Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 20, Issue 3, 2020
PRINT ISSN 2284-7995, E-ISSN 2285-3952

PHYTOMONITORIZATION OF THE INTENSITY OF PHOTOSYNTHESIS, RESPIRATION AND TRANSPIRATION IN HAIR PLANTS

Gheorghe ŞIŞCANU, Gheorghe SCURTU, Nina TITOVA, Gheorghe BALMUS, Maia RUSU, Emil КLEIMAN

Institute of Genetics, Phyziology and Plant Protection, 20 Padurii Street, 2002, Chisinau, Republic of Moldova. Phone: (+373 022) 66-45-58, Email: nvtmd@mail.ru, ghsiscanu@rambler.ru

Corresponding author: ghsiscanu@rambler.ru

Abstract

The paper presents the results regarding the phytomonitoring of physiological processes in hair plants. Among the physiological processes that characterize the activity of the production process is photosynthesis, which, like other physiological processes, is influenced by light, temperature and other ecological factors. Based on these considerations, the saturation curve of the light for photosynthesis was monitored. The modern RTM-48A phytomonitor was used, which allowed the measurement of physiological indices in the form of film-phytodiagram in automatic regime that allowed the diagnosis of the properties of the genotype and the physiological state of the plants. The saturation curve of light for photosynthesis in hair trees was determined as a result of assessing the intensity of photosynthesis, sweating, respiration and conductivity of stomata depending on temperature, humidity and CO_2 content in air. The minimum value of the light at which the photosynthesis process is initiated was established. With the increase of the light intensity (to 1/3 of the total light) the intensity of the photosynthesis increases after the essential optimization of the process took place. In hair plants, the intensity of photosynthesis begins with the appearance of light and continues to increase until the illumination of 100-150 micromol / m2 s, decreasing to 500 after maintaining at the same level until the illumination of 1500, then it increases to 1800. It was been established that the effect of temperature influence on photosynthesis in hair plants depended on the intensity of light. Respiration, transpiration and conductivity of the stomata confirmed light saturation curves for photosynthesis. As a result of the research, the positive influence of SBA Reglalg and microelements (B, Zn, Mn, Mo) on the activity of physiological processes in hair plants was established. The more pronounced stimulation of the activity of the physiological processes takes place under the influence of the Reglalg preparation in the presence of microelements.

Key words: *phytomonitoring, phytogram, gross photosynthesis, net photosynthesis, respiration, sweating, stoma conductivity, Republic of Moldova*

INTRODUCTION

It is known that plant productivity is determined by the activity of a complex of physiological and biochemical processes, among which the primary role belongs to photosynthesis. It is necessary to mention that this process is carried out in connection with other processes, first of all the breathing, a process in which a considerable amount of organic substances is consumed and which, in coordination with photosynthesis, ensures the viability of the plant organism. It is also known that the production potential of plants is determined by the genome, but its realization to a considerable extent depends on the ecological factors. Physiological processes, including photosynthesis, are permanently subject to the influence of various factors, such as light, temperature, humidity, which influences the productivity of plants.

Based on these considerations parallel with the monitoring of the functioning of the physiological processes, the saturation curve of the light was recorded for photosynthesis-performance element, photosynthesis (gross and net), perspiration, respiration, conductivity of stomata, weather conditions: temperature, humidity, CO_2 concentration and other factors. We carried out phytomonitoring research for 72 hours in the hairs under the influence of SBA and microelements.

MATERIALS AND METHODS

Fig. 1. Distribution of respondents by districts of the Republic of Moldova.
Source: Mapeurope.ru.

The work was carried out on the terms: 06 - 08. 07. 2018 - 06-08. 07. 2019 in lysimeters (Institute of Genetics, Physiology and Plant Protection).

