Study of the adaptability of scion-rootstock combinations of plum tree to temperature stressors in the Krasnodar Territory

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Abstract. The relevance of the research is due to a change in the strength, frequency and direction of harmful weather stresses associated with climate change, which has an extremely negative effect on the general condition and productivity of plants, disrupts the conditions for the exit of plants from the dormant stage, while accelerating the rate of spring development. The rise of positive temperatures in the autumn period delays the entry of plants into the phase of organic dormancy, impairing their preparation forthe winter. This paper provides an assessment of the adaptive response of the optimal course of growth and development of scion-rootstock combinations (SRC), taking into account changes in environmental conditions. The complexity of interaction mechanisms in the "scion-rootstock-environment" system is presented. Analysis of variance has shown that quantitative traits have complex genetic systems, which are characterized by multivariance of the reaction associated with multilevel redefinition of the genetic organization of quantitative traits of the SRC when changing the environmental limits. The value of the work is in the fact that the selected objects are perennial fruit crops, which are an interacting complex of two genotypes. The best combinations of grafts and rootstocks in the studied varieties in the specific environmental conditions and with given growing technologies were identified: Stanley / PK SK 1, Stanley / Druzhba, Renklod Donetskiy-1 / Evrika 99, Renklod Donetskiy-1 / cherry plum, Milena / Evrika 99 The highest-yielding under the changed conditions, and hence the most adaptive, were the combinations of plum variety Stanley on the rootstocks of PK SK 1 and Druzhba.

1 Introduction

The stability of the production process in fruit crops largely depends on the influence of natural environmental factors, primarily climatic ones. The complexity of identifying the mechanisms of this interaction requires the study of the reaction of the integral system "scion-rootstock" both between plant components and between the influences of periodically arising

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climatic stresses on it. The same environmental factors have a different effect on scion-rootstock combinations of fruit trees, depending on their synchronicity with the phases of development and the degree of adaptation to the specific factor in all phenophases [1-6].

The study of the mutual influence of rootstocks and scions in fruit trees has been done practically all over the world. This is necessary to identify the most adapted adaptive SRC to specific environmental conditions and to increase the cultivation area of a number of crops and varieties, which is the basis for the creation of resource-saving technologies [7-12]. Such work is also important for conducting the advanced breeding taking into account the direction of climate change [13].

The relevance of the research is due to the increased harmfulness of the weather stresses on most varieties used in production, especially the stone fruit crops in the Krasnodar Territory. The peculiarities of changes in the temperature regime complicate the passage of the phenophases of the autumn-winter-spring period of fruit plants, which are of decisive importance for the optimal development and fruiting of plants. The increased temperature regime at the end of the autumn, which has become more frequent in recent years, has an extremely negative effect on the preparation of plants for the winter, prolonging it, which makes plants more vulnerable to even slight drops in temperature. For example, the weather stress such as the increase in temperature led to a tangible decrease in the yield of stone fruit crops in 2019, and in 2020 the harvest was observed only on single varieties of sweet cherry, cherry, plum, cherry plum, peach and apricot. Consequently, the most important task is to identify varieties and SRC of fruit crops, in particular plums, with maximum adaptability to stressors of abiotic nature in specific growing conditions.

2 Materials and methods

The research included plum varieties: Stanley, selection of the USA; Milena, Renklod Donetskiy -1, FGBSC NCFSCHVW on rootstocks: cherry-plum seedlings, VVA 1, VSV 1, Evrika 99, Alab 1, Druzhba of selection of the Crimean OSS; PC SK 1 of joint selection of FGBSC NCFSCHVW and Stavropol OSS in combinations: Milena / cherry plum, Milena / VVA 1, Milena / PC SK 1, Milena / Evrika 99; Renklod Donetsk-1 / Alab 1, Renklod Donetskiy -1 / cherry plum, Renklod Donetskiy -1 / VVA 1, Renklod Donetskiy -1 / VSV 1, Renklod Donetsk-1 / Evrika 99; Stanley / Alab 1, Stanley / cherry plum, Stanley / VVA 1, Stanley / Druzhba, Stanley / PK SK 1, Stanley / Evrika 99.

The meteorological database of 1950-2020 was used (meteorological station "Kruglik", Krasnodar). Daily temperature values were taken (absolute maximum, minimum, daily average).

