IMPACT OF SCION-ROOTSTOCK COMBINATIONS ON DROUGHT RESISTANCE OF PEACH TREES

VLIV KOMBINACÍ ODRŮDY A PODNOŽE NA ODOLNOST BROSKVONÍ VŮČI SUCHU

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ABSTRACT

In recent years, mean annual air temperature in Ukraine and the world continues to rise steadily. The transition of warm climate crops, including peach, from southern regions to cooler areas latitudes is observed. The article is devoted to the study of drought resistance of new scion-rootstock combinations of peach in modern agroclimatic conditions of the Northern Forest-Steppe zone of Ukraine. Water-physical properties, such as water-holding capacity, moisture deficit and water content in the leaf tissues, were investigated in laboratory conditions. As a result of the experiment on moisture loss resistance, it was established that the level of drought tolerance is high in all combinations. It was determined that ‘Liybymets Ⅱ’, ‘Knyazhe bahatstvo’ and ‘Redhaven’ cultivars are characterized by the lowest indices of water deficit, and ‘Knyazhegradskyi’ by the highest. The highest water content in the leaf tissues was noted in the scion-rootstock combinations ‘Liybymets Ⅱ’ on Pumiselect (76%), ‘Knyazhe bahatstvo’ and ‘Knyazhe zoloto’ on apricot seedlings (84–79%). The tissues of the ‘Redhaven’ cultivar grafted on apricot seedlings were the least hydrated (66%). According to the complex of the determined indicators, Druzhba, Krymsk® 1 and Krymsk® 86 rootstocks are characterized by the lowest adaptive capacity to drought compared to the rest of the rootstocks.

Keywords: *Prunus Persica* Mill., adaptability, water-holding capacity, hydration, moisture deficit

ABSTRAKT

V posledních letech průměrná roční teplota vzduchu na Ukrajině i ve světě neustále roste. Je pozorováno šíření teplomilných plodin, včetně broskvoní, z jižních oblastí do středních zeměpisných šířek. Článek je věnován studiu odolnosti nových odrůd a podnožových kombinací broskvoně vůči suchu v dnešních agroklimatických podmínkách severní lesostepní

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zóny Ukrajiny. Fyziologické vlastnosti kombinací pěti odrůd a šesti podnoží, jako je schopnost zadržovat vodu, deficit vlhkosti a hydratace pletiv listů, byly zkoumány v laboratorních podmínkách. Ve výsledcích studií odolnosti proti ztrátě vlhkosti bylo zjištěno, že úroveň odolnosti proti suchu je vysoká ve všech kombinacích. Bylo zjištěno, že nejnižší ukazatel vodního deficitu je charakterizován odrůdami 'Liybymets Ⅱ', 'Knyazhe bachatstvo', 'Redhaven' a nejvyšší je u odrůdy 'Knyazhegradskyi'. Nejvyšší hydratace pletiv listů byla zaznamenána u kombinací odrůdy a podnože 'Lyubumets Ⅱ' na Pumiselect (76%), 'Knyazhe bahatstvo' a 'Knyazhe zoloto' na semenáčích meruněk (84–79%). Nejméně hydratovaná byla pletiva odrůdy 'Redhaven' na semenáčích meruněk (66%). Podle souboru stanovených ukazatelů podnože Družba, Krymsk® 1 a Krymsk® 86 vykazovaly nejnižší adaptační schopností na sucho ve srovnání s ostatními.

Klíčová slova: *Prunus perscica* Mill., adaptabilita, schopnost zadržovat vodu, hydratace, nedostatek vláhy

INTRODUCTION

In Ukraine, peach cultivation was historically possible only in the South and in Transcarpathia, since the rest of the territory had rather low winter temperatures, critical for peach (> –25 °C). In connection with global warming, winters in the entire territory of Ukraine, including in the Forest-Steppe zone, have become less severe, which allows cultivation of this crop without the threat of frost damage to generative buds and trees as a whole. At the same time, unfavourable weather conditions are observed annually in the Forest-Steppe of Ukraine during the growing season. Spring and summer are characterized not only by rising temperatures, but also by frequent droughts. And although the average amount of precipitation for these periods is within the normal range, the rainfall is extremely uneven. Such temperature shift and insufficient precipitation negatively affect the growth and development of plants (Silaev, 2003; Kryvoshapka *et al.*, 2016; Tereshchenko *et al.*, 2019). It is known that life processes in plants, as well as in other organisms, take place in the water environment. Water is a solvent and a medium in which the movement of substances and their exchange take place, and its high heat capacity helps to stabilize the temperature of plants (Skryaga *et al.*, 2005; Kryvoshapka, 2012). Due to a lack of moisture in fruit plants, growth processes stop, leaves and fruits wither and fall off, the initiation of generative buds decreases, and, accordingly, the productivity gets lower not only in the year of drought but also in the following year (Zakharov, 2011; Zhu *et al.*, 2023).