As object of study were the hair trees, the late variety Noiabriscaya, the species Pyrus, the family Rozaceae, 4 years old, during the intensive growth of the plants. This variety possesses excellent qualities: the weight of the fruits constituted 600 grams, industrial use: fresh, long storage in the refrigerator, multidirecţional processing on preservation [8]. Currently, there is a special interest regarding the practical application of biologically active substances (SBA) with an ecologically harmless character, the use of which can serve as an effective lever for regulating the growth and development processes in the crop plants. As a SBA, the preparation obtained from algae under the name of Reglalg was used [7]. This preparation stimulates the increase of the crop in different crops. The use of the preparation contributes to the adaptation and formation of plant resistance to ecological changes [7]. The action of the SBA on the photosynthetic activity of the apple plants according to the ecological conditions is poorly elucidated [7; 15]. Phytomonitoring historically emerged as an instrumental section of plant biocibernetics in the 50s of the last century [9; 11; 12]. Phytomonitoring has historically emerged as an instrumental section of plant biocibernetics in the 50s of the last century [9; 11; 12]. The term "phytomonitoring" itself was proposed in 1987 by scientists from the Leningrad Plant Biocibernetics Laboratory [11]. Further development of this direction contributed to the emergence of a phytomonitoring methodology, which was proclaimed by O.L.Lyalin as a new methodology of plant physiology (physiological phytomonitoring) [12]. The set of records of physiological indices (usually in a day or more) can be considered as a description of the functional state of a cultivated plant or as signals about its functional state. This allows us to include the facilities in the production process management based on feedback control. At present, phytomonitoring, as a new methodology of plant physiology, has received universal recognition in Russia, Europe, Australia, Israel, USA, Chile, the Republic of Moldova and other countries.

Fig. 2. PTM-48A phytomonitoring device in operation immediately after rain.
Source: Original photo.

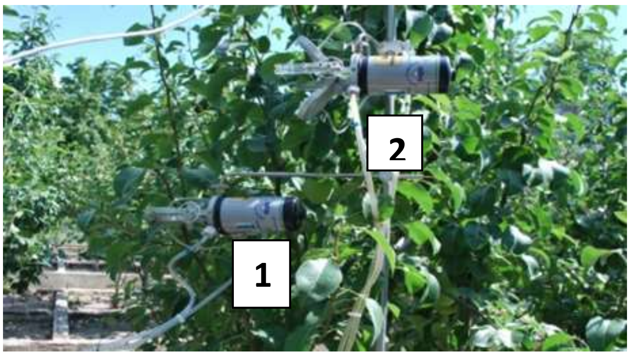

Fig. 3. Measuring chambers; 1, closed – for measurement, 2, open - for calibration.
Source: Original photo.

The task of phytomonitoring, together with physiological and biochemical studies, is to diagnose the properties of the genotype and the physiological state of the plants. The results of the latest researches have made possible the development of scientific and practical technologies for optimizing the cultivation of plants in natural environment and controlled environment in relation to the climatic changes. There are modern gas analyzers that work successfully as a photograph - ADC Bio Scientific Ltd-LGi [2; 6; 13; 14]. The first ISP-2T multichannel phytometric installation was developed in KB "Biopribor" (Chisinau). In the late 90's and early 21st century, based on the latest information technology, foreign companies Bio Instruments SRL, ADC Bio Scientific Ltd-LG gas analyzers and others built small phytomonitoring systems that allow the measurement of environmental parameters. The development of information technologies continues to this day. With the help of the modern PTM-48A phytomonitor, used in parallel with soy [10], we performed the phytomonitoring during 72 hours. We evaluated: photosynthesis (gross, net), perspiration, respiration, conductivity of the stomata under the action of weather conditions: temperature, humidity, CO_2 concentration and other factors, depending on the influence of SBA on the hair, showing - the physio light saturation for photosynthesis [7; 13; 14].

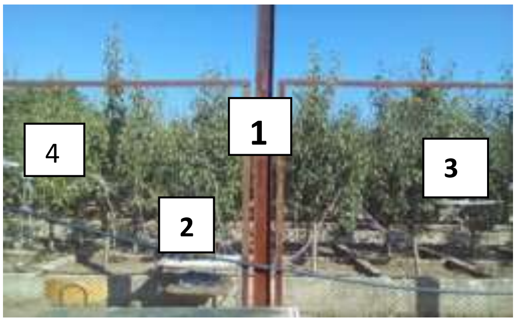

Fig. 4. *Phytomonitoring f*or 72 hours in hair trees.1- general appearance; 2- PTM -48 A apparatus**;** 3- measuring room; 4- RTH-48-weather module + measuring chamber.
Source: Original photo.

