Formation of adaptive responses of grapes to the action of abiotic stressors of the winter period

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Abstract. The purpose of this work is to study the formation of adaptive reactions of grapes to the action of stressors of the winter period, by physiological and biochemical parameters, to identify varieties that have increased adaptive abilities for use in breeding. Objects of research are grape varieties of different origins: Kristall (control), Dostoynyi, Krasnostop AZOS, Vostorg, Aligote, Zarif. It was revealed that the increased resistance to winter stress conditions in the varieties Kristall, Dostoyny is achieved by a decrease in the water content of the buds by 9.09-10.40 %. In the varieties Vostorg, Dostoyny, Krasnostop AZOS adaptive resistance is achieved by increasing the starch content in the tissues of the shoots by 2.81-5.50 times in the pre-winter period. In varieties Krasnostop AZOS, Vostorg an important contribution to the formation of adaptive processes was made by water-soluble sugars, the content of which increased 2.82 and 2.89 times as a result of starch hydrolysis. An increase in the activity of peroxidase (2.49-2.75 times) indicated the instability of varieties Zarif, Aligote. Varieties Vostorg, Dostoynyi, Krasnostop AZOS have increased adaptive abilities in comparison with other studied varieties and are recommended for use in the breeding process.

1 Introduction

In recent decades, in many regions of grape cultivation, there has been a decrease in its resistance to the action of abiotic stressors in a changing climate [1, 2]. Resistance to low temperatures is an important component of the adaptive potential of the regional grape variety. In this regard, the study of the formation of adaptive reactions of grapes to the action of stressors of the winter period, the identification of the most stable genotypes for optimization of selection work in viticulture are relevant.

Physiological and biochemical processes occurring in the tissues of the vine during hardening, during preparation for winter, are accompanied by the accumulation of substances with cryoprotective properties that increase the adaptive mechanisms of cell defense to low temperatures. The metabolic rearrangement involves carbohydrates, proteins, phenolic

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compounds, amino acids, enzymes, which to a large extent ensure the winter hardiness of the grape plant [3-15].

It was revealed that the resistance of grapes to winter low temperatures correlates with the degree of maturation of tissues, their lignification and water content by the beginning of winter [16]. Winter hardiness of grapes is largely determined by the dynamics of the starch content in the shoots and buds, which is hydrolyzed during the winter to sugars. It was found that sugars have well-pronounced protective properties and increase plant resistance to low negative temperatures [5, 9-11].

Numerous studies have shown that under the influence of low temperatures the accumulation of the amino acid proline is noted in fruit plants and grapes, which performs the function of an osmoprotector during adaptation while maintaining the functional integrity of cell membranes [8, 11-14]. In grape varieties unstable to low temperatures, the activity of antioxidant enzymes, in particular peroxidase, is higher. It was found that an increase in peroxidase activity in winter indicates a stress response associated with impaired respiration. In unstable grape varieties, peroxidase activity increases after exposure to stress temperatures and performs a protective function in neutralizing high levels of peroxide compounds [15].

Recently, great progress has been made in studying the grape genome, in identifying genes that are activated at low temperatures, and also in the detection of stress proteins associated with resistance to hypothermia [17, 18].

Therefore, all of the listed indicators are reliable criteria for the adaptation assessment of grapes to stressful conditions of the winter period. The purpose of this work is to study the formation of adaptive reactions of grapes to the action of stressors of the winter period, to identify varieties that have increased adaptive abilities for use in breeding.

2 Materials and methods

The research was carried out on the basis of the ampelographic collection of the FSBSI AZESV&W, located in the Anapa, Krasnodar region, a quarter of technical varieties of grapes on the southern carbonate chernozem. Plants of 1995 planting, rootstock is Kober 5BB. Formation – double-sided high-stem spiral cordon AZOS. Planting scheme is 3x2.5 m.

The objects of research were grape varieties of various ecological and geographical origin: interspecific hybrids of European-American origin Dostoynyi, Krasnostop AZOS, Vostorg, Western European origin variety – Aligote, Eastern European origin variety – Zarif. Control is frost-resistant variety Kristall - an interspecific hybrid of Euro-Amuro-American origin. The tissue water content was determined by the gravimetric method and was expressed as % of the wet weight. The content of starch, soluble sugars, proline, and peroxidase activity were determined by the method used by Kaya [15]. All studies were carried out on the instrumentation of the Center of Collective Using of Technological Equipment in the following areas: genomic and post-genomic technologies, physiological, biochemical and microbiological studies; soil, agrochemical and ecotoxicological research; food safety.

