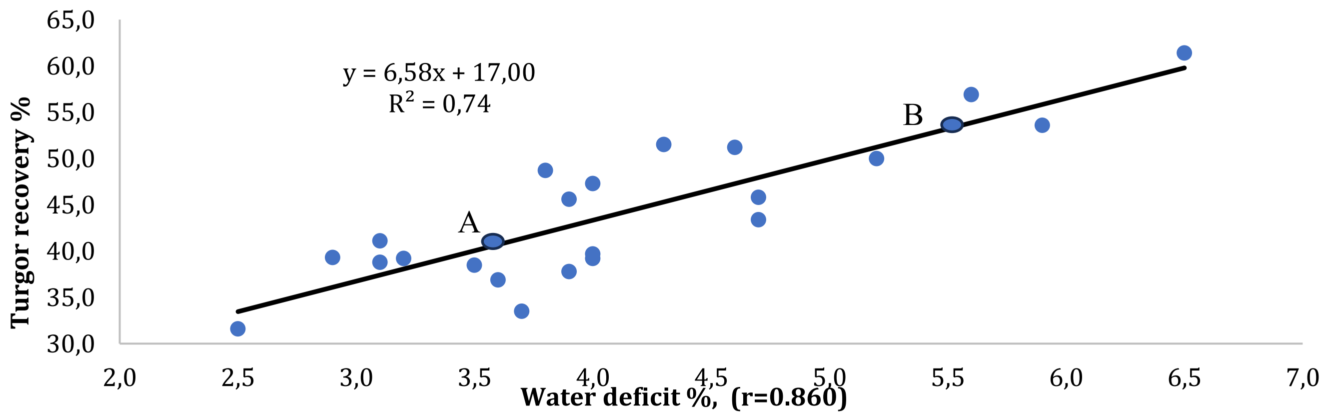

Figure 6 Characteristics of the relationship between turgor recovery in leaf tissues and water deficit in studied cherry rootstock-cultivar combinations (A – B – optimal range turgor recovery leaf from 40.3–52.7%)

Conclusions

A comprehensive analysis of physiological drought resistance indicators confirmed the adaptive potential of all studied cherry cultivars under the conditions of the Western Forest-Steppe region. It was established that the average water deficit across rootstocks ranged from 4.70–5.50%. Leaf tissue hydration in the studied rootstock-cultivar combinations varied by cultivar between 60.87–65.93% and by rootstock between 60.23–64.19%, indicating resistance to atmospheric drought. The water retention capacity of cherry leaf tissue in the rootstock-cultivar combinations showed water losses of 10.90–13.70% after two hours. After 4-6 hours, the increase in water retention capacity was noted at 2.41–3.45% per hour. It was found that the turgor recovery level ranged from 40.3–52.7%. Notably, as the water deficit increased, the turgor recovery indicator also rose. The factors affecting drought resistance in the studied cherry rootstock-cultivar combinations were identified: weather and climatic factors accounted for 26.0%, while cultivar and rootstock form contributed 17.0 and 9.0%, respectively. Significant interactions were observed between weather-climate factors and cultivars (22.0%) and between rootstock form and cultivar (18.0%). The results demonstrated that all studied cherry rootstock-cultivar combinations are highly drought-resistant, with drought resistance primarily influenced by the compatibility between cultivar and rootstock and the growing conditions.

Conflict of interest

The authors declare no conflict of interest to declare.

Ethical statement

This article doesn't contain any studies that would require an ethical statement.