The modern PTM-48A phytomonitor (Bioinstruments SRL) [17; 1] has been used, which allows to make measurements in film-phytodiagram format every 15 minutes, for 72 hours, through phytomonitoring in automatic mode (Fig. 1 - 4.). The fitomonitor is compatible with the research drone “Phantom-2” [16; 17] through direct connections and through its own programs for interpreting the recorded information. The phytomonitoring in automatic regime of the indices characteristic of the energy [4, 5] and production processes is ensured [3; 16; 17]. We performed the detection of the basic physiological parameter - Light saturation curve for photosynthesis and crude, net photosynthesis - as a result of evaluating photosynthetic activity, sweating, breathing, conductivity of stomata under the direct action of weather conditions: temperature, humidity, CO_2 concentration in dependence by the influence of SBA (biologically active substances) on hair trees: on intact leaves, located in the middle part of the shoot. Through the tube with Ascarit- [10] (calcium hydroxide Ca(OH) 2 75.5%; Sodium hydroxide - NaOH with water addition 21.0%; Indicator (inorganic salt), as a constructive element of the phytomonitor PTM-48A, in which the calibration of the CO_2 content and the humidity of the air is automatically carried out in 4 measuring chambers, before each measurement, and immediately the measurements were made immediately (Fig. 2.–4.). Automatic phytomonitoring is performed through the analog contact points of the PTM-48A and sensors [13; 17]. The processing of the results allows to obtain the physiological element of performance: the light saturation curve for photosynthesis (micromol CO_2/m2 * s), the gross and net photosynthesis (micromol CO_2)/sq.m * s). Statistical interpretation of the results was performed using the statistical software applications Statistics 10 (Stat software INC, USA) and Microsoft Excel 2010. For the modeling and two-dimensional data, the methods of the smallest squares and the heavily weighted regression at the local level were used. All calculations were performed at significance level $P \leq 0.05$.

RESULTS AND DISCUSSIONS

The main way of researching photosynthesis, whether its mechanisms or biological properties, is based on establishing the reciprocal links of photosynthesis with other metabolic processes of the plant organism. The presence of light, as one of the main exogenous factors, is the main condition for the photosynthesis process to activate, which has determined the study of the influence of this factor on the intensity of photosynthesis, having at hand the possibilities of the automatic monitoring device PTM-48A. The research carried out presents the basic physiological element of the light saturation *curves for photosynthesis* (Fig. 5).

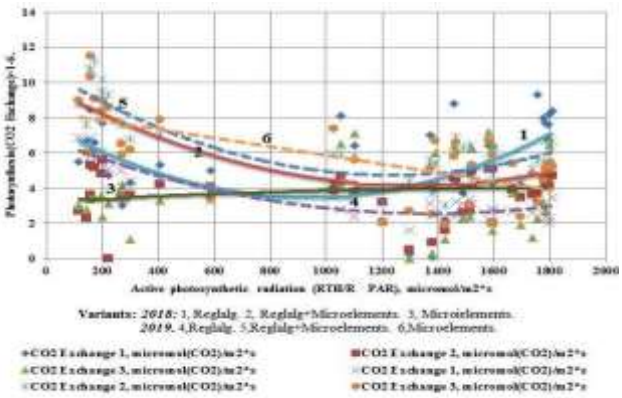

Fig. 5. Light saturation curves for photosynthesis.
Source: Own design reflecting the obtained results (Original).