The geographical location of the experiment is Plodovod CJSC (Krasnodar). Prikubanskaya fruit zone. Soil type - leached black soil, weak humus, powerful, light clayey on loess-like loam. Year of planting - 2006, planting scheme 5 × 2 m. Crown formation is fusiform, technology without irrigation.

The studies were carried out according to the standard methods "Program and methodology for the variety study of fruit, berry and nut crops", "Methodological and analytical support for research in horticulture", 2010. The structure of variability of the considered traits was studied using analysis of variance [14]. The agglomerative procedure of hierarchical cluster analysis according to Ward's method (English agglomerative, when the new clusters are created by combining smaller clusters) was used to group the studied AECs [15]. The calculations were performed using the statistical package StatSoft Statistica 10.0.

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3 Results and discussion

One of the ways to regulate the mechanisms of adaptation of fruit crops is to study the reactions of various rootstock-scion systems to environmental conditions in specific growing zones [16-18].

The result of the analysis of daily temperature indicators (average daily, maximum, minimum, the difference between the maximum and minimum temperatures, the sum of positive temperatures) over the years for the past 70 years, has proved that the increase in both the maximum temperatures and the sum of positive temperatures, especially in the spring and autumn periods, which , as a rule, has a negative effect on obtaining full yields in fruit (Fig. 1, 2, 3) [13, 19]. Studies have shown that in March, when flower buds are actively developing, the most significant increase in the sums of positive temperatures and their higher amplitude have been noted since 2002. In the autumn period, an increase in positive temperatures is especially noticeable since 2006, which can delay the entry of the plum SRC into the phase of organic dormancy, increasing the harmfulness of possible low temperatures during this period.

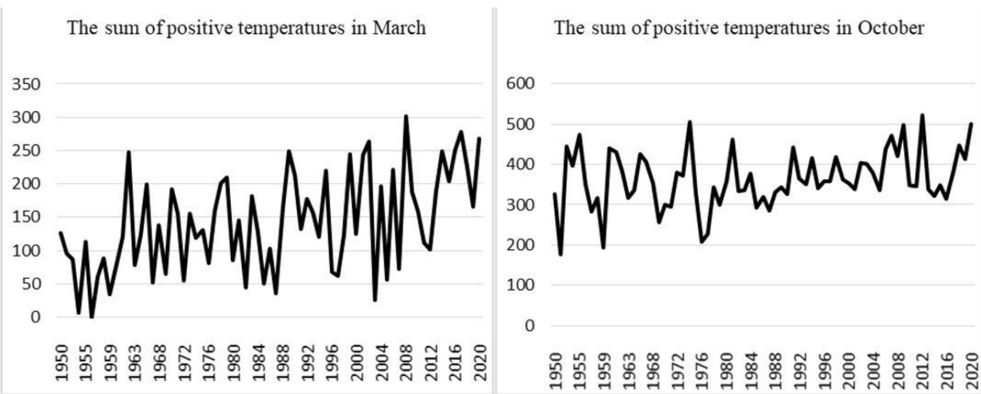


Fig. 1. The sum of positive temperatures (° C) for a long-term period (1950-2020) in the Prikubanskaya zone of horticulture (Krasnodar)

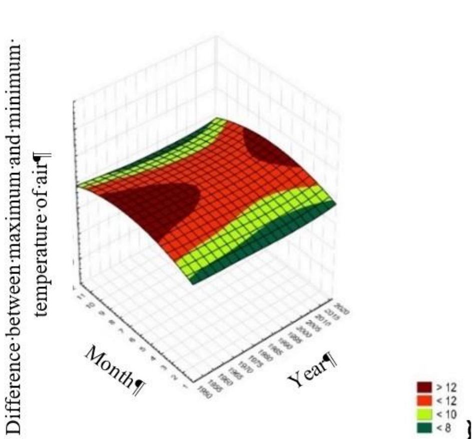


Fig. 2. Difference between daily maximum and minimum temperatures (° C) for the period 1950-2020. in the Prikubanskaya zone of horticulture