References

Barabash, O., Dubrovskyi, V., & Kytaiev, O.I. 2000. Otsinka posukho- ta zharostiikosti odnorichnykh sorto-pidshchepnykh kombinuvan yabluni za funktsionalnym stanom yikh lystkovoho aparatu [Evaluation of drought and heat resistance of one-year varieties and rootstock combinations of apple trees according to the functional state of their leaf apparatus]. In *Sadivnytstvo*, 51, 246–251. [In Ukrainian]

Basile, B., Rouphael, Y., Colla, G., Soppelsa, S., & Andreotti, C. 2020. Appraisal of emerging crop management opportunities in fruit trees, grapevines, and berry crops facilitated by the application of biostimulants. In *Scientia Horticulturae,* 267, 109330. https://doi.org/10.1016/j.scienta.2020.109330

Basu, S., Ramegowda, V., Kumar, A., & Pereira, A. 2016. Plant adaptation to drought stress. In *F1000 Research,* 5, 1554. https://doi.org/10.12688/f1000research.7678.1

Berdeja, M., Nicolas, P., Kappel, C., Dai, Z.W., Hilbert, G., Peccoux, A., Lafontaine, M., Ollat, N., Gomès, E., & Delrot, S. 2015. Water limitation and rootstock genotype interact to alter grape berry metabolism through transcriptome reprogramming. In *Horticulture Research,* 2(1), 15012. https://doi.org/10.1038/hortres.2015.12

Chukhil, S.M., Chyzh, O.D., & Kytaiev, O.I. 2007. Vyvchennia posukhostiikosti klonovykh pidshchep ta sorto-pidshchepnykh kombinuvan yabluni [Study of drought resistance of clonal rootstocks and variety- rootstock combinations of apple trees]. In *Sadivnytstvo*, 60, 227–238. [In Ukrainian]

Dai, A. 2013. Increasing drought under global warming in observations and models. In *Nature Climate Change*, 3(1), 52–58. https://doi.org/10.1038/nclimate1633

Daszkowska-Golec, A., & Szarejko, I. 2013. Open or close the gate-stomata action under the control of phytohormones in drought stress conditions. In *Front Plant Science*, 4, 138. https://doi.org/10.3389/fpls.2013.00138

Dolhova, S.V. 2014. Potentsial adaptyvnosti chereshni (Cerasus avium Moench.) u pivdennomu Stepu Ukrainy [Sweet cherry (*Cerasus avium* Moench.) adaptive potential in the Ukraine's southern Steppe]. In *Sadivnytstvo*, 68, 91–96. [In Ukrainian]

Faghih, S., Zamani, Z., Fatahi, R., & Omidi, M. 2021. Influence of kaolin application on most important fruit and leaf characteristics of two apple cultivars under sustained deficit irrigation. In *Biology Research,* 54(1), 1. https://doi.org/10.1186/s40659-020-00325-z

Fang, Y.J., & Xiong, L.Z. 2015. General mechanisms of drought response and their application in drought resistance improvement in plants. In *Cellular and Molecular Life Sciences*, 72(4), 673–689. https://doi.org/10.1007/s00018-014- 1767-0

Hu, H.H., & Xiong, L.Z. 2014. Genetic engineering and breeding of drought-resistant crops. In *Annual Review of Plant Biology*, 65(1), 715–741. https://doi.org/10.1146/annurev-arplant-050213-040000

Joshi, R., Wani, S.H., Singh, B., Bohra, A., Dar, Z.A., Lone, A., Pareek, A., & Singla-Pareek, S.L. 2016. Transcription factors and plants response to drought stress: current understanding and future directions. In *Front. Plant Science Section Plant Biotechnology,* 7. https://doi.org/10.3389/fpls.2016.01029

Khodakivska, Yu.B. 2018. Posukhostiikist sortiv hrushi (*Pirus communis* L.) u pivnichnii chastyni Lisostepu Ukrainy [Pear (*Pirus communis* L.) cultivars drought-resistance in the northern part of the Ukraine's Lisosteppe]. In *Sadivnytstvo*, 73, 149–153. [In Ukrainian]

Kishchak, O.A., Kishchak, Yu.P., Lysaniuk, V.H., & Vasiuta, V.M. 2015. Dobir perspektyvnykh sorto-pidshchepnykh kombinuvan vyshni (*Cerasus vulgaris* Mill.) dlia stvorennia intensyvnykh nasadzhen [Selection on the cherry (*Cerasus vulgaris* Mill.) promise cultivar-rootstock combinations to create intense orchards]. In *Sadivnytstvo*, 69, 44–53. [In Ukrainian]