The minimum values of the light intensity at which the photosynthesis process begins are set. The PTM-48A fitomonitor has the minimum recording capacity, which is very small in hair trees (tables for the years 2018-2019). With the increase of the light (up to 1/3 of the total sunlight) the intensity of the photosynthesis increases after its optimization in comparison with the intensity of the light. With the further increase of light, the process of photosynthesis saturation takes place. Analyzing the data presented, we observe that, in photosynthetic hair plants, the light starts to appear and continues until the illumination of 100-150 micromol/sq.m, gradually decreasing to 500 micromol/sq.m , and stays at the same level until the illumination of about 1,500 micromol/sq.m, then increases to 1,800 micromol/sq.m. The energy base of photosynthesis (Fig. 5.) is represented by the rays absorbed by chlorophyll. As it is known the energy of photosynthetically active radiation represents about 50% of the total energy of solar radiation. It is known that all solar energy does not participate in the photosynthesis process, but only the visible part - the active photosynthetic radiation with wavelengths from 380 to 720 nm (or millimicrons). The good yields correspond to 2-3% of the ROP use. When cultivating varieties of intensive type and optimizing all the processes of growth and development of the plants, the accumulation of 3.5-5% PAR and more predominantly takes place in the harvest. The effect of temperature on the influence of photosynthesis depends on the intensity of the illumination. Consequently, at a low level of illumination (diapazon - 15-25^0C) photosynthesis is performed at the same speed. At high light, the intensity of photosynthesis is determined by the activity of the processes that take place in the dark phase. The temperature of the leaf and the penetration of the leaf by the light depends on its thickness and structure. Thin leaves with lower heat capacity are more responsive to fluctuating light intensity. The following variants were installed in the IGFPP lysimeters with the hair plants: 1-SBA (biologically active substance) Reglalg; 2 – SBA Reglalg + Microelement; 3-Control. *The presented data confirm that the light saturation curves for photosynthesis* in hair plants largely vary depending on the factors in the research (Fig. 5.) is characterized by starting 6 curves in the region of active photosynthetic radiation (RTH / R PAR-100 micromol/sq.m, stable.

It was established that in the research years 2018-2019, stimulation of photosynthesis takes place under the influence of Reglalg preparation and more pronounced in the presence of microelements. *The light saturation curve for photosynthesis* - a performance element, is further confirmed by photosynthesis (gross, net photosynthesis), perspiration, respiration, stoma conductivity. A graphical representation was established depending on the factors studied - the relationship between the intensity of light and photosynthesis, the light penetration of the leaves. Essentially, it is a modification of the Michaelis-Menten equation, which shows a positive correlation between light intensity and photosynthesis intensity. Essentially, it is a modification of the Michaelis-Menten equation, which shows a positive correlation between light intensity and photosynthesis intensity. In the case of evaluating the intensity of photosynthesis, the magnitude of the observed photosynthesis is obtained (net photosynthesis- Fig. 6 and 7). An important indicator of photosynthesis is its intensity, i.e. the amount of CO_2 absorbed per unit time and the respiration of the leaves. In order to evaluate the value of real photosynthesis (gross photosynthesis), a change of breath must be added to the observed photosynthesis.

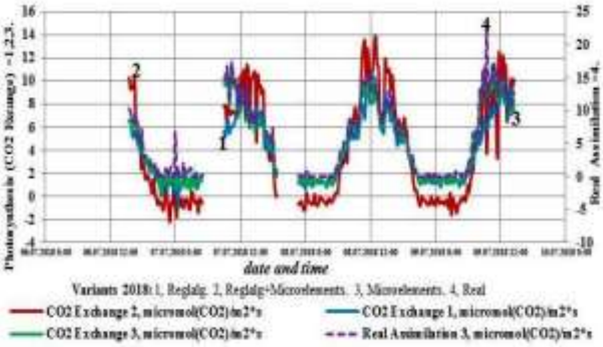

Fig.6. Crude photosynthesis (1,2,3), net photosynthesis (4).
Source: Own design reflecting the obtained results (Original).

The daily weight gain of the dry matter accumulated per unit of leaf area of a whole plant forms the *productivity of photosynthesis*. As the respiration process occurs simultaneously with photosynthesis, in order to obtain the value of a real intensity of photosynthesis (gross photosynthesis) it is necessary to make a respective modification to the intensity of the observed photosynthesis. Thus we obtain the weight increase of the dry substance on a unit of surface of the leaves or of a plant that defines photosynthetic productivity. How the intensity, as well as the photosynthetic productivity in the plants of different species, are essentially different. Hair shafts are very independent of nutritional conditions and especially in low light.

Fig. 8- 10 show results regarding the influence of SBA and air temperature on the intensity of photosynthesis in hair trees.