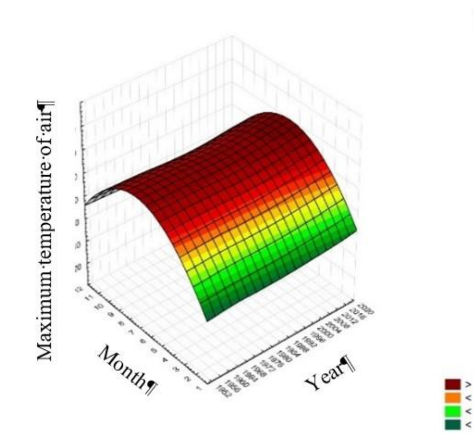


Fig. 3. Daily maximum air temperature (° C) for 1950-2020. in the Prikubanskaya zone of horticulture

In the studied conditions of plum growing, the influence of scions and rootstocks on the height, diameter of the stem and its yield is clearly visible as in a young two-year-old garden and in subsequent years (in the first period of full fruiting and at its end). This is clearly evidenced by the analysis of variance data for each year of research. The dispersion of traits was revealed, starting from 2007, in terms of the effect on the tree size of both scions and rootstocks up to 80%, from 2008 and on their yield for scions up to 77.9% and rootstocks up to 82.0% (Table 1, 2). In the presented tables on the influence of rootstocks on the studied signs of growth, the values of the proportions of dispersion are given in the period of active fruiting (2013), when growth stops. Even during this period, the variance values are significant (Tables 1, 2), although all trees were grown using the same technology (crown formation - fusiform, planting pattern 5x2). During the period of active growth in various combinations in plants kept in gardens of both extensive and intensive types, the dispersion of these indicators, as a rule, is always regularly high [20].

Table 1. Results of one-way analysis of variance on the effect of Stanley, Milena, Renklod Donetskiy-1 plum scions on the yield, height and diameter of the stem of two-year and perennial fruit trees grafted onto the stock of cherry plum seedlings (JSC Plodovod, planting scheme 5 × 2, planting 2006)

Variability	df	mS	F	G	%
Diameter 2008					
Scion influence	2	7,38	41,0**	0,64	77,9
Residual	31	0,18	–	0,18	22,1
Height 2008					
Scion influence	2	15498,20	41,0**	1334,18	77,9
Residual	31	377,54	–	377,54	22,1
Harvest 2008					
Scion influence	2	2,45	19,2**	0,20	61,2
Residual	31	0,13	–	0,13	38,8
Diameter 2013 г.					
Scion influence	2	43,38	15,4**	3,69	56,7
Residual	30	2,82	–	2,89	43,3
Height 2013г.					
Scion influence	2	14228,28	27,6**	1246,69	70,8
Residual	30	514,68	–	514,68	29,2
Harvest 2013 г.					
Scion influence	2	628,36	11,3**	52,10	48,5
Residual	30	55,28	–	55,28	51,5
Harvest 2020 г.					
Scion influence	2	1225,42	51,0**	109,22	82,0
Residual	30	23,98	–	23,98	18,0

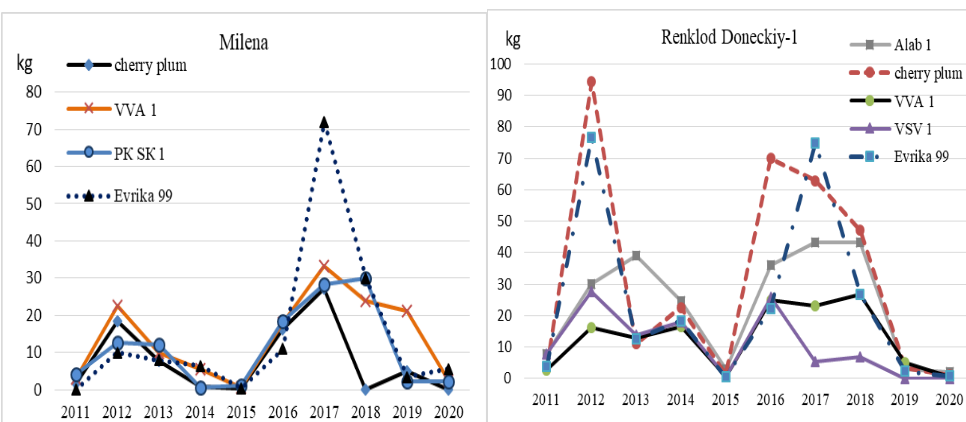
Note: Here and in similar tables it is indicated: * - the influence of the factor on the variability of the trait is reliable with a probability of 95%, ** - the influence of the factor on the variability of the trait is reliable with a probability of 99%.