Among the fruit crops, peach is drought-resistant, because it is characterized by the increased water-holding capacity of the leaves, the relatively quick recovery of trees after wilting, the ability to use the low content of free water in the soil, etc. (Smykov and Fedorova, 2009). Drought resistance is carried out by a well-developed vascular system, which is explained primarily by the genetics of the organism, physiological, biochemical, and anatomical features of the above-ground organs. During drought, there is a decrease of moisture consumption for transpiration to a minimum, and increased heat resistance of the tissues, therefore, high drought resistance of the peach on the whole tree level (Bunchuk, 2013).

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However, even for relatively drought-resistant crops, individual cultivars vary greatly in their level of drought resistance (Kryvoshapka, 2012). At the same time, in order to obtain high yields with marketable fruit quality, especially under arid conditions, peach crop needs a significant amount of water. The main part of the water balance is precipitation. Its insufficient amount in period May–August leads to significant crop loss (Sokolova and Sokolov, 1987; Omelchenko and Zhuk, 2005). Therefore, drought resistance is an important economically valuable feature of a fruit crop cultivar, as it reflects adaptive properties to the lack of moisture and affects the general condition of plants (Smykov and Fedorova, 2009). This article studies the adaptive capacity of new scion-rootstock combinations of peach in the Northern Forest-Steppe zone of Ukraine under the conditions of global climate warming.

MATERIALS AND METHODS

The research was conducted in the conditions of the Northern Forest-Steppe of Ukraine in Kyiv, in the second field of the nursery of the Institute of Horticulture of the National Academy of Agrarian Sciences (IH NAAS) of Ukraine during the period of the greatest stress on the water regime in 2012–2014. The weather and climatic conditions of the summer months varied during the research years. In 2012, the beginning of summer was dominated by rainy weather (109.2 mm, which is 43% higher than the norm), and July, on the contrary, had an increased mean air temperature of 23.5 °C (20.0 °C is the long-term mean) with insufficient precipitation of 36.8 mm (45% of the norm). 2013 was marked by moderately warm and rainy weather. Significant fluctuations in air temperature were observed in June (min. 11.2 °C, max. 32.6 °C). The monthly amount of precipitation was 65.5 mm (86% of the monthly norm). During July, only short-term rains occurred. A dry period was observed in the first half of July, when insufficient precipitation (20.3 mm) was combined with high air temperatures (max. 32.6 °C). 2014 was quite favourable, both in terms of temperature and precipitation. In general, 203.9 mm of precipitation fell during the summer, which is 91% of the norm with a fairly favourable temperature regime in June – 17.9 °C and July – 21.9 °C.

The objects of the research were 5 peach cultivars: 'Knyazhe zoloto', 'Redhaven' (control), 'Knyazhe bahatstvo', 'Knyazhegradskyi', 'Liybymets Ⅱ' and 6 rootstocks: cherry-plum seedlings (control), apricot seedlings, Pumiselect, Druzhba, Krymsk® 1 and Krymsk® 86. The rootstocks were planted utilising 1.4×0.2 m scheme. The experiment had 3 replications, with 10 plants per replication. The soil of the experimental plot is dark grey podzol, with loamy texture, formed on carbonate loess loam. The content of alkaline hydrolysed nitrogen is low to medium 68–120 mg/kg of soil; mobile phosphorus 80–126 mg/kg (low to medium); potassium 105–159 mg/kg, humus content 1.26–2.75%. Nursery plants were grown according to generally accepted technology according to methodical recommendations (Andrienko and Gulko, 1990; Kondratenko and Bublyk, 1996). The study of the water-physical properties of the leaves of the studied cultivars was carried out according to the "Program and methodology for variety studies of fruit, berry and nut crops" (Sedov and Ogoltsova, 1999).

Leaves for the study were sampled from the middle layer of the canopy, the middle part of the shoot, evenly located within the canopy. Determination of all indicators was carried out in

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duplicate. To determine the water content, for each replication a sample of 10 leaves was placed in a metal weighting bottle and dried in a thermostat at a temperature of 105 °C to a constant weight. After that, the total amount of water (B) as a percentage of the raw weight of the sample was determined according to the formula:

$$\mathbf{B} = \frac{\text{в}-\text{c}}{\text{в}-\boldsymbol{a}} \times \mathbf{100}, \text{ where}$$

a – weight of the empty weighting bottle (g);
в – weight of the weighting bottle with the raw sample (g);
c – weight of the weighting bottle with the dried sample (g).

