Influence of variety of soil-ground conditions of sandy soils (by the example of the Ust-Donetsk sandy massif) on the quality of the grape vine

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Abstract. The paper reveals the influence exerted on the development of post vitro grape mother plants and various microzones found on the Ust-Donetsk sand massif. The differences in the microzones were in the fertility level and a number of soil properties. The considerable influence provided by the growing conditions not only on the development of plants but also on the survival rate and life expectancy of mother bushes observed during the use of mother plants for 17 years has been noted. To ensure effective land management, a detailed site study and, depending on the differences identified, the use of precision farming techniques is required before laying out the parent plants. The reason for this is that sandy soils, in general, have a high degree of heterogeneity due to physical and chemical characteristics such as flowability, susceptibility to wind transport, low organic substance content, and cation exchange capacity.

1 Introduction

During the preparation of improved planting material of grapes in in vitro culture, one of the most crucial stages is the adaptation of test tube plants to non-sterile conditions, the completion of growing them before field setting and the laying out of the parent plants. Methods for obtaining improved planting material using extremely small apical meristems (up to 0.1 mm), regeneration of plants from them, micropropagation, adaptation of improved plants to non-sterile conditions, and methods for their completion of growth have been developed in the biotechnology laboratory at FSBSI « FCTRBS-ARRVI » [1-3]. Meanwhile, a significant economic effect is observed when using the original planting material grown in an improved collection in vitro for laying out the mother plants [4]. To lay out the basic mother plants with an improved planting material, it is reasonable to use sandy massifs [5]. The main factor defining the prospect of using such soils is as follows: with a high content of sand particles in such soils, they are usually not affected by the phylloxera, a malicious pest of the vine. Therefore, improved in vitro plants can be planted with own-rooted vegetative seedlings post vitro. Additionally, the positive aspects of using sandy soils emphasize the development of the root system of grapes to a greater depth and the longevity

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of the bushes. Also, deep warming and aeration of the sands promote an earlier completion of the physiological processes of the vine and a better accumulation of macronutrients in the shoots. Sandy soils may have a large depth of humus-accumulative horizon. Meanwhile, they contain less humus than the zonal soils. The only exceptions are primitive soils, the humus horizon of which has been partially or completely ruined [6, 7]. Due to precipitation washing, there are usually fewer basic nutrients in them than in fixed- sandy soils [8]. The lands classified as "sandy" occupy about 31% of the total area of the entire world's land. The soils of sandy massifs differ considerably from fixed- sandy soils. Meanwhile, the issues arising in the study of sands can be divided into three groups: physical and hydrological; chemical and agronomic; and biological and environmental problems [6].

It is sandy soils that are most susceptible to ruination in conditions of intense agricultural activity. Thus, the most crucial task in studying them is to develop measures contributing to the protection and preservation of their natural potential. For this, it is necessary to understand the changes occurring during the operation of sand massifs: compaction of soil horizons, salinization, leaching, blowing, loss of natural biodiversity, etc. One of the most significant features of sandy soils is that these soils are highly susceptible to deflation. Due to the impact of deflation and human economic activity, specific soil-grounded conditions are formed on sandy massifs. They have a large soil diversity [9, 10]. Edaphic conditions may differ significantly from each other within the soil body. It is essential to take this diversity into consideration both in the development of new territories and in the operation of existing agricultural lands. Thus, the lands of soil massifs of interest for development require type assignment – the identification of agro-ecological groups followed by the preparation of technological maps for their development. Moreover, it is believed that sandy alluvial soils are the most difficult to detect and classify [11]. In recent years, Russia has renewed interest in research aimed at the typification and classification of sand massifs. The soil cover of the Archedin-Don sand massif of the Volgograd region has been investigated and typified [7]. Ecological and geographical analysis as well as typification of sandy soils of the semidesert zone of the North Chechen lowland were performed [12]. In relation to the cultivation of mother plantings of grapes, typification was designed and zoning of the Ust-Donetsk sandy massif was conducted. [13, 14].

All researchers, as a rule, when typing, distinguish the diversity and heterogeneity of sand massifs (associated with the peculiarities of their formation) by economic properties. Based on previous studies on the typification of existing conditions for the basic mother plant, the objective of our study was to establish the development features of mother bushes on different types of soil conditions.