A significant influence of rootstocks on the traits of grafted plants was observed practically in all years of research, but no general regularities were found over the years in fluctuations in the percentage of variance by cultivars, which indicates the complex mechanisms of interaction in the "rootstock-scion-environment" system and their different reactions to environmental factors (table 2).

Table 2. Contribution of the rootstock genotype to the structure of yield variability (2010–2020) and growth indicators by SRC, calculated using analysis of variance, varieties Milena on cherry plum stocks, VVA 1, PK SK 1, Evrika 99; varieties Renklod Donetskiy-1 on rootstocks Alab 1, cherry plum, VVA 1, VSV 1, Evrika 99; Stanley varieties on rootstocks Alab 1, cherry plum, VVA 1, Druzhba, PK SK 1, Evrika 99

Year of research	Yield											Diameter 2013	Height 2013
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
Stanley	62,9	49,3	81,6	45,4	18,6	91,3	72,7	63,4	72,0	14,2	82,2	51,7	72,7
Milena	0,0	69,8	0,0	0,0	40,4	64,8	30,0	68,4	90,4	31,2	0,0	32,2	0,0
Renklode Donetskiy -1	90,6	51,5	85,9	68,7	0,0	0,0	88,0	83,6	62,3	39,5	0,0	63,0	71,3

The dependence of the yield of plum varieties on rootstocks is clearly visible both in unfavorable (2010, 2015, 2019, 2020) and in the most favorable years (2012, 2016, 2017) for setting and forming a crop. Therefore, in favorable years for the Milena variety in 2017 on the PK SK 1 rootstock the yield is 1.7 times higher than on Evrika 99, in 2018 already on the Evrika 99 rootstock it is 2.5 times more than on the PK SK1 rootstock. The maximum yield for the variety Renklod Donetskiy-1 was obtained for the cherry plum rootstock in 2012 - 94.3 kg, for the Milena variety for the Evrika 99 rootstock - 72.1 kg in 2017, for the Stanley variety - in 2012, 2016, 2017 on the PK SK 1 rootstock - 82.5 kg, 98.3 kg and 90.6 kg, respectively (Fig. 4, 5).



LSD	2	6,6	2,3	3,6	0,4	3,9	25,2	16,8	10,4	2,7
LSD	2,6	36	12,5	3,6	1,1	20,9	30	17	1,9	0,8

Fig. 4. Fluctuations in the yield of SRC plums Milena and Renklod Donetskiy-1 in various combinations with rootstocks by years of research 2011-2020.

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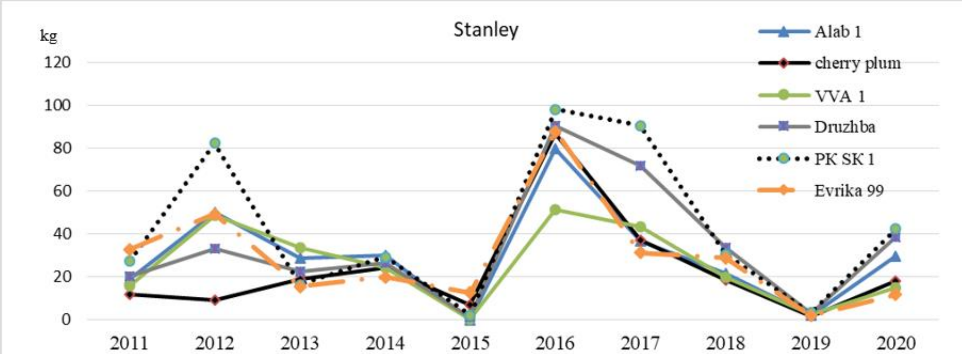

LSD	7,4	23,1	6,9	3,6	4,8	15,8	23	6,1	0,6	12,4

Fig. 5. Fluctuations in the yield of SRC of plum variety Stanley in various combinations with rootstocks by years of research 2011-2020.

The problem of identifying the best SRC of plums in terms of the yield, and hence adaptability to environmental conditions with specific cultivation technologies, associated with the complexity of interaction in the "variety - rootstock - environment" system, was solved using cluster analysis from the category of multidimensional. As a result, the best combinations for the studied varieties were identified, into the first cluster were included: Stanley / Druzhba; Stanley / PK SK1, Stanley / cherry plum, Stanley / Evrika 99, Stanley / Alab 1, Rd Donetskiy-1 / Evrika99, Renklod Donetskiy-1 / cherry plum (Fig. 6). Comparing the average, the highest yield was observed in the combination of Stanley variety on the PK SK 1 rootstock (Fig. 7).