To determine the water deficit, 5 whole leaves were sampled for each replication, the cuts were renewed, leaves were weighed and placed with petioles in a flask with water for saturation. The flasks were placed in a crystallizer with water and covered with the same crystallizer to form an air chamber. After 24 hours of saturation, leaf petioles were wiped with filter paper and the leaves were weighed again. The water deficit (WD) in the leaves was determined according to the formula:

$$\mathbf{WD} = \frac{\mathbf{M2}-\text{M}\mathbf{1}}{\text{M}\mathbf{3}-\text{M}} \times \mathbf{100} \text{ , where}$$

M – weight of the dry sample, g;
M_1 – weight of the water before the saturation, g;
M_2– weight of the water after the saturation, g;
M_3 – weight of the leaves after full saturation with water, g.

Peach scion-rootstock combinations were divided into three groups according of indicator water deficit, determined according to the “Program and methodology for variety studies of fruit, berry and nut crops” (Sedov and Ogoltsova, 1999).

Obtained experimental data were subjected to analysis of variance using computer software Agrostat. Standard error of the pairwise identities of groups was calculated using Statistica software (Dospekhov 1985, Mezhenskyj, 2017).

RESULTS AND DISCUSSION

In order to obtain a generalized assessment of the drought resistance of peach scion-rootstock combinations, the mean values of the results obtained during the research period (2012–2014) are presented. The study of the dynamics of changes in the water-holding capacity showed that the leaves lost water most intensively in the first 2 hours after the weighing (Table 1). Thus, the highest percentage of water loss was recorded in ‘Knyazhe zoloto’ cultivar grafted on Druzhba and Krymsk® 1 rootstocks (25%), as well as ‘Knyazhegradskyi’ on Krymsk® 1 (24%). The lowest rate of moisture loss was noted for ‘Lyubimets Ⅱ’ cultivar (within 11–18%).

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The control cultivar ‘Redhaven’ lost 15–23% of water in the first 2 hours. After 4 hours of exposure, the leaves lost, depending on the rootstock, from 3 to 6% (‘Knyazhe zoloto’, ‘Knyazhe bahatstvo’) to 7% (‘Knyazhegradskyi’) additional moisture, and the water loss for the control cultivar amounted up to 8%.

Table 1. *Water-holding capacity of peach variety-rootstock combinations, on average from 2012–2014*
Tabulka 1. *Schopnost zadržovat vodu kombinací odrůd broskvoně a podnože, průměr v letech 2012–2014*

Rootstock Faktor B	Variety Faktor A	Hydration of leaves, %	Water-holding capacity, %			Water deficit, %
			2 h	4 h	6 h	
Druzhba	Knyazhe zoloto	69	25	30	34	12
	Redhaven	73	21	25	30	11
	Knyazhe bahatstvo	71	13	16	19	9
	Knyazhegradskyi	70	18	22	25	12
	Liubymets II	72	17	21	24	11
Krymsk® 1	Knyazhe zoloto	70	25	31	36	12
	Redhaven	70	22	30	33	10
	Knyazhe bahatstvo	69	19	25	32	9
	Knyazhegradskyi	68	24	30	36	12
	Liubymets II	71	14	18	21	12
Pumiselect	Knyazhe zoloto	69	18	23	28	9
	Redhaven	73	17	23	30	10
	Knyazhe bahatstvo	69	13	19	26	10
	Knyazhegradskyi	70	19	23	28	10
	Liubymets II	76	11	16	21	9
Krymsk® 86	Knyazhe zoloto	69	21	27	34	10
	Redhaven	70	23	28	30	10
	Knyazhe bahatstvo	71	21	27	30	10
	Knyazhegradskyi	71	19	25	30	10
	Liubymets II	74	18	23	28	9
Cherry-plum seedlings	Knyazhe zoloto	68	11	14	17	10
	Redhaven	75	15	20	25	7
	Knyazhe bahatstvo	70	13	16	21	10
	Knyazhegradskyi	69	17	21	26	10
	Liubymets II	70	16	20	31	9
Apricot seedlings	Knyazhe zoloto	79	20	25	30	6
	Redhaven	66	17	23	27	8
	Knyazhe bahatstvo	84	13	18	21	7
	Knyazhegradskyi	72	18	25	30	8
	Liubymets II	72	14	17	21	8
P factor A P factor B P factor AB		**0.512 0.028 0.001**	**0.0006 0.005**	**0.006 0.002**	**0.102 0.090**	**0.237 0.00004 0.830**

