

THE STUDY OF THE PRODUCTIVITY POTENTIAL OF GRAPE VARIETIES
ACCORDING TO THE INDICATORS OF FUNCTIONAL ACTIVITY OF LEAVES

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ABSTRACT

Photosynthetic activity in the leaf of ten grape varieties was studied in the conditions of the northern part of Forest-Steppe of Ukraine. From 2019 to 2020 meteorological data were recorded by the "Metotrek" meteorological station. The influence of weather conditions of the spring-summer period at the beginning of the vegetation phases, which in 2019 took place on average 12 days earlier than in 2020, was noted. Analysis of changes in the induction of chlorophyll fluorescence (ICF) in leaves revealed the more efficient use of quantum energy of absorbed light by F_0 in the leaves of most varieties was noted in the phase "the beginning of berry ripening". During the three periods of the study, the varieties Aromatnyj, Zagadka, Ilichevskij rannij, and Kardishah showed a lower content of chlorophyll molecules, which do not have a functional connection with the reaction centers (RC). According to the F_p index the highest intensity of photosynthesis on average for all varieties was observed in the phase "the beginning of ovary growth", the lowest – "the inflorescence is visible". The potential productivity of grape plants determined by the ICF coefficient for all varieties was at a very high level and had a weak or moderate correlation with weather conditions during the growing season. The hydrothermal coefficient and $\Sigma \text{act } t \geq 10^\circ \text{C}$ had a weak effect on the efficiency of the light phase of photosynthesis (K_i) and a noticeable one (correlation coefficient $r = 0.50 - 0.69$) on the efficiency of dark photochemical processes (Rfd) in the leaves of most grape varieties.

Keywords: grape variety; chlorophyll fluorescence; phenology; photosynthesis; potential productivity

INTRODUCTION

The specificity of viticulture industry development is determined by its close connection with the weather and climatic conditions. Due to global climate change, there is a need to assess the response of grape plants to possible changes in agro-climatic growing conditions to use the resources of a particular region more efficiently and increase gross harvest and crop quality (Kovalyshyna et al., 2020a).

Grapes are in demand in many countries around the world. The share of fertile grape plantations in the world is over 3.1%, which is about 12.5 thousand hectares. Most of these plantations are concentrated in the Middle East and European countries (Zheplinska et al., 2019). Ukraine ranks in the world in terms of grape production. According to the FAO, the world grape market is underfunded. According to scientifically sound standards, the annual consumption of grapes per capita should be 2 (Zheplinska et al., 2021). World grape production should reach 14 million tons to ensure such volumes.

The weather has a significant impact on the formation of the grape harvest. Weather conditions change from year to year, which determines the variability of crop values

(Kovalyshyna et al., 2020b; Kolyanovska et al., 2019). The fundamental process, during which the formation of the crop takes place, is photosynthesis (Smetanska et al., 2021). The intensity of photosynthesis in fruit and grape plants is most often investigated by assessing the functional state of their photosynthetic apparatus using the method of induction of chlorophyll fluorescence (ICF). This method determines the sensitivity of the process of photosynthesis to various stress factors, such as temperature, light intensity, the action of toxins, heavy metals, air pollution, and changes in vertical zonation, precipitation, etc. (Mamonova et al., 2018). Studies using the method of ICF and correlation analysis make it possible to determine the potential productivity of grape varieties and establish the level of influence of weather conditions on them. Therefore, this work aimed to determine the level of functional activity of leaves of different grape varieties during the growing season and to establish the influence of weather conditions on the processes of photosynthesis in plants grown in vineyards in the northern part of Ukraine.

Scientific Hypothesis

Determining the potential productivity of grape plants in new soil and climatic conditions based on the influence of weather conditions during the growing season on the efficiency of photosynthesis in the leaves will assess the adaptive properties and productivity of plants in the northern forest-steppe of Ukraine for further introduction of the best grape varieties into industrial crops.