Kryvoshapka, V. 2012. Diahnostyka funktsionalnoho stanu roslyn u zviazku z yikh stiikistiu do posukhy ta vysokykh temperature [Diagnostics of the functional state of plants in connection with their resistance to drought and high temperatures]. In *Sadivnytstvo,* 65, 196–203. [In Ukrainian]

Kryvoshapka, V.A., Bublyk, M.O., Kytaiev, O.I., & Hrusha V.V. 2016. Klimatychni zminy ta ryzyky pry vyroshchuvanni plodovykh i yahidnykh kultur v umovakh pivnichnoi chastyny Lisostepu Ukrainy [Climatic changes and risks when growing fruit and small fruit crops in the conditions of the northern part of the Ukraine's Lisosteppe]. In *Sadivnytstvo*, 71, 130–139. [In Ukrainian]

Kryvoshapka, V.A., Yareshchenko, O.M., & Yezhov, V.M. 2014*.* Otsinka posukhostiikosti sortiv i hibrydnykh form chornoi smorodyny (*Ribes nigrum* L.) v Lisostepu Ukrainy [Estimation of the black currant *(Ribes nigrum L.)* cultivars and hybrid forms drought-resistance in the Ukraine's Lisosteppe]. In *Sadivnytstvo*, 68, 344–351. [In Ukrainian]

Kucukyumuk, Z., Kucukyumuk, C., Erdal, İ., & Eraslan, F. 2015. Effects of different sweet cherry rootstocks and drought stress on nutrient concentrations. In *Journal of Agricultural Sciences,* 21(3), 431–438. http://dx.doi.org/10.15832/ankutbd.25153

Kumar, S., Sachdeva, S., Bhat, K.V., & Vats, S. 2018. Plant Responses to Drought Stress: Physiological, Biochemical and Molecular Basis. In*: Biotic and Abiotic Stress Tolerance in Plants.* Springer Nature Singapore, 1–25. https://doi.org/10.1007/978-981-10-9029-5_1

Liu, X., Gao, T., Li, C., Mao, K., Gong, X., & Li, C. 2023. Fruit crops combating drought: Physiological responses and regulatory pathways. In *Plant Physiology*, 192(3), 1768–1784. https://doi.org/10.1093/plphys/kiad202

Lobet, G., & Draye, X. 2013. Novel scanning procedure enabling the vectorization of entire rhizotron-grown root systems. In *Plant Methods*, 9(1), 1. https://doi.org/10.1186/1746-4811-9-1

Lynch, J.P. 2019. Root phenotypes for improved nutrient capture: an underexploited opportunity for global agriculture. In *New Phytologist,* 223(2), 548–564. https://doi.org/10.1111/nph.15738

Maurel, C., Simonneau, T., & Sutka, M. 2010. The significance of roots as hydraulic rheostats*.* In *Journal of Experimental Botany,* 61(12), 3191–3198. https://doi.org/10.1093/jxb/erq150.

Melnychuk, M.D., Posudin, Yu.I., & Hodlevska, O.O. 2009. Fluorestsentnyi analiz roslyn protiahom rozvytku v stresovykh umovakh [Fluorescent analysis of plants during development under stressful conditions]. In *Ahrobiolohiia: zb. nauk. prats*, 1(64), 1–8. [In Ukrainian]

Morris, E.C., Griffiths, M., Golebiowska, A., Mairhofer, S., Burr-Hersey, J., Goh, T., Wangenheim, D., Atkinson, B., Sturrock, C.J., & Lynch, J.P. 2017. Shaping 3D root system architecture. In *Current Biology,* 27(17), 919–930. https://doi.org/10.1016/j.cub.2017.06.043