As you can see the intensity of carbon dioxide absorption essentially depends on the temperature factor. The presented data also confirm the light saturation *curves for photosynthesis.*

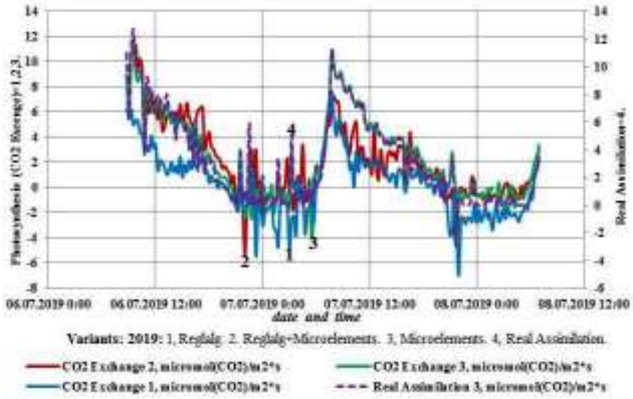

Fig. 7. Crude photosynthesis (1,2,3), net photosynthesis (4).
Source: Source: Own design reflecting the obtained results (Original).

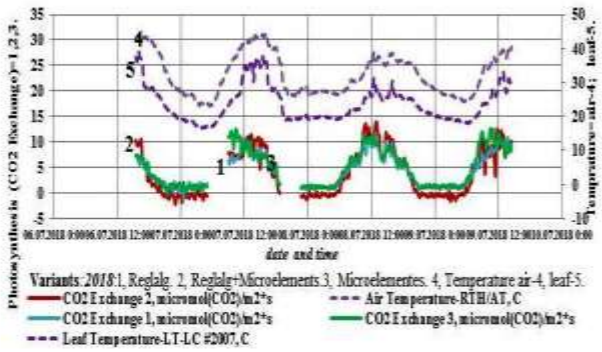

Fig. 8. Photosynthesis (1,2,3); Temperature (4.5).
Source: Source: Own design reflecting the obtained results (Original).

Photosynthesis is possible even at leaf air temperatures (Fig. 8 – 10) at which the growth of plants stops. Particularly low temperatures at night prevent the transport of plastic substances from the leaves to other plant organs, and in the leaf itself there is less room for new photosynthesis products, which artificially restricts its intensity. The activity of the photosynthetic apparatus and the flow of assimilated leaves can be significantly disturbed when the temperature in the root zone drops to 15°C. In turn, the root supply of photosynthetic products of soil and air humidity and air. The temperature limits for photosynthesis activity differ in different plants. The drop in air temperature directly affects photosynthesis, reducing the activity of enzymes involved in dark reactions and indirectly due to organ damage. The minimum temperature for plant photosynthesis is about 0°C. The optimum temperature of photosynthesis for most plants is about 20-25 °C. The minimum temperature for plant photosynthesis is approximate 0°C. The optimum temperature of photosynthesis for most plants is about 20-25°C. At temperatures higher than optimum temperatures, the intensity of photosynthesis drops sharply. Thus, increasing the temperature increases the rate of dark responses of photosynthesis. At the same time, at a temperature of 25-30°C, the process of inactivation of chloroplasts takes place. Higher temperature rise may also cause stoma cracks to stop (Fig. 8 - 10). Positive temperatures stimulate the intensity of respiration and in this sense decreases the intensity of visible photosynthesis (the difference between photosynthesis and respiration). Low temperatures reduce the intensity of photosynthesis because enzyme activity is inhibited, the speed of diffusion processes decreases, and the flow of assimilated. The temperature of the leaf depends on its thickness and consistency. In thin leaves, the heat capacity is low and reacts more strongly to the fluctuations of illumination. Sweating (Fig. 10 - 11) represents the process of water movement through plants and its evaporation through its external organs, such as leaves, stems and flowers. Water is needed for the life of the plant, but only a small part of the water that enters through the roots is used directly for the needs of growth processes and metabolism. The rest of over 99% is lost through sweating.

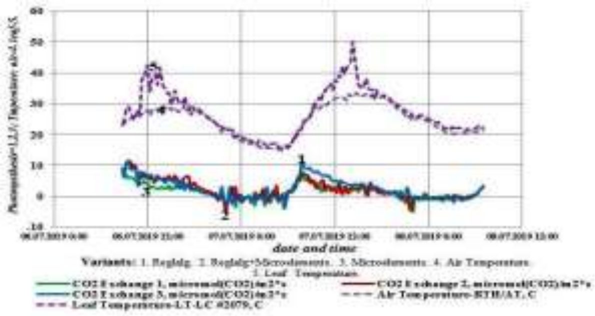

Fig. 9. Photosynthesis (1,2,3); Temperature (4,5).
Source: Source: Own design reflecting the obtained results (Original).