MATERIAL AND METHODOLOGY

Samples

Studies to determine the functional state of the leaves of grape plants were conducted in the Laboratory of Plant Physiology and Microbiology of the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (IH NAAS). The objects of the study were ten varieties of grapes selected by NSC "Institute of viticulture and wine-making after V. Ye. Tairov". Plants were planted in the spring of 2017 on rootstock 101-14 '*Riparia × Rupestris*' on the territory of the training laboratory (TL) "Fruit and Vegetable Garden" of the National University of Life and Environmental Sciences of Ukraine (Kyiv) according to the scheme 3.0 × 1.5 m. The soil of the experimental plot is sod-podzolic, light loam with optimal pH (6.47 – 6.81), and high content of nitrogen and phosphorus. The soil retention system is black fallow; the plot is irrigated. Grape culture is covered. Meteorological indices for the period 2019 – 2020 were recorded by the "Metetrek" meteorological station, which is located at a distance of 80 m from the experimental vineyard, and processed in Excel.

Chemicals

No chemicals were used.

Biological Material:

The study used green fully formed leaves of ten varieties of grapes which were on the same side of the row and the leaf blade was evenly lit.

Instruments

A portable chronofluorometer "Floratest" developed at the Institute of Cybernetics. V. M. Glushkova NAS of Ukraine. The device online registers the fluorescence of the plant leaf. Information in the form of a chlorophyll fluorescence induction curve is displayed on the device displays. This curve reflects the physiological state of the entire chain of photosynthesis and the kinetics of its various links. The shape of this curve and its sections can be used to assess and predict the degree of influence on the plant of both the main environmental factors and endogenous ones.

Laboratory Methods

Diagnosis of the functional activity of grape leaves was performed with a portable chronofluorometer "Floratest", which monitors the work of Photosystems II (PSII) and chloroplasts (Figure 1). The device registers the "Kautsky curve" (induction changes in fluorescence), the shape of which fully reflects the course of photosynthesis in the chloroplasts of leaves (Brajon et al., 2000). Kautsky effect (induction of chlorophyll fluorescence) is a phenomenon of change in the glow of chlorophyll, which occurs during prolonged illumination of a plant leaf previously adapted to darkness.

During the assessment of the functional state of the photosynthetic apparatus by inductive changes in chlorophyll fluorescence, a set of parameters was used, which allowed us to analyze the changes in photosynthetic processes in the leaves, namely:



Figure 1 Functional activity research of grape leaves using a portable chronofluorometer "Floratest".

F_0 – “background” level of fluorescence; depends on the loss of excitation energy during the migration of the pigment matrix, as well as on the content of chlorophyll molecules that have no functional connection with the reaction centers (RC). At the initial moment (F_0) all the channels of photosynthetic electron transfer are open and the maximum energy of the excited electrons goes to the photosynthetic process.

F_p – the maximum value of fluorescence, which characterizes the highest level of fluorescence of chlorophyll *a* (*Chla*) and is displayed as a maximum on the induction curve.

F_t – a stationary level, which is characterized by a dynamic equilibrium between the processes that cause an increase in fluorescence and the processes that lead to its decrease.

The following indicators were calculated by the analytical method:

K_i – coefficient of induction of chlorophyll fluorescence shows the share of chlorophylls involved in photosynthesis, from their total number and determines the efficiency of the light phase of photosynthesis: $(F_p - F_0)/F_p$;

F_{fd} – coefficient of efficiency of dark photochemical processes or the coefficient of decline fluorescence, which characterizes quantum efficiency of photosynthesis (viability index): $(F_p - F_t) / F_t$ (Havryliuk et al., 2019).

