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Dynamics of carbohydrates in woody elements of the vine

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Abstract: *The anatomo-morphological structure of the grapevine trunk becomes increasingly complex from year to year: the aerial part and the root system increase in size, the anatomical structure of the woody organs is modified through the formation of new tissues, and generative organs appear. The morpho-physiological, anatomical, and structural changes occurring during the life of the plant are determined by the accumulation of carbohydrates and the synthesis of florigenic hormones, biochemical compounds that induce the differentiation of fruiting buds and the initiation of the fruiting process.*

The aging of the grapevine is a continuous process; however, it occurs simultaneously with the annual renewal of vegetative organs, which ensures a state of biological balance. This balance is maintained as long as the root system supplies the aerial part of the vine with the elements necessary for growth and fruiting.

The gradual and irreversible weakening of the root system, associated with the reduction in the proportion of active roots and their increasing distance from the underground stem, disrupts this biological balance, leading to progressively reduced annual growth. The decline in production potential and the reduction of vegetative growth mark the approach of the grapevine to the final stage of its ontogenetic cycle text.

Introduction

Non-structural carbohydrates, especially starch and soluble sugars, constitute the main energy reserves of the grapevine during periods when photosynthetic activity is reduced or absent. These reserves play an essential role in ensuring the survival of the plant during vegetative dormancy and in supporting the resumption of growth processes at the beginning of the growing season.

During the autumn, after the cessation of active growth, the vine accumulates carbohydrate reserves in various organs of the plant, especially in the woody tissues of the strings and in the multi-year wood. These reserve substances are later mobilized in the spring, when the energy requirements of the developing buds increase significantly.

Numerous studies have shown that the distribution and dynamics of carbohydrate reserves are influenced by a number of factors, including climatic conditions, position on the vine and the physiological state of the plant. Under low temperature conditions, soluble sugars may play an important role in frost protection, contributing to the stabilization of cell membranes and the maintenance of osmotic balance.

The purpose of this work is to analyze the dynamics of glucose reserves in the woody elements of the grapevine during the autumn and spring periods, prior to the start of vegetation, as well as to evaluate the relationship between these reserves and the metabolic activity of the buds.

Material and method

Plant material and sampling:

The research was carried out on vine ropes belonging to the species Vitis vinifera L., harvested in two distinct physiological periods of the annual vegetation cycle: the post-vegetative period in autumn and the period preceding the start of vegetation in early spring. The choice of these intervals aimed to highlight the dynamics of the accumulation and mobilization of glucose reserves in the woody tissues of the vine, processes considered essential for the resumption of plant growth and development after the vegetative dormancy period [6]. Sampling was carried out at regular intervals, as follows:

- Autumn: September 21, September 28, October 5, October 12, October 21 and October 26.
- Spring: March 13, March 20, March 27, April 3, April 10 and April 25.

The biological material was represented by annual canes harvested from representative plants. To assess the spatial distribution of carbohydrate reserves along the cane, samples were taken from nodes and internodes corresponding to segments 1–5, 6–10, 11–15 and 16–20. Samples were also collected from multiannual wood (LV), in order to compare the capacity of accumulation of reserves in annual and perennial woody tissues. The woody organs of the grapevine represent the main storage compartments of reserve carbohydrates, which are subsequently mobilized to support shoot growth and bud development in the spring [8].

To highlight the possible influences of microclimatic conditions on the accumulation of reserve substances, the samples were collected from both northern and southern exposed ropes, as differences in exposure to solar radiation may influence physiological processes and the accumulation of reserve compounds in plant tissues [2], [3].

The collected samples were transported and processed under appropriate laboratory conditions, so as to prevent biochemical changes before analysis.

Chemical analyses:

The biochemical characterization of woody tissues was carried out by determining relevant physiological indicators for the evaluation of carbohydrate reserves and the water status of the tissues. The following parameters were determined during the analyses:

- starch content (A)
- total sugars (T.S.)
- reducing sugars / soluble sugars (S.R./S.S.)
- dry matter (D.M.)
- free water
- bound water

The determinations were carried out using standard biochemical methods, established in plant physiology studies for the analysis of carbohydrate compounds in woody plant tissues [4].