Nemeskeri, E. 2007. Water relations of sour cherries (minireview). In *International Journal of Horticultural Science,* 13(3), 103–107*.* http://dx.doi.org/10.31421/IJHS/13/3/756

Rachappanavar, V., Padiyal, A., Sharma, J.K., & Gupta, S.K. 2022. Plant hormone-mediated stress regulation responses in fruit crops - a review. In *Scientia Horticulturae,* 304, 1113. https://doi.org/10.1016/j.scienta.2022.111302

Shkinder-Barmina, A.M. 2014. Adaptyvnyi potentsial sortiv vyshni i diukiv (*Cerasus vulgaris* Mill.) u pivdennomu Stepu Ukrainy [Adaptive potential of sour cherry and dukes (*Cerasus vulgaris* Mill.) varieties in the southern Steppe of Ukraine]. In *Sadivnytstvo*, 68, 80–84. [In Ukrainian]

Skriaha, V.A. 2007. Hospodarsko-biolohichna otsinka sortiv i pidshchep vyshni v pivnichnomu Lisostepu Ukrainy [Economic and biological evaluation of cherry cultivars and rootstocks in the Northern Lisosteppe of Ukraine]: dissertation theses.Kyiv, 226. [In Ukrainian]

Skriaha, V.A., Bublyk, M.O., Moiseichenko, N.V., & Kytaiev, O.I. 2005. Kompleksna otsinka posukho- ta zharostiikosti sortiv vyshni v pivnichnomu Lisostepu Ukrainy [Comprehensive assessment of drought and heat resistance of cherry varieties in the Northern Forest Steppe of Ukraine]. In *Sadivnytstvo*, 57, 480–486. [In Ukrainian]

Skriaha, V.A., Bublyk, M.O., Moiseichenko, N.V., & Kytaiev, O.I. 2006. Otsinka produktyvnosti sortiv vyshni na osnovi pokaznykiv funktsionalnoi aktyvnosti lystkovoho aparatu [Evaluation of the productivity of cherry varieties based on indicators of the functional activity of the leaf apparatus]. In *Sadivnytstvo*, 58, 167–174. [In Ukrainian]

Solovyova M.O. 1983. Fiziolohichni osnovy formuvannia morozostiikosti plodovykh roslyn ta zakhyst vid zymovykh poshkodzhen [Physiological bases of the formation of frost resistance of fruit plants and protection against winter damage]. Silskohospodarska biolohiia, 7, 108-113. [In Ukrainian]

Stollen, W.G. & Sharp, R.E. 1991. Spatial distribution of turgor and root growth at low water potentials. In *Plant Physiology*, 96(2), 438–443.

Sedov, E.N., & Ogoltsova, T.P. 1999. Prohrama i metodyka sortovyvchennia plodovykh, yahidnykh i horikhoplidnykh kultur [Programm and methods of the strain investigation of fruit, small fruit and nuciferous crops], 608. [In Ukrainian]

Taran, N.I. 2001. *Adaptatsiinyi syndrom roslyn v umovakh posukhy* [Adaptation syndrome of plants in drought conditions]: thesis abstract , 42. [In Ukrainian]

Tereshchenko, Ya.Iu, Kryvoshapka, V.A., & Yareshchenko, O.M. 2019. Adaptyvnist novykh sortiv zhymolosti (*Lonicera coerulea* L.) v umovakh Lisostepu Ukrainy [Adaptivity of the new sweet-berry honeysuckle (*Lonicera coerulea* L.) cultivars under the conditions of the Ukraine's Lisosteppe]. In *Sadivnytstvo*, 74, 32-39. https://doi.org/10.35205/0558-1125-2019-74-32-39.