Description of the Experiment

For integrated assessment of the state of the photosynthetic apparatus by ICF, a green, fully formed, pre-adapted to the darkness grape leaf was placed between the plates of the remote optical sensor of the device “Floratest” and changes in chlorophyll fluorescence were recorded for 4 min. Plant samples (each in five repetitions) – leaves 30 – 35 days of age were analyzed in three phases of grape development: the first – the inflorescence is visible; the second is the beginning of ovary growth; the third is the beginning of berry ripening.

Sample preparation: leaves of grape plants were selected from the middle part of the vine, in the morning from 8 to 9 o'clock. Which are on one side of the row, well lit, and not shaded by other leaves. They were placed in dark plastic bags, without access to light, and after 2 – 3 hours analyzed in the laboratory.

Number of samples analyzed: 300 leaves for 2 years.

Number of repeated analyses: leaves of 10 grape varieties in five repetitions.

Number of experiment replication: three times during the growing season, for two years.

Statistical Analysis

Data from the device was transferred to a PC, where it was interpreted by the program “Floratest” in Microsoft Excel 2016.

Using correlation analysis, the strength of the connection between meteorological elements for the years of the field experiment and indices of photosynthesis efficiency in the leaves of the studied grape varieties was calculated. The influence of the factor by the correlation coefficient is weak ≤ 0.29 , moderate: 0.30 – 0.49, noticeable: 0.50 – 0.69, high: 0.70 – 0.89, very high: 0.90 – 0.99. Statistical

processing was performed in Microsoft Excel 2016 in combination with XLSTAT.

RESULTS AND DISCUSSION

According to agro-climatic zoning, the study area according to the average long-term data belongs to the northern part of Forest-Steppe (HTI 1.0 – 1.3, the sum of active temperatures of 10 °C and more is 2700 °C). Several scientists from Ukraine and Europe were engaged in similar scientific researches, they carried out the scientific work, both in the open and in the closed ground in various climatic zones (Conradie et al., 2019; Malu, Sharma and Pearce, 2017; Schwerz et al., 2017; Alameldin, 2017). Over the years of the field experiment during the growing season, various weather conditions developed, which allowed assessing the degree of their influence on the functional activity of the leaves of grape plants in certain phases of development of the latter. In 2019, during the growing season, the hydrothermal coefficient fluctuated in the range of 0.8 – 1.2, the lowest being at the end of summer. The sum of active temperatures of 10 °C and more ($\Sigma \text{act } t \geq 10 \text{ }^\circ\text{C}$) during the growing season was 3317 °C. The weather of 2020 differed from 2019 by less heat accumulation in the spring and summer and more precipitation (HTI 1.6 – 3.6). According to $\Sigma \text{act } t \geq 10 \text{ }^\circ\text{C}$ the terms of the study were almost the same (2020 – 3370 °C), which is on average 644 °C more than the climatic norm.

In 2019, from the beginning of the growing season to the phase “the inflorescence is visible” $\Sigma \text{act } t \geq 10 \text{ }^\circ\text{C}$ was 577 °C, in 2020 – 522 °C, but its accumulation occurred 12 days later, compared with 2019. In the phase “the beginning of ovary growth” $\Sigma \text{act } t \geq 10 \text{ }^\circ\text{C}$ was 1300 °C, which in 2019 was recorded 11 days earlier compared to 2020 (1308 °C). In 2019, from the beginning of the vegetation to the phase “the beginning of berry ripening” $\Sigma \text{act } t \geq 10 \text{ }^\circ\text{C}$ was equal to 1906 °C and occurred 12 days earlier than in 2020 (1944 °C).

A comparative analysis of precipitation in the years of the study showed that in 2020 in all three terms of measuring the amount of precipitation was higher by 64, 53, and 48%, respectively. In May 2020, precipitation was 3.2 times more than in 2019 and 3.1 times more than the climatic norm. June precipitation of 2019 and 2020 accounted for only 62% of the long-term norm, for July the situation with humidity was also different: in 2020 precipitation was almost the norm – 92%, and in 2019 only half of the climatic norm. In August, the amount of precipitation in 2019 was 75%, in 2020 – 45% of long-term values.