3 Results and discussion

In the autumn, during hardening under the influence of phytohormones, growth processes are inhibited, the process of maturation of the tissues of the vine begins. By the beginning of the winter period, a multilayer periderm is formed, which performs the function of protection, and the water content of shoots and buds decreases. This indicator is a reliable criterion for evaluating a variety for winter hardiness.

In our studies in November, differences in the water content of the buds (total water content) of various grape varieties were revealed. By November, the water content of the buds was 50.04-54.05 %, depending on the variety. In January, during the period of the greatest frost resistance, the water content of the buds decreased in comparison with November and amounted to 43.46-46.99 %. It decreased to the greatest extent in the Kristall and Dostoynyi varieties – by 9.09 and 10.4 %, respectively, which correlates with the increased resistance of these varieties to cold (Fig. 1).

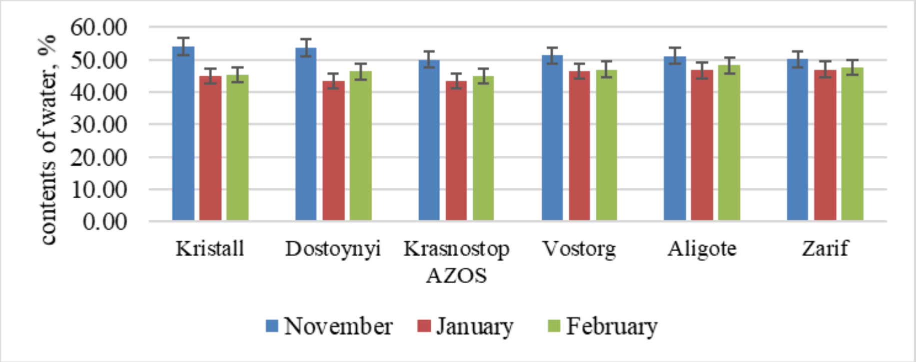

Fig. 1. Content of water of grape buds in the autumn-winter period 2018-2021 (average values). LSD $_{0.5}$: November – 1.47; January – 2.41; February – 1.27

At the end of February, the total water content in dormant buds slightly increased due to their release from physiological dormancy and amounted to 45.01-48.23 %, depending on the variety. The most significant increase in the water content of the buds was observed in Dostoynyi and Aligote varieties – by 2.95 and 1.55 %, respectively, indicating a rapid loss of their winter hardiness and emergence from dormancy.

Starch accumulated during the fall is the main reserve metabolite, contributing to the formation of the winter-hardy state of plants. The starch content in November was 3.52-7.91 mg/g dry weight, depending on the variety. Due to hydrolysis in sugar, its content decreased in January in comparison with November for all varieties. Most of all, the starch content decreased 5.5 times in the Vostorg variety, in the Dostoynyi and Krasnostop AZOS varieties it decreased 3.76 and 2.81 times, respectively (Fig. 2).

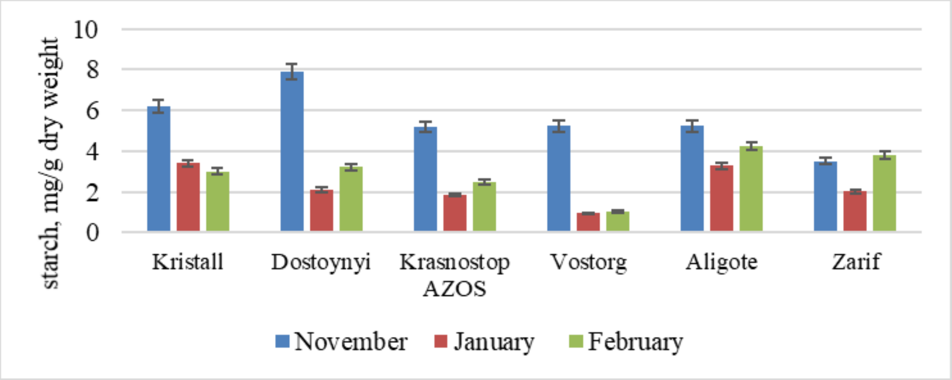

Fig. 2. Dynamics of starch content in grape shoots in the autumn-winter period 2018-2021 (average values). LSD $_{0.5}$: November – 1.56; January – 3.51; February – 2.12.

Consequently, in the varieties Vostorg, Dostoynyi, Krasnostop AZOS, starch made an important contribution to the formation of winter hardiness. In February, the starch content increased to varying degrees due to the end of physiological dormancy, except for the Kristall variety, which was still in deep winter dormancy.

Soluble sugars formed as a result of intensive hydrolysis of starch are osmotically active compounds that weaken processes of protein denaturation at low temperatures and stabilize the structure of the cytoplasm.