2 Materials and methods

Studies and observations for the basic mother plant have been performed since 2004 in the conditions of the Nizhnekundryuchensk branch of the experimental field, currently part of the Research Equipment Sharing Center "The Don Ampelographic Collection named after Ya.I. Potapenko". The site is located on the territory of the Donetsk-Kundryuchensky sand massif, which covers an area of about 15 thousand hectares between the Kundryuchya and Donets rivers (near its mouth). The topography of the massif is flat, sometimes undulated in nature. The depth of groundwater in the area allocated for the mother plant is about 1.8-2.0 m, which is a favorable factor for grapes on sandy soils [16, 17]. The annual rainfall is 507 mm [5]. The number of active temperatures (>10^0C) is 3200^{0}C. The duration of the period with an average daily temperature of >10^0C is between 170 and 175 days [18]. During the research, the methods generally adopted in vine growing were used: 1) to trial establishment [19, 20]; 2) in carrying out agrobiological records and observations; 3) and to determine the biological productivity of bushes [21, 22]. The laying out and keeping of mother plants was

performed according to the guidelines of A.G. Mishurenko [23], V.A. Ursu [24], and L.M. Maltabar [25]. Containment measures were taken in accordance with the recommendations of A.I. Talash [26] and V.F. Burdinskaya [27]. The cultivating head-trained bushes are for covered grape cultures, and the palmet pruning is for open-earth ones. Statistical data analysis for morphometric parameters of plant development was performed on Excel 2013 software; the Wilson E.B. technique described by Grzybowski A.M. [28] was used to analyze data on the survival rate of plants from mother plants; the confidence interval was calculated with 95% accuracy.

The type assignment of the soil conditions of the Ust-Donetsk sandy massif involves the division of all encountered soil conditions into five types (Table 1).

Table 1. The main physical and chemical characteristics of various types of soil-ground conditions for the growth of mother plants

Type of conditions	Hydrophysical constants				Humus, %	Nitrate nitrogen, mg/kg	Phosphorus, mg/kg	Potassium, mg/kg
	Maximum hygroscopic moisture, %		Minimum moisture-holding capacity, %					
	Depth of the soil layer, cm							
	0-100	100-200	0-100	100-200				
1	3.0	3.0	8.5	10.1	2.1	3.5	26.5	180.0
2	3.1	3.2	8.4	7.3	1.6	4.0	20.0	110.0
3	1.5	2.0	6.8	6.8	0.5	2.4	17.5	65.0
4	1.2	1.6	5.8	5.7	0.4	1.1	20.0	40.0
5	0.9	1.1	4.9	4.8	0.28	0.6	16.5	32.0

Type 1, due to its complex granulometric composition, has good hydrophysical properties, accumulating a large amount of moisture and easily giving it to plants. Type 2 is close to type 1 in terms of water-retaining properties, nitrogen and phosphorus content. However, it is significantly lower in terms of humus and potassium content (by 20 and 40%, respectively). Type 3 contains a much smaller percentage of physical clay particles. This significantly worsens its hydrophysical properties by 2 times compared to type 1 and type 2. The content of nitrogen and phosphorus was lower than in types 1 and 2 and amounted to about 30 %. The greatest difference was in the content of humus (four times) and potassium (three times) compared to the conditions attributed to type 1. The type 4 conditions in terms of hydrophysical properties, compared with the type 3, were significantly worse, being close to the type 3 properties in terms of phosphorus content. The nitrogen content compared to type 1 was three times lower, and with type 3 it was two times lower. The humus content was 20% and potassium 40% lower compared to the type 3. Type 5 had the lowest indicators in terms of the content of both nutrients and clay particles [13, 14].

3 Results and discussions

The conducted studies of soil conditions found on the Ust-Donetsk sand massif promoted the outline of contours of microzones that differ in qualitative criteria. The objective of our research, as mentioned above, was to study the influence of isolated microzones with different types of soil-ground conditions on the morphogenesis features of improved plants. In the course of the study, we have summarized data on the preservation (survival) of mother bushes in various grape varieties with a long growing time on several types. In our case, the age of the studied plantings was 17 years. During the experiment, varieties from different

ecological and geographical groups were observed. No more than 500 of them were planted on the basic mother plant. The obtained findings are shown in Figure 1.