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Among the studied cultivar, on average, regardless of the rootstock, 'Liybymets Ⅱ' lost 24.3% of moisture and 'Knyazhe bahatstvo' – 24.8% after a 6-hour exposure, which indicates a high level of adaptivity to drought conditions. Other cultivars were almost at the same level with an average of 29% loss. Smykov *et al.* (2017), investigating the photosynthetic activity of peach leaves in connection with drought, also determined that after exposure for 8 hours, peach leaves lost 23–35% of water. When comparing the rootstocks, the lowest water loss by leaves was observed on seedling rootstocks – 24–25%. Water loss for Druzhba leaves amounted to 26.4% and Pumiselect – to 26.6%. Leaves of the plants grafted on Krymsk® 86 and Krymsk® 1 rootstocks lost the most water – 30.4 and 31.6%, respectively. Ranjbar *et al.* (2019) in their research on drought resistance of almond cultivars depending on the rootstock also note that the effects of rootstock, scion and their interactions are significant.

In general, the following scion-rootstock combinations can be distinguished in terms of drought resistance: 'Knyazhe zoloto' on cherry-plum seedlings (17%) and Pumiselect (28%); 'Redhaven' on cherry-plum seedlings (control) and apricot seedlings (25–27%); 'Knyazhe bahatstvo' on Druzhba (19%), cherry-plum seedlings (control) and apricot seedlings (21%) and Pumiselect (26%); 'Knyazhegradskyi' on Druzhba (25%), cherry-plum seedlings (26%) and Pumiselect (28%); 'Liybymets Ⅱ' on Pumicelect, Krymsk® 1 and apricot seedlings (21%).

Thus, 'Liybymets Ⅱ' and 'Knyazhe Bahaststvo' were the most drought-resistant cultivars, and among rootstocks, cherry-plum and apricot seedlings, Pumiselect and Druzhba.

The assessment of drought resistance of the plants based on the water deficit was carried out according to the following classification: 10–15% is the moderate effect of drought; more than 18% – significant tension of the water regime, which causes irreversible disturbances in the structural structure of membranes (Mezhenskyi, 2017). It should be noted that the water deficit indicator among the studied cultivars does not exceed 12%, which confirms fairly high drought resistance of peach scion-rootstock combinations and their high ability to survive the hydrothermal stress conditions of the summer period. Similar data were obtained in previous studies of drought tolerance of ornamental peach cultivars (Komar-Tyomnaya, 2021). However, 'Knyazhe bahastvo' cultivar is characterised by the lowest moisture deficit, with an average indicator of 9.2%, and 'Knyazhegradskyi' – by the highest (10.3%), which indicates a somewhat lower adaptive potential in drought conditions. Depending on the rootstock, the smallest moisture deficit was recorded in cherry-plum and apricot seedlings – 7.4–9.2% and Pumiselect – 9.6%, the largest – in Druzhba and Krymsk® 1 (11.2%).

Ability to maintain an optimal level of hydration of leaf tissues is an important element in assessing the physiological state of the plants during the drought. A decrease in water content in the plant can lead to irreversible processes, such as a decrease in shoot and root growth, premature wilting of leaves, even to their drying and leaf fall, a decrease in the amount of reserve nutrients and violation of CO_2 assimilation. However, such anatomical features as hydration and water deficit are used only as an auxiliary criterion for determining drought resistance (Mezhenskyi, 2017). The level of hydration of the studied scion-rootstock combinations ranged from 66 to 84%. 'Liybymets Ⅱ' and 'Knyazhe bahastvo' cultivars had the highest values of leaf hydration, on average for all the rootstocks (72%), and 'Knyazhegradskyi' cultivar had the lowest (70%).

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According to the statistical analysis of the data, it was determined that both the rootstock and scion-rootstock interaction had a significant effect on the leaf water content (P = 0.03 and P = 0.001, respectively) while the influence of the cultivar was not significant (P = 0.512). The rootstock had the most significant influence on water deficit (P < 0.001), and both the cultivar and the rootstock had a significant influence on the water-holding capacity during 2- and 4-hour exposure (P < 0.01 in all cases). When the exposure time was 6 hours, there was no significant influence of factors of the experiment.

Over the years of the research, the influence of weather and climate conditions on the drought resistance of peach can be seen. In particular, it was established that leaf hydration has a strong positive correlation with the amount of precipitation (r = 0.726 ± 0.074), and water deficit – with the mean monthly air temperature (r = 0.846 ± 0.052).

In general, peach scion-rootstock combinations were divided into three groups according to indicator water deficit: highly drought-resistant, drought-resistant, and moderately drought-resistant (Table 2).