After the onset of light influence on the previously adapted to the dark leaf of the plant, the fluorescence intensity of chlorophyll changes significantly during the measurement period. The time dependence of ICF has the characteristic appearance of a curve with several maxima. The shape of this curve reflects the changes that occur in the photosynthetic apparatus of the plant during its adaptation to different environmental conditions.

According to Korniyev (2002), the level of chlorophyll fluorescence emitted by PS II complexes with “open” reaction centers depends on the loss of excitation energy during its migration through the pigment matrix of light-harvesting complexes.

Table 1 A characteristic of the functional state of grape leaves according to F_0 and F_p (c. u.) NULES of Ukraine, 2019 – 2020.

Varieties	F_0			F_p		
	according to phenological phases					
	inflorescence is visible	beginning of ovary growth	beginning of berry ripening	inflorescence is visible	beginning of ovary growth	beginning of berry ripening
Aromatnyj	264ab	238 a	226 a	1506a	987 a	1309 a
Zagadka	243ab	270ab	245ab	1520a	1166ab	1480ab
Ilichevskij rannij	256ab	243ab	226 a	1662ab	1208ab	1477ab
Kardishah	253ab	269ab	230 a	1600ab	1202ab	1333ab
Kishmish tairovskij	269ab	282 b	274 b	1694ab	1379 b	1558 b
Kometa	274b	293bc	270b	1763ab	1302 b	1606 b
Muskat odesskij	235a	240 a	261b	1523 a	1141ab	1474ab
Persej	286 b	272 b	251ab	1768 b	1310 b	1541 b
Shkoda	270ab	318 c	253ab	1669ab	1347 b	1469ab
Yarilo	272 b	274 b	254ab	1653ab	1222 b	1461ab

Note: Different letters indicate values that differ significantly according to the 5% level of significance (for all tables).