As can be seen from the presented data, the type of soil-ground conditions and varietal specificity have a considerable impact on the preservation of bushes of improved grape plants in the conditions of growing in a sandy massif. The best safety indexes for all varieties were when growing under type 1 and type 2 conditions. On type 3, significantly fewer plants of the Krasnostop Zolotovsky variety were preserved, and the Cabernet northern and Tsimlyansky black varieties had approximately the same safety index as the RR 101-14 rootstock variety. On type 4, the persistence of these varieties was noticeably lower (about 40%) than that of the RR 101-14 variety (about 65%), but markedly higher than that of the Krasnostop Zolotovsky variety (about 15%). On spots with type 5 soil conditions, plants, as a rule, when growing (about 5 years), extinguished completely; the only exception was the RR 101-14 rootstock variety. Its survival rate in such areas was about 20%.

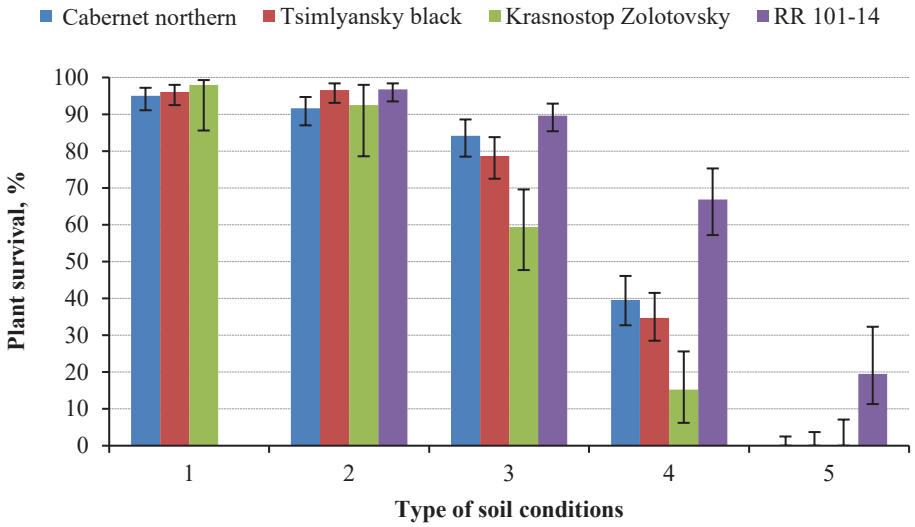

Fig. 1. The safety index of grape bushes depends on the types of soil-ground conditions after 17 years of growing on a basic mother plant, 2005-2022.

Moreover, the safety indexes of the mother bushes are highly correlated with the indicators of plant development. The data on the development of mother bushes on various types of soil conditions by variety are shown in Table 2-6.

The highest development rates of all varieties in the study were in RR 101-14 varieties (Table 2). The first type of soil conditions was not found on the site of the mother rootstock, where this variety is located. Thus, the development of plants in this variety of type 1 is not reflected in our study. Nevertheless, it should be noted that in RR 101-14 varieties, bush development indicators in type 2 and type 3 were at the same level or even higher than those in varieties that grew in type 1 soil conditions.

Table 2. Agrobiological indicators of the RR 101-14 rootstock grape variety on various types of soil-ground conditions, 2019 –2021.

Type of conditions	Development of shoots			Ripening of shoots		Number of leaves, pcs.	Area, cm^2	
	number, pcs.	d, mm	length, cm	cm	%		of a single leaf	leaves per shoot
2	12.7	6.6 ±0.4	383.3 ±50.0	183.3 ±10.8	50.6 ±9.4	45.7 ±5.3	96.7 ±6.7	4502.3 ±356.0
3	8.3	6.0 ±0.3	248.3 ±40.3	133.3 ±24.6	53.1 ±1.5	34.7 ±3.4	81.4 ±9.2	2869.7 ±342.5
4	3.0	4.0 ±0.2	65.0 ±20.3	40.0 ±9.5	61.5 ±2.8	21.0 ±9.2	39.7 ±5.4	833.7 ±220.3
5	2.0	3.3 ±0.2	42.4 ±5.0	21.7 ±1.5	56.3 ±4.5	15.3 ±0.6	33.5 ±7.0	536.0 ±112.4

The following feature was also mentioned. The development of shoots on the type 4 soil conditions in the rootstock variety was significantly lower than the development of other varieties in the study, except for the Krasnostop Zolotovsky variety (Table 6.). The latter practically does not take root in the type 4 conditions. Our study includes the parameters of plant development of one more rootstock variety, called Kober 5 BB (Table 3).