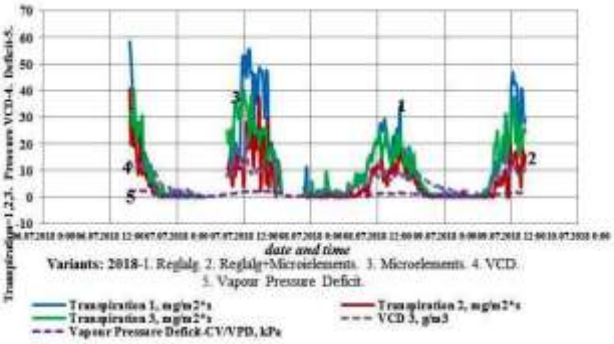

Fig. 10. Sweating (1,2,3); Cellular pressure (4); vapor pressure deficit (5).
Source: Source: Own design reflecting the obtained results (Original).

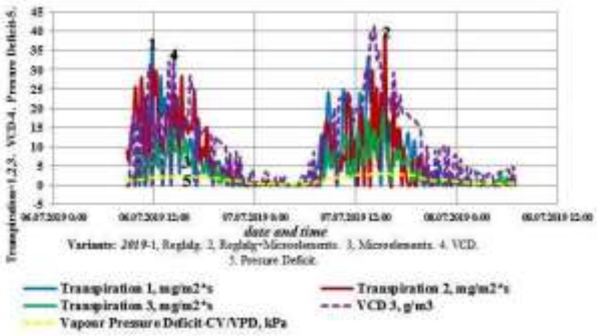

Fig. 11. Sweating (1,2,3); Cellular pressure (4); vapor pressure deficit (5).
Source: Source: Own design reflecting the obtained results (Original).

The surface of the leaf is covered with stomata, which in most fruit plants are located in the lower part of the leaf. Sweat intensity (Fig.10 – 11) confirms the performance. The stomata are limited by the closing cells and the accompanying cells (collectively known as the stomata complex), which open and close the pores.
Sweating occurs through fissures of the stomata through which at the same time they enter the carbon dioxide required for photosynthesis. In the process of sweating, the osmotic pressure in the cells that ensures the movement of water and nutrients from roots to shoots changes. The water is absorbed by the roots of the soil with the help of osmosis and moves into xylem together with dissolved nutrients. Gravity can be overcome only by reducing hydrostatic pressure in the upper parts of the plant, due to the diffusion of water through stomata. Stomach conductivity confirms light *saturation curves for photosynthesis*.

Modern high sensitivity equipment for calculating the conductivity of stomata in the computerized processing of physical indicators of gas exchange is based on the hypothesis of complete saturation of the water vapor cavity [6, 13].

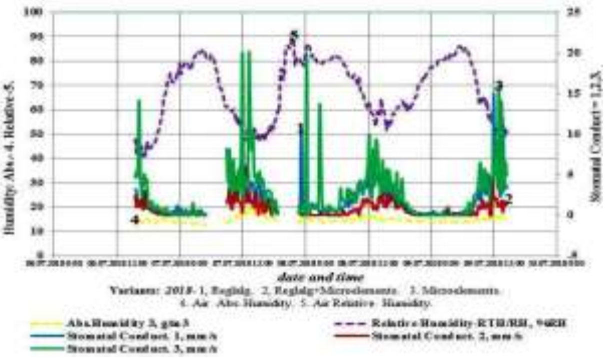

Fig. 12. Conductivity of stomata (1,2,3). Air humidity (4.5).

Source: Source: Own design reflecting the obtained results (Original).

Of particular interest is the evaluation of the quantitative ratio of respiration and photosynthesis (Fig. 13.).

Condensation of water from the surface of the leaves of the plants reduces the temperature of the leaves below the dew point, regardless of the cooling mechanism of the leaves and shoots, shows that all plants can condense the humidity of the air, especially in the absence of direct sunlight, provided that the dew point.