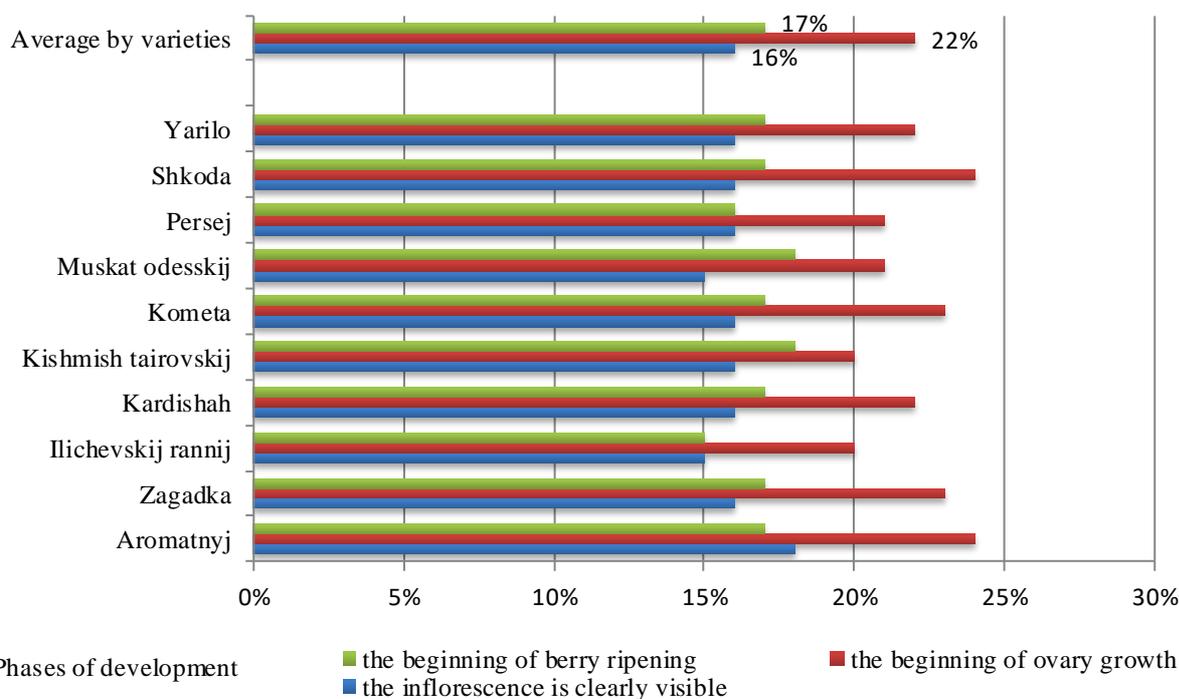


Figure 2 The level of energy use for the synthesis of organic matter (F_0/F_p) at different phases of plant development of the studied grape varieties.

In active photosynthesis, when all reaction centers are in the open operating state, in low light conditions, about 3% of the absorbed light energy is not used in the process of photosynthesis. But the authors of the following scientific papers argue that in active photosynthesis when all reaction centers are in normal light, about 10% of absorbed light energy is not used in photosynthesis, which can have a significant impact on the yield and quality of grapes (Palamarchuk et al., 2020; Drenjančević et al., 2017). As a rule, in conditions of cultivation favorable for the plant, the value of F_0 is insignificant which indicates the active use of energy of absorbed light by cells. At different phases of development of grape bushes, the background

level of chlorophyll fluorescence in leaves varied in the range of 235 – 286, 238 – 318, and 226 – 274 c. u. (Table 1).

The more efficient use of quantum energy of absorbed light by F_0 in the leaves of most varieties was noted in the phase “the beginning of berry ripening”. During the three periods of the study, the varieties Aromatnyj, Zagadka, Ilichevskij rannij, and Kardishah showed a lower content of chlorophyll molecules, which do not have a functional connection with the reaction centers (RC) (Pascale et al., 2017; Martínez et al., 2018).

Table 2 Characteristics of the functional state of grape leaves according to *Ki* and *Rfd* (c. u.). NULES of Ukraine, 2019 – 2020.

Varieties	<i>Ki</i>			<i>Rfd</i>		
	according to phenological phases					
	inflorescence is visible	beginning of ovary growth	beginning of berry ripening	inflorescence is visible	beginning of ovary growth	beginning of berry ripening
Aromatnyj	0.822 a	0.740 a	0.825ab	1.94 a	1.80 a	1.83 b
Zagadka	0.836 a	0.761ab	0.834ab	2.64 b	1.79 a	2.09bc
Ilichevskij rannij	0.844 a	0.792 b	0.842 b	2.61 b	1.93 b	1.94bc
Kardishah	0.838 a	0.771ab	0.824 a	2.73 b	1.84ab	2.01bc
Kishmish tairovskij	0.841 a	0.792 b	0.823 a	2.52 b	2.01 b	1.87bc
Kometa	0.843 a	0.771ab	0.829ab	2.77 b	2.18ab	2.21bc
Muskat odesskij	0.845 a	0.784 b	0.823 a	2.18ab	1.50 a	1.52 a
Persej	0.833 a	0.788 b	0.835ab	2.77 b	2.02 b	2.13 c
Shkoda	0.837 a	0.756ab	0.825ab	2.50 b	2.04 b	1.79ab
Yarilo	0.831 a	0.770ab	0.824 a	2.23ab	1.79 a	2.19 c

Table 3 Correlation between meteorological elements and intensity of photosynthesis of grape plants (according to *Ki* and *Rfd* indices). NULES of Ukraine, 2019 – 2020.