Table 3. Agrobiological indicators of the Kober 5BB rootstock grape variety on various types of soil-ground conditions, 2019 –2021.

Type	Development of shoots			Ripening of shoots		Number of leaves, pcs.	Area, cm^2	
	number, pcs.	d, mm	length, cm	cm	%		of a single leaf	leaves per shoot
2	6.3	6.2 ±0.4	492.5 ±78.6	185.0 ±55.1	39.6 ±8.5	51.7 ±6.9	133.7 ±14.0	7087.7±825.3
3	5.7	5.4 ±0.2	216.4 ±40.2	122.9 ±22.0	61.4 ±2.5	29.7 ±3.0	83.7 ±12.7	2514.0±417.8
4	4.5	4.5 ±0.3	183.3 ±12.7	125.8 ±16.2	62.5 ±2.4	28.5 ±3.1	81.3 ±10.7	2308.1±299.8
5	-	-	-	-	-	-	-	-

The development peculiarity of this variety on a sandy massif was that the diameter of its shoots depended greatly on the load of shoots on the bush. Thus, the number of shoots on the bush in this variety was one of the lowest. Notwithstanding the longest shoots received by us in the study on this variety on type 2 soil (up to 7 meters), their the maturity rate when growing in such conditions was the lowest.

In our study, the largest area of a single leaf was in the Cabernet Northern variety (Table 4). This variety in all variants of the experiment demonstrated optimal development parameters in comparison with other varieties. Even on type 4, the indicators of the cuttings obtained were close to the standard values, though in a markedly smaller amount. It should be mentioned that the indicator of the leaf area per shoot most reflected the impact of growing conditions on the development of plants. The area of a single leaf did not always reflect proportionally the influence of the type of soil conditions on the development of plants as a whole. As a rule, on types 1, 2 of soil conditions, and for the Krasnostop Zolotovsky variety and on type 3, it changed insignificantly. A marked decrease in the area of a single leaf was observed consistently only on type 4 of sandy soils.

Table 4. Agrobiological indicators of the Cabernet northern rootstock grape variety on various types of soil-ground conditions, 2019-2021.

Type	Development of shoots			Ripening of shoots		Number of leaves, pcs.	Area, cm^2	
	number, pcs.	d, mm	length, cm	cm	%		of a single leaf	leaves per shoot
1	11.4	6.3 ±0.5	217.5 ±5.0	173.8 ±7.8	79.9 ±3.4	34.7 ±3.0	150.3 ±18.8	5168.2 ±651.9
2	9.8	6.5 ±0.6	222.0 ±34.8	188.0 ±37.8	83.1 ±4.0	32.5 ±2.8	141.0 ±17.8	4106.6 ±528.7
3	6.6	5.8 ±0.4	138.6 ±34.2	106.4 ±26.7	76.8 ±2.3	27.4 ±4.5	91.8 ±9.3	2767.4 ±423.9
4	4.6	4.8 ±0.4	121.4 ±20.6	92.9 ±18.4	74.8 ±3.9	24.0 ±3.5	80.2 ±5.3	2023.4 ±172.1

In the native Don variety Tsimlyansky black (Table 5), the best and stable development characteristics for growth options were found among all grafted varieties growing on the mother plant (35 post vitro varieties). It is essential to note the optimal parameters of such key development indicators as the diameter of the shoots, and the length and the percentage of ripening of the shoots. The diameter of the shoots preserved acceptable parameters, including on the fourth poorest type of conditions.

Table 5. Agrobiological indicators of the Tsimlyansky black rootstock grape variety on various types of soil-ground conditions, 2019–2021.