In our studies, the sugar content increased from November to January, and began to decrease in February. Thus, in November, the content of water-soluble sugars increased to the greatest extent in the varieties Krasnostop AZOS and Vostorg – by 2.82 and 2.89 times, indicating their important contribution to the protective function. In the rest of the studied varieties, it increased 1.6-2.3 times (Fig. 3).

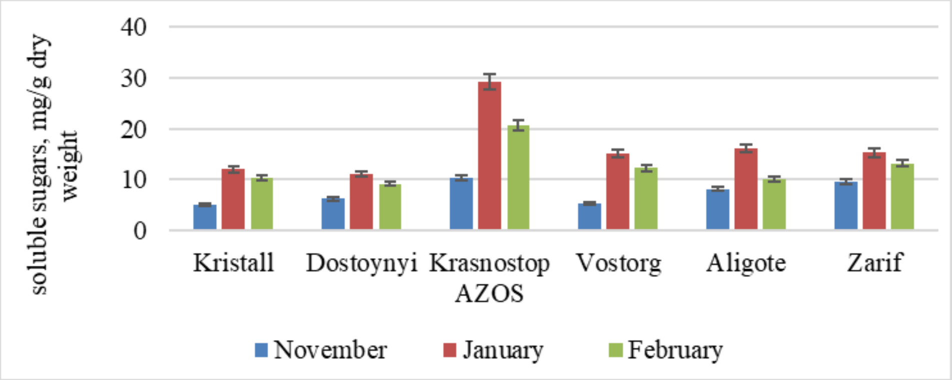

Fig. 3. Dynamics of the content of soluble sugars in grape buds in the autumn-winter period 2018-2021 (average values). LSD $_{0.5}$: November - 2.12; January - 2.51; February - 1.46.

In February, the content of water-soluble sugars decreased in all varieties by 1.15-1.57 times, depending on the variety. So, in January, sugars showed the maximum effect in the protective function and, along with starch, played a significant role in adaptive processes.

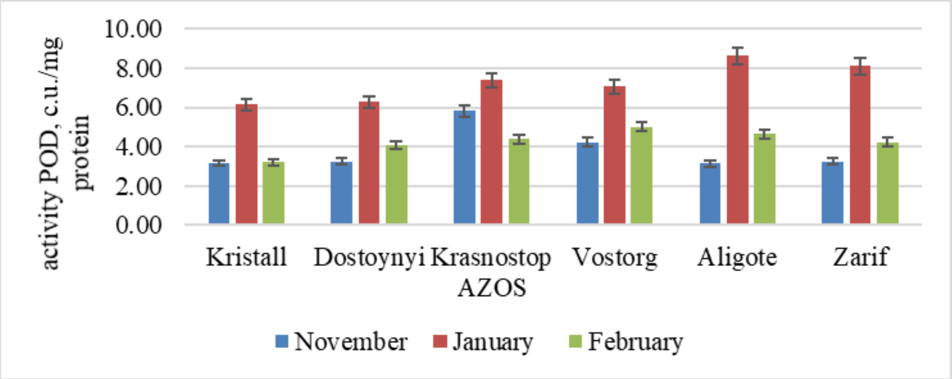

Fig. 4. Dynamics of peroxidase activity in apple buds in the autumn-winter period of 2018-2021 (average values). LSD $_{0.5}$: November - 2.72; January - 1.64; February –5.33.

Enzymes, in particular peroxidase (POD), play a significant role in adaptive processes. The functions of peroxidase are associated with its compensatory effect on the level of reactive oxygen species that arise under stressful conditions, including at low temperatures.

According to the results of the studies carried out, it was shown that the peroxidase activity increased in January, and to a greater extent in the varieties Zarif, Aligote (2.75 and 2.49 times, respectively), indicating their instability. In the rest of the studied varieties, the peroxidase activity increased by 1.26-1.94 times (Fig. 4).

4. Conclusion

Studies have shown that increased resistance to winter stresses in the Kristall and Dostoynyi varieties is achieved by a decrease in the water content of the buds. In the varieties, Dostoynyi, Krasnostop AZOS an increase in the starch content in the shoots by 2.81-5.50 times. In varieties Krasnostop AZOS and Vostorg, an important contribution to the formation of adaptive processes was made by soluble sugars formed as a result of starch hydrolysis. An increase in the activity of peroxidase (2.49-2.75 times) in response to low temperatures indicated the instability of varieties, Aligote. It was revealed that the varieties Vostorg, Dostoynyi, Krasnostop AZOS, according to the specified parameters, have increased adaptive abilities in comparison with other studied varieties and are recommended for use in breeding.

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