During photosynthesis, there is accumulation of organic substances that in the process of respiration, are mobilized to ensure all vital processes.

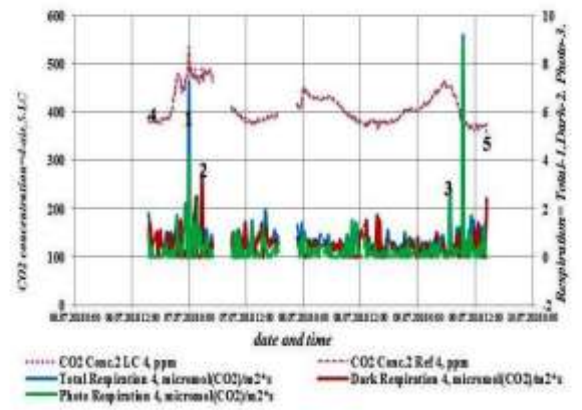

Fig. 13. Breathing (1,2,3). CO2 concentration in air (4) and measuring chamber (5).

Source: Own design reflecting the obtained results (Original).

Breathing provides energy for the biosynthesis, absorption and transport of plastic substances, the realization of the functional energy mechanism (organ movement, internal organ movement), and other activities in the cell. Thus, respiration, like photosynthesis, plays a fundamental role in the vital activity of plants.

As the atmosphere is known, which represents, on average, the main source of CO_2 for plants, it contains 0.03% CO_2. Increasing the CO_2 concentration in air from 0.2 to 0.6% accelerates the photosynthesis process; leads to an increase of the productivity of plants by 12-16% and to the acceleration of the maturation of plants by 7-12 days. When the CO_2 concentration in the air is higher than 0.6%, the growth of plants may slow down. In greenhouses, due to tight spaces, air exchange is difficult, and during the day, when CO_2 is actively absorbed by plants, its content in the air drops sharply. Therefore, in greenhouses, fertilizing plants with carbon dioxid is particularly important. In the measuring chamber the same air flows for a necessary period of time, passing successively through the concentration measuring device and through the measuring chambers. Therefore, photosynthesis occurs with a continuous decreasing concentration of CO_2. Its rate at any time can be evaluated based on the known CO_2 volume of the system and the slope of the light saturation curve, which describes the change in CO_2 concentration over time. Modern equipment requires very precise methods of determining the CO_2 concentration in the air, so that its decrease is slow (and at the same time measurable). In relation to the mentioned, it can be said that in the experiments with the hair plants the concentration of CO_2 was in the norm, which results from the presented information (Fig. 13.).

CONCLUSIONS

The peculiarities of the physiological processes in the hair trees were established based on the phytomonitoring, using the modern phytomonitor PTM-48A.

Photosynthesis (gross, net), just as the breathing, transpiration and conductivity of the stomata confirm the performance of light saturation curves for photosynthesis.

Based on the phytomonitoring of the physiological processes, it was established that their activity during the vegetation period in the hair trees essentially changes depending on the fluctuation of the factors of light, temperature, humidity and CO_2 content in the atmosphere.

The positive effect of SBA Reglalg and microelents was confirmed based on the phytomonitoring of the intensity of photosynthesis, respiration, sweating, stoma conductivity and weather conditions, the saturation curve of photosynthesis was established in the hair plants.

The positive influence of the Reglalg preparation in the presence of microelements was established in the hair plants.

REFERENCES

[1]Balaur, N.S., Vorontsov, V.A., Kleyman, E.I., 2009, Ton YU.D. Novaya tekhnologiya monitoringa CO_2-obmena u rasteniy // Fiziologiya rasteniy (A new technology for monitoring KO2 metabolism in plants // Plant Physiology), Vol. 56. No.3.

[2]BCI, 1994**,** Instruction for using the Lci - 4 Portable Photosynthesis System, Ed. UK (in England).

[3]Bondarenko, S. G., 1990, Sistemnyy analyze v vinogradarstve. Kishinev (System analysis in viticulture. Kishinev). p. 232.