The methodology used allowed highlighting both the processes of accumulation of reserve substances and the changes in the water status of tissues during the transition period between vegetative dormancy and the resumption of metabolic activity.

Reserve carbohydrates, especially starch and soluble sugars, play an essential role in the energy metabolism of the grapevine, being involved both in the processes of maintaining basal metabolism during the dormancy period and in supporting subsequent vegetative growth [5].

Metabolic activity of buds:

The physiological state of buds during the transition period from vegetative dormancy to resumption of growth was evaluated by determining some indicators of metabolic activity, namely:

- respiration intensity, an indicator of the general level of tissue metabolic activity
- catalase enzyme activity, a parameter associated with oxidative metabolism and cellular detoxification processes.

The determination of these indicators allowed the assessment of the degree of metabolic reactivation of buds before the start of vegetation and the highlighting of the existing relationships between the metabolic activity of buds and the dynamics of glucose reserves in the woody tissues of the vine. The activation of respiratory processes and antioxidant enzymes is a sign of the resumption of cellular metabolism and the mobilization of reserves necessary for the initiation of vegetative growth [1],[7].

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Results and discussion

Dynamics of carbohydrates, dry matter and water in woody elements of the grapevine:

The analysis of the variation of carbohydrate content in woody elements of the grapevine during the autumn period highlights important changes in their distribution and dynamics, determined by physiological processes associated with tissue maturation and preparation of the plant for the vegetative dormancy period.

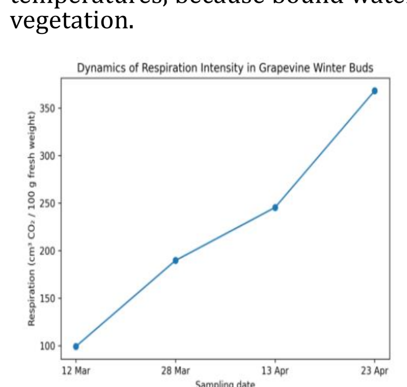
In general, the starch content (A) shows higher values in multi-year wood and in the node area, which confirms the role of these structures as the main centers of accumulation of reserve substances. This phenomenon is closely related to the hardening process of the plant, which takes place towards the end of the growing season, when photosynthetic products are translocated and stored in the woody organs as reserve compounds.

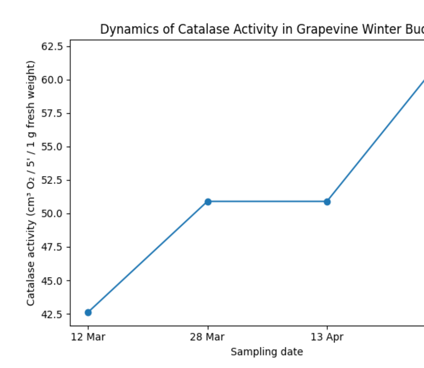
The accumulation of starch in the node area can be explained by their proximity to the buds, where an important part of the processes of storing energy substances necessary for the resumption of growth in the following season takes place. In these regions, starch constitutes the main form of energy reserve, being subsequently mobilized in the period preceding the start of vegetation.

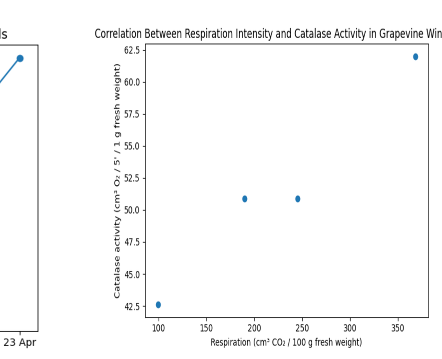
Compared to annual cords, multiannual wood does net show a massive accumulation of starch, which suggests that it functions rather as a stable reservoir of reserve substances, while annual cords participate more actively in the seasonal processes of carbohydrate accumulation and mobilization. Regarding total sugars (T.S.) and reducing sugars (R.S.), their variations are less pronounced compared to those of starch. However, the results indicate a shift of the maximum and minimum values along the cord, a phenomenon that reflects the processes of carbohydrate redistribution and translocation in the different segments of the woody organs. An important aspect highlighted by the results is the fact that the decrease in starch content is not immediately accompanied by a corresponding increase in total and reducing sugars, which suggests that the transformation of starch into soluble sugars does not occur simultaneously in all analyzed tissues or that the resulting sugars are quickly used in metabolic processes.