Titarenko, T.I., Kirizii, D.A., & Kytaiev, O.I. 2001. Vplyv zatoplennia gruntu na SO2 – hazoobmin, transpiratsiiu, vmist plastydnykh pihmentiv i fluorestsentsiiu khlorofilu u plodovykh roslyn [Effect of soil flooding on CO2 gas exchange, transpiration, content of plastid pigments and chlorophyll fluorescence in fruit plants]. In *Fiziolohiia i biokhimiia kulturnykh roslyn*, 33(3), 268–274. [In Ukrainian]

Trokhymchuk, A.I., & Makarova, D.H. 2012. Fiziolohichna posukhostiikist perspektyvnykh sortiv yabluni (*Malus domestica* Borkh.) v umovakh pravoberezhnoi pidzony Zakhidnoho Lisostepu Ukrainy [Physiological drought-resistance of perspective apple *(Malus domestica* Borkh.) cultivars in the right – bank subzone of the Ukraine's Western Lisosteppe]. In *Sadivnytstvo*,66, 230–241. [In Ukrainian]

Vasylenko, V.I. 2014. Vyvchennia vodno-fizychnykh parametriv lystia derev vyshni (*Cerasus vulgaris* Mill.) u zviazku z posukhostiikistiu yii sortiv [Determination of the cherry (*Cerasus vulgaris* Mill.) trees leaves water and physical parameters connected with drought-resistance of cultivars].In *Sadivnytstvo*, 68, 337–343. [In Ukrainian]

Vasylenko, V.I. 2016. Otsinka fiziolohichnoho stanu derev elitnykh form vyshni (*Cerasus vulgaris* Mill.) u period posukhy [Estimation of the physiological state of the cherry (*Cerasus vulgaris* Mill.) elite forms trees during the droughty period] In *Sadivnytstvo*, 71, 139–146. [In Ukrainian]

Viljevac, M., Dugalic, K., Mihaljevic, I., Šimic, D., Sudar, R., Jurkovic, Z., & Lepeduš, H. 2013. Chlorophylls content and photosynthetic efficiency in two sour cherry *(Prunus cerasus L.)* genotypes under drought stress. In *Acta Botanica Croatica*, 72(2*).* https://www.abc.botanic.hr/index.php/abc/article/view/722

Viljevac, Vuletić M., Horvat, D., Mihaljević, I., Dugalić, K., Šimić, D., Čupić, T., Jurković, V., & Lepeduš H. 2022. Photosynthetic Variability of Oblačinska Sour Cherry Ecotypes under Drought. In *Plants*, 11(13), 1764. https://doi.org/10.3390/plants11131764

Wan, T., Feng, Y., Liang, C., Pan, L., He, L., & Cai, Y. 2021. Metabolomics and Transcriptomics Analyses of Two Contrasting Cherry Rootstocks in Response to Drought Stress. In *Biology*, 10(3), 201.

Wu, Q.S., Srivastava, A.K., & Zou, Y.N. 2013. AMF-induced tolerance to drought stress in citrus: a review. In *Scientia Horticulturae*, 164, 77–87. https://doi.org/10.1016/j.scienta.2013.09.010

Xu, Y., Wang, Y., Xu, J., Lv, Z., Manzoor, M.A., Mao, J., Zhang, X., Liu, R., Wang, S., Whiting, M.D., Jiu, S., & Zhang, C. 2023. Strigolactone and salicylic acid regulate the expression of multiple stress-related genes and enhance the drought resistance of cherry rootstocks. In *Scientia Horticulturae,* 313, 111827. https://doi.org/10.1016/j.scienta.2023.111827

Yaremko, N.O. 2015. Posukhostiikist sortiv funduka (*Corylus maxima* L.) v matochnyku v umovakh pravoberezhnoho Lisostepu Ukrainy [Hazelnut (*Corylus maxima* L.) cultivars drought-resistance in a mother garden under the conditions of the Ukraine's right-bank Lisosteppe]. *In Sadivnytstvo*, 69, 167–176. [In Ukrainian]

Yordanov, I., Velikova, V., & Tsonev, T. 2012 Plant responses to drought, acclimation, and stress tolerance. In *Photosynthetica*, 38(2), 171–186. https://doi.org/10.1023/A:1007201411474