[4]Bondarenko, S. G., 1999, Metodologicheskiye i energeticheskiye problem vinogradarstva. Kishinev (Methodological and energy problems of viticulture. Kishinev). p. 270.

[5]Budak, A. B., Scurtu Gh. I., Kharchuk, O. A**.**, 2019, Soybean light use efficiency upon sufficient soil moisture. May 20-25, 2019, Poznan, Poland.

[6]Cârlig, N., Scurtu, Gh., Iurcu-Străistaru, E., Ţîţei,V., 2017, Studiul proceselor fiziologice al transpiraţiei şi activităţii fotosintetice la cultura *Polygonum sachalinense* F. Schmidt în condiţiile Republicii Moldova. In: Agricultura durabilă în Republica Moldova: provocări actuale şi perspective: Culegere de articole ştiinţifice Filiala Bălţi a AŞM. Bălţi (Study of the physiological processes of perspiration and photosynthetic activity in the culture of Polygonum sachalinense F. Schmidt in the conditions of the Republic of Moldova. In: Sustainable agriculture in the Republic of Moldova: current challenges and perspectives: Collection of scientific articles Balti Branch of the ASM. Balti), pp. 298-302.

[7]Dascaliuc, A., 2003, Reglalgul este certificat în Republica Moldova ca Reglator de Creştere a Plantelor, Autorizaţia N00448 din 12 februarie 2003 cu termen de valabilitate prelungit până la 1 iunie 2023 (Reglalgul is certified in the Republic of Moldova as a Plant Growth Regulator, Authorization N00448 of February 12, 2003 with extended validity period until June 1, 2023).

[8]Dushutina, K., 1979, Selektsiya grushi. Kishinev. (Selectia la pere, Chisinau). pp.166-168.

[9]Karmanov, V. G., 1959, Prilozheniye avtomatiki i kibernetiki k rasteniyevodstvu. DAN SSSR. t. 128, N 1. (The application of automation and cybernetics to crop production. DAN USSR. Vol. 128, No.1).

[10]Kleyman, E., 2002, Bio Instruments S.R.L., MD-2002, Kishinev, Republic of Moldova.

[11]Lyalin, O. O., Radchenko, S.S., Karmanov, V. G., 1987, Problemy fitomonitoringa na sovremennom etape. Fizicheskiye metody i sredstva polucheniya informatsii v agromonitoringe (Problems of phytomonitoring at the present stage. Physical methods and means of obtaining information in agro monitoring). pp. 30-35.

[12]Lyalin, O. O., 1993, Transportnyye funktsii kornya intaktnogo rasteniya. / Fiziologiya rasteniy (Transport functions of the root of an intact plant. / Plant Physiology), Vol. 40. No.5, 811-820.

[13]Scurtu, Gh., Bujoreanu, N., Harea, I., Nicuţă, A., Paşa, R., Cornea, V., Dadu, D., Chisili, S., Donica, N., Gribcova, A., 2017, Evaluation of photosynthetic activity in pear trees depending on the action of biological active substances. Revista Botanică No. 15. p. 108.

[14]Siromeatnicov, Iu., Cotenco, E., Scurtu, Gh., 2017, Intensitatea fotosintezei şi transpiraţiei la diverse linii de tomate obţinute in vitro. Mater. Confer. şt. intern. (Ed.VI) „Genetica, Fiziologa şi Ameliorarea Plantelor”**,** Chişinău (Intensity of photosynthesis and transpiration in various tomato lines obtained in vitro. Mater. Confer. intern. (Ed.VI) "Genetics, Physiology and Plant Breeding", Chisinau), pp.75.

[15]Şişcanu, Gh., 2018, Fotosinteza şi funcţionalitatea sistemului donator-acceptor la plantele pomicole. Chişinău (Photosynthesis and functionality of the donor-acceptor system in fruit plants. Kishinev), p. 194.

[16]Todiraş V., 2003, Agricultura de precizie: Tehnologii geospaţiale şi informaţionale în managementul culturilor agricole. Chişinău (Precision agriculture: Geospatial and information technologies in agricultural crop management. Kishinev), pp.13-156.

[17]Todiraş, V., 2019, Agricultura de precizie pentru dezvoltare. Chişinău (Precision agriculture for development. Chisinau). pp. 5-133.