At the last determination carried out in the autumn period, with the decrease in the average air temperature, an increase in the content of total and reducing sugars is observed. This change can be interpreted as a physiological mechanism of adaptation to low temperatures, since soluble sugars contribute to increasing frost resistance by stabilizing cell membranes and maintaining the osmotic balance of cells. In parallel with the changes in the carbohydrate composition, variations in dry matter (D.M.S.), as well as in the content of free water (F.W.) and bound water (B.W.).

As the season progresses towards the end of the vegetation period, the proportion of dry matter increases, a phenomenon associated with the processes of maturation and lignification of woody tissues. At the same time, the ratio between free water and bound water undergoes important changes. Reducing the free water content and increasing the proportion of bound water contributes to increasing the resistance of tissues to low temperatures, because bound water is less susceptible to freezing compared to free water. Metabolic activity of buds in the period preceding the start of vegetation.







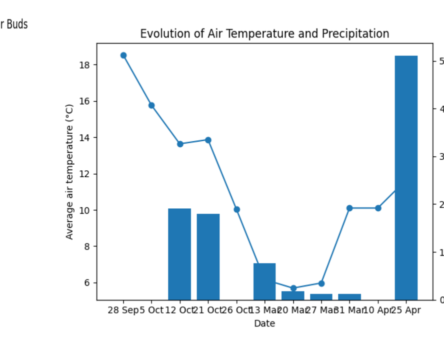


Fig. 1. Dynamics of breathing intensity **Fig. 2. Dynamics of catalase activity** **Fig. 3. Correlation between respiration intensity and catalase activity** **Fig. 4. Evolution average air temperature and precipitation during of the analyzed periods (autumn–spring)**

Respiration and catalase activity dynamics:

Analysis of respiration intensity and catalase activity in winter buds of grapevines reveals a progressive increase in metabolic activity during March–April, corresponding to the transition from vegetative dormancy to the resumption of physiological activity.

Respiration intensity values increase from 99.29 cm³ CO_2/100 g s.v. on March 12 to 189.67 cm³ CO_2/100 g s.v. on March 28, which represents an increase of approximately 91%.

In the following period, respiration continues to increase, reaching 245.45 cm³ CO_2/100 g s.v. on April 13, which represents an additional increase of approximately 29%.

The most pronounced increase is observed between April 13 and April 23, when the respiration intensity reaches 368.18 cm³ CO_2/100 g s.v., representing an increase of approximately 50% compared to the previous determination and of approximately 271% compared to the initial value. This evolution reflects the reactivation of the cellular metabolism of the buds, a process determined by the mobilization of the glucose reserves accumulated in the woody organs of the plant. Starch hydrolysis and its transformation into soluble sugars provide the energy substrate necessary for the processes of cell division and elongation.

Regarding catalase activity, the results indicate an increase from 42.6 cm³ O_2/5'/1 g s.v. on March 12 to 50.9 cm³ O_2/5'/1 g s.v. on March 28, which represents an increase of approximately 19%. During the period March 28 - April 13, the values remain relatively constant, after which a significant increase is observed up to 62.0 cm³ O_2/5'/1 g s.v. on April 23, representing an increase of approximately 45% compared to the initial value.

The increase in catalase activity is closely related to the intensification of oxidative metabolism. During cellular respiration, oxidation reactions increase, which causes the formation of reactive oxygen compounds, such as hydrogen peroxide (H_2O_2). Catalase has the role of breaking down this compound into water and oxygen, preventing the accumulation of toxic substances and protecting cellular structures.

Correlation between respiration and catalase activity:

Analysis of the relationship between respiration intensity and catalase activity highlights a very strong positive correlation between the two parameters, with the Pearson correlation coefficient being $r \approx 0.98$ and the coefficient of determination $r^2 \approx 0.96$.