The lowest yield was noted in combinations such as Milena variety for almost the entire study period, except for 2017, when the yield on Eureka 99 was 72.1 kg per tree. Perhaps this was due to the fact that intensive cultivation technology is not suitable for this variety.

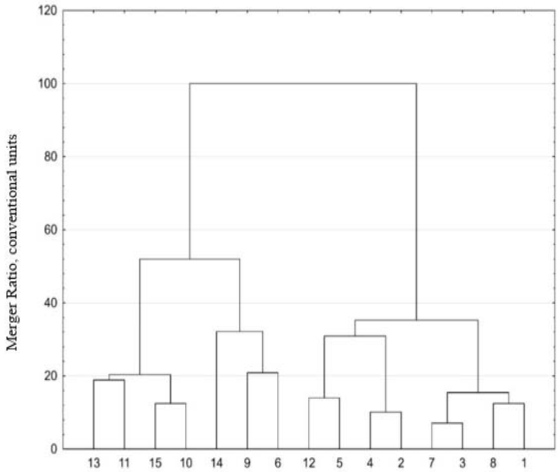

Fig. 6. Results of cluster analysis of the productivity of plum trees Stanley, Renklod Donetskiy 1, Milena on different rootstocks for a long-term period (2010-2020). Milena / cherry plum (1); Milena / VVA 1 (2); Milena / PK SK 1 (3); Milena/ Eureka 99 (4); Renklod Donetsk-1 / Alab 1 (5); Renklod Donetskiy-1 / cherry plum (6); Renklod Donetsk-1 / VVA 1 (7); Renklod Donetsk-1 / VSV 1 (8); Renklode Donetskiy-1 / Eureka 99 (9); Stanley / Alab 1 (10); Stanley / cherry plum (11); Stanley / VVA 1 (12); Stanley / Druzhba (13); Stanley / PK SK 1 (14), Stanley / Evrika 99 (15).

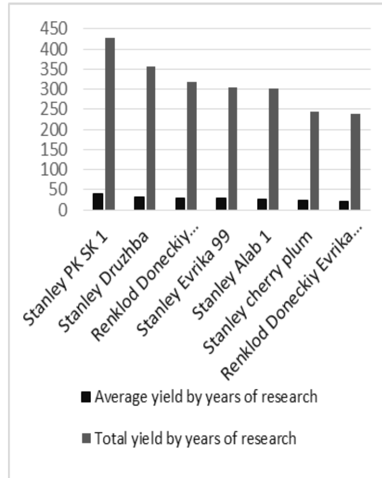

Fig. 7. Productivity of SRC trees in first cluster (2010-2020)

4 Conclusion

1. Continuous monitoring of temperature indicators (maximum temperatures, the difference between maximum and minimum, the sum of positive temperatures) over a long period (1950-2020) revealed a significant increase in air temperature in the Kuban zone of the Krasnodar Territory.

2. Under conditions of intensive garden, the genotype of the rootstocks has a significant influence on the characteristics of plant growth (height and diameter), including even the period of active fruiting.

3. The high variability of the yield in the combinations of plum SRC indicates the complex mechanisms of interaction in the «rootstock-scion-environment» system, to the disclosure of which the carried out works are approaching.

4. The best SRC of different varieties of plum tree are Stanley, Milena, Renklod Donetskiy-1 and the most adaptable to environmental conditions and, therefore, productive combinations of scions and rootstocks in the proposed cultivation technologies in the Prikubanskaya fruit zone - Stanley on the rootstocks of PK SK 1 and Druzhba.

5. The possibility of studying the mutual influence in the system "rootstock - scion - environmental conditions" is shown, which is very significant especially with climate change. However, this direction of study needs further development with the aim of both fundamental research on the disclosure of the mechanisms of mutual influence of grafted fruit plants in different environmental conditions and applied in the creation of databanks of genotypes' reactions to specific environmental conditions, which will help the selection of optimal

combinations of rootstocks and grafts to obtain maximum yields in specific zones cultivation of crops and expansion of areas for cultivation of domestic plum.

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