Table 2. *Groups of drought resistance of varieties and rootstock combinations of peach*
Tabulka 2. *Skupiny suchovzdornosti odrůd a podnožových kombinací broskvoně*

Drought resistance	Hydration of leaves, %	Water deficit , %	Rootstock	Variety
Moderately drought-resistant	70,43 ± 0,65	11,71 ± 0,36	Krymsk® 1 Druzhba	Liubymets Ⅱ Knyazhegradskyi Knyazhe zoloto Redhaven
Drought-resistant	70,54 ± 0,50	9,67 ± 0,22	Pumiselect Krymsk® 86 Cherry-plum seedlings	Liubymets Ⅱ Knyazhegradskyi Knyazhe zoloto Redhaven Knyazhe bahatstvo
Highly drought-resistant	74,67 ± 2,55	7,33 ± 0,34	Apricot seedlings	Liubymets Ⅱ Knyazhegradskyi Knyazhe zoloto Redhaven Knyazhe bahatstvo

Data presented as mean ± SE.

The dynamics of water loss depending on the group of drought resistance showed that highly drought-resistant combinations were characterized by the highest water-holding capacity during the entire exposure (Graph 1). The curve depicting the dynamics of water loss in highly drought-resistant combinations even shows a decrease in water loss compared to other groups at the end of exposure.

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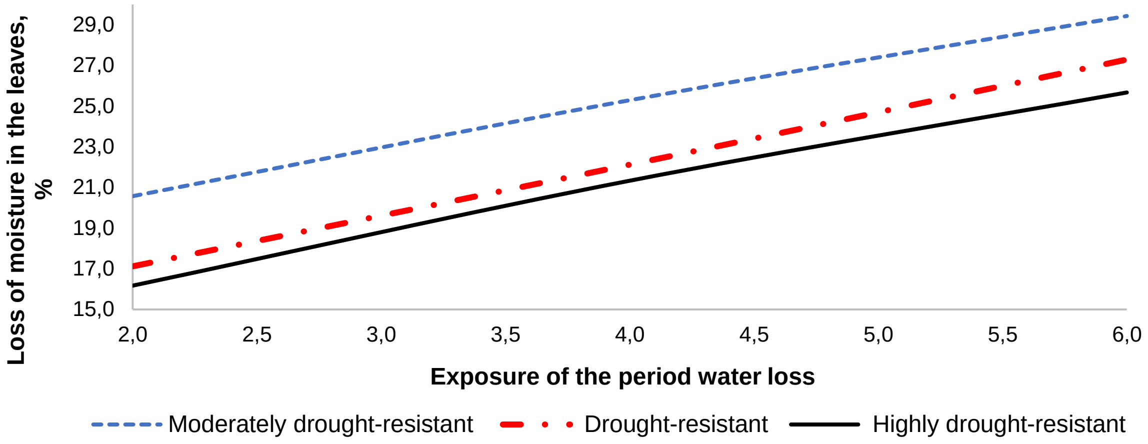
Graph 1. *The dynamics of water loss by peach leaves depending on the drought resistance of plants*
Graf 1. *Dynamika ztráty vody listy broskvoně v závislosti na odolnosti rostlin vůči suchu*



CONCLUSIONS

As a result of the laboratory experiment, the following peach scion-rootstock combinations can be distinguished according to resistance to moisture loss in the leaves: 'Knyazhe zoloto' grafted on cherry-plum seedlings and on Pumiselect; 'Redhaven' on seedling rootstocks; 'Knyazhe bahastvo' on Druzhba, seedlings, and Pumiselect; 'Knyazhegradskyi' on on cherry-plum seedlings and on Pumiselect; 'Liybymets Ⅱ' on Pumiselect, Krymsk® 1 rootstocks and apricot seedlings. It was determined that the level of drought resistance is high in all combinations.

'Liybymets Ⅱ', 'Knyazhe bahastvo' and 'Redhaven' cultivars are characterized by the lowest values of water deficit indicator, and among the rootstocks – cherry-plum, and apricot seedlings, as well as Pumiselect.

The highest hydration of leaf tissues was noted in the scion-rootstock combinations 'Liybymets Ⅱ' on Pumiselect (76%), 'Knyazhe bahastvo' and 'Knyazhe zoloto' on apricot seedlings (84–79%). The tissues of 'Redhaven' cultivar grafted on apricot seedlings are the least hydrated (66%). According to the set of determined indicators, Druzhba, Krymsk® 1 and Krymsk® 86 rootstocks are characterized by the lowest adaptivity to drought compared to other rootstocks.

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