Type	Development of shoots			Ripening of shoots		Number of leaves, pcs.	Area, cm^2	
	number, pcs.	d, mm	length, cm	cm	%		of a single leaf	leaves per shoot
1	15.3	8.1 ±0.7	358.8 ±41.0	288.8 ±4.4	83.1 ±8.4	44.3 ±4.5	147.6 ±17.9	6671.1 ±866.8
2	13.0	7.3 ±0.9	244.4 ±21.1	193.1 ±9.5	78.6 ±2.5	34.5 ±0.5	108.6 ±10.0	3753.8 ±344.3
3	9.0	6.3 ±0.7	172.5 ±12.5	153.8 ±8.1	89.5 ±2.6	28.3 ±2.6	95.6 ±12.6	2757.2 ±391.1
4	5.3	5.2 ±0.4	112.0 ±10.9	82.5 ±8.8	72.8 ±2.6	22.7 ±2.6	56.5 ±10.2	1311.9 ±284.1

The Krasnostop Zolotovsky variety (Table 6), demonstrated the greatest demands on the type of sandy soil. Its development indicators across all variants were the lowest. This probably stems from the fact that, according to the classification, this variety belongs to low-growing varieties. The growth of shoots and maturation of the bush of this variety has already been two times worse on the second soil type than on the first. As for the third type, the development, as a rule, was already weak. According to our studies, Krasnostop Zolotovsky, turned out to be sensitive to the application of compound fertilizers (CF). The fertilizer included the main macro- N_{20}, P_8, K_{30} Mg_5 S_5 and micronutrients Mn1,0; $Zn_{0,5}$; $B_{0,5}$; $Mo_{0,1}$, created by us specifically for grapes, considering the analysis of soil data. We thought that would be a good place to test the application of root fertilizing on the third type of soil condition, having an average level of nutrients. A hole borer was applied to a depth in the range of 40-50 cm. About 80-100 grams of fertilizer was applied to a single plant. The culture feeding was applied once every three years; there were 50 plants per variant in the experiment. The effect of using a complex fertilizer on this soil type was very visible and

exceeded the control option by more than two times in most indicators based on the bush. Meanwhile, most of the indicators were at the level of plants that grew on the first soil type.

Table 6. Agrobiological indicators of the Krasnostop Zolotovsky rootstock grape variety on various types of soil-ground conditions, 2019–2021.

Type	Development of shoots			Ripening of shoots		Number of leaves, pcs. numbe, pcs.	Area, cm^2	
	numbe r, pcs.	d, mm	length, cm	cm	%		d, mm	length, cm
1	7.0	6.0 ±0.3	158.8 ±11.4	132.5 ±10.2	83.5 ±2.2	28.9 ±1.9	61.8 ±5.4	1821.7 ±168.0
2	3.5	5.6 ±0.6	130.0 ±23.8	108.0 ±20.9	82.3 ±5.4	22.5 ±3.4	74.3 ±9.8	1506.4 ±225.2
3	3.0	4.6 ±0.4	95.7 ±4.1	72.1 ±5.6	74.3 ±4.5	24.3 ±2.0	58.8 ±7.1	1430.7 ±182.7
4	2.2	3.9 ±0.5	55.7 ±4.1	42.1 ±5.6	75.3 ±4.1	22.5 ±2.0	54.5 ±6.7	1226.4 ±163.3
3 + CF	5.6	5.9 ±0.3	177.9 ±0.3	155.0 ±17.2	84.4 ±1.8	33.8 ±3.8	81.2 ±7.2	2788.6 ±312.0

According to the presented data, the better the soil conditions, the more optimal development parameters are formed in the mother bushes, which directly influences the quantity and quality of the cuttings obtained. Similarly, it is essential to note the varietal specificity, which is manifested in varying degrees of adaptability of varieties to unfavorable conditions of sandy soils. We have observed the best indicators of development in the RR 101-14 rootstock variety; the weakest were those of the native Krasnostop Zolotovsky variety. Moreover, it is essential to note the appropriateness of the use of complex mineral fertilizers, the efficiency of which was studied on the third type of soil conditions.

4 Conclusion

The long-growing basic plants on the mother plant in the conditions of a sandy massif largely depend on the soil-ground conditions of a particular site (microzone). In the conditions related to the first and second types, the preservation of mother plants after 15-17 years of growth was high. It averaged 95%. On the third type of conditions, it declined to 80%, and fell sharply on the fourth type to 30% or below, depending on the variety. The plant extinctions in all the observed varieties (except 101-14) were 100% in the fifth type of conditions. The growth of plants in the first and second types was the best. The quantitative and qualitative indicators of the harvested vine were optimal. It is possible to obtain high-quality planting material of the third type, but in significantly smaller quantities. It is impractical to cultivate mother plants of the fourth type without regular fertilization.

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