This relationship indicates that approximately 96% of the variation in catalase activity can be explained by the variation in respiration intensity. As respiratory processes intensify, the activity of antioxidant enzyme systems involved in maintaining cellular redox balance also increases.

This correlation confirms that in the period preceding the start of vegetation, an intense metabolic reactivation of the buds takes place, characterized by the mobilization of glucose reserves, the intensification of respiration and the activation of enzymatic mechanisms of cellular protection.

Climatic conditions during the studied periods:

The analysis of climatic conditions during the experimental period represents an important element for the interpretation of the physiological processes observed in grapevine. Environmental factors, especially air temperature and soil temperature, directly influence plant metabolism, the dynamics of carbohydrate reserves, and the metabolic activity of buds.

Climatic Conditions During the Autumn Period:

In the autumn period (September–October), climatic conditions are characterized by a gradual decrease in air and soil temperature, a phenomenon specific to the transition from the active vegetation period to vegetative dormancy. This decrease in temperature causes important changes in the plant's metabolism, favoring the processes of accumulation of reserve substances in the woody organs. As temperatures decrease, photosynthetic activity gradually decreases, and the products of photosynthesis are translocated and stored in the woody tissues in the form of starch and other reserve carbohydrates. During this period, the process of ripening of the strings also takes place, characterized by lignification of the tissues and an increase in the dry matter content.At the same time, changes in the thermal regime also influence the water balance of the tissues, causing a decrease in the proportion of free water and an increase in the proportion of bound water. These changes contribute to increasing the resistance of the tissues to low temperatures and preparing the plant for the winter period.

Climatic conditions in the spring period:

The spring period (March–April) is characterized by a gradual increase in air and soil temperatures, which determines the resumption of the plant's metabolic activity after the vegetative dormancy period. The increase in temperature leads to the activation of enzymatic processes and the mobilization of glucose reserves accumulated in the woody organs in the previous period. These reserves are used to support the metabolic processes involved in the reactivation of buds and the initiation of vegetative growth.During this period, the increase in air temperature and the accumulation of active temperatures determine the intensification of respiratory processes and enzymatic activity, a phenomenon highlighted by the increased values of respiration intensity and catalase activity observed in experimental determinations.

The role of temperature accumulation:

An important climatic indicator for assessing the resumption of vegetative activity is represented by the sum of active temperatures or the accumulated global temperature. The increase of this indicator in the spring period favors overcoming the state of dormancy and initiating the physiological processes associated with the start of vegetation. The accumulation of active temperatures contributes to the activation of the cellular metabolism of the buds, stimulating respiratory processes and the mobilization of reserve substances. Consequently, the dynamics of the physiological parameters analyzed in the study reflects the adaptation of the vine to the changes in climatic

Conclusions

The dynamics of carbohydrate reserves in the woody elements of the vine highlights the fact that, during the autumn period, the accumulation of starch in the annual strings and in the multiannual wood takes place rhythmically, with the alternation of phases characterized by increases and decreases in the starch content, in close correlation with the evolution of climatic conditionsThe reduction in the content of total sugars and reducing sugars in the first part of the autumn period is followed by their accumulation with the decrease in air temperature, a phenomenon associated with the physiological processes of plant adaptation to low temperature conditions and with the increase in frost resistance. The analysis of the distribution of reserve substances along the strings indicates that the nodes represent the main areas of accumulation of starch, soluble sugars and dry matter, both in the autumn and spring periods, confirming their role in ensuring the energy resources necessary for the development of budsIn the period preceding the start of vegetation, a decrease in starch content in woody tissues is observed, determined by the mobilization of carbohydrate reserves necessary to activate bud metabolism and support the processes of cell division and elongation. The intensification of respiration and the increase in catalase activity in buds in the budding phase highlight the activation of oxidative metabolism and the role of antioxidant enzymatic mechanisms in maintaining cellular redox balance during the transition period from vegetative dormancy to resumption of growth.The graft cords harvested in the autumn period present higher values of starch, dry matter and soluble sugars content compared to those harvested in the spring, which indicates a higher biological potential and a superior quality of the plant material used for grafting.The results obtained confirm the essential role of glucose reserves and climatic conditions in regulating the physiological processes of the vine during the transition period between vegetative dormancy and resumption of growth.