Varieties	<i>Ki</i>			<i>Rfd</i>		
	Meteorological elements					
	HTI	Σ act $t \geq 10$	Σ precipitation	HTI	Σ act $t \geq 10$	Σ precipitation
Aromatnyj	0.19	0.22	0.46	0.53	-0.12	0.30
Zagadka	0.16	0.21	0.38	0.37	-0.49	-0.19
Ilichevskij rannij	0.16	0.19	0.36	0.52	-0.55	-0.07
Kardishah	0.29	0.03	0.35	0.74	-0.54	0.04
Kishmish tairovskij	0.38	-0.17	0.23	0.41	-0.63	-0.36
Kometa	0.27	0.01	0.28	0.30	-0.55	-0.28
Muskat odesskij	0.36	-0.14	0.25	0.50	-0.60	-0.29
Persej	0.03	0.36	0.35	0.51	-0.51	-0.18
Shkoda	0.18	0.01	0.14	0.50	-0.59	-0.09
Yarilo	0.23	0.14	0.42	0.42	-0.07	0.17

Adaptive changes in the structure of the pigment complex to the lighting conditions because the *Fp* index is the most variable. The values of the maximum value of fluorescence depend on the intensity of the excited radiation and they are proportional to the total number of chlorophylls and inversely proportional to the density of the reaction centers. It is believed that at the point *Fp* at the maximum level of chlorophyll fluorescence photosynthesis is at a minimum one (Kytaiev et al., 2005). Thus, the highest intensity of photosynthesis on average for all varieties was observed in the phase “the beginning of ovary growth”, the lowest – “the inflorescence is visible”. Analyzing in detail the *Fp* index by varieties, it was found that the intensity of photosynthesis was significantly higher in the second measurement period compared to the first, namely: for the variety Aromatnyj – by 34%; Zagadka – 23%; Ilichevskij rannij – 27%; Kardishah – 25%; Kishmish tairovskij – 18%; Kometa – 26%; Muskat odesskij – 25%; Persej – 26%; Shkoda – 19%; Yarilo – 26%, which in our opinion is due to insufficient insolation in the first measurement period. The process of photosynthesis under such conditions is limited

by the intensity of light entering the plant (Lukatkin et al., 2011).

According to long-term studies of the Laboratory of Plant Physiology of the IH NAAS, the optimal level of background fluorescence is not more than 20 – 25% of the maximum value of fluorescence (*Fp*). We found that for all studied varieties of grapes pigment complex functions actively in all phases of bush development (Figure 2).

In the phases “the inflorescence is visible” and “the beginning of berry ripening” the index *F₀/F_p* fluctuates on the average on grades in the range – 16 – 17%, in a phase “the beginning of ovary growth” – 22%. We believe that this is due to the large amount of energy expended on the intensive growth of the fruit (ovary).

An effective way to monitor the impact of environmental stress on the plant is a calculated indicator – the fluorescence induction coefficient of chlorophyll (*Ki*), which shows the share of chlorophylls involved in photosynthesis, their total number and determines the efficiency of the light phase of photosynthesis. According to the obtained data (Table 2), the *Ki* index in the leaves of grape plants in the first and third measurement periods ranged in the same range of 0.822 – 0.845 and 0.823 –

0.842 c. u. respectively, in the second – 0.740 – 0.792 c. u. Studies performed by **Lukatkin et al., (2011)**, indicate a high level of efficiency of photophysical processes near the reaction. Several scientists (**Hu et al., 2019; Conde et al., 2018; Kernaghan, Mayerhofer and Griffin, 2017**) have been engaged in similar scientific researches and found that the *Ki* index in the leaves of grape plants in the first and third measurement periods ranged in the same range of 0.810 – 0.838 and 0.813 – 0.822 s. u. respectively, in the second – 0.720 – 0.762 s. u.

The value of *Ki* is associated with changes in the efficiency of the process of photochemical quenching of chlorophyll fluorescence. This index of dark-adapted plants reflects the potential quantum efficiency of PS II, used as an indicator of photosynthesis productivity, the optimal value of which for most plant species, under saturating intensity of exciting light, does not exceed 0.83 (**Ivanova et al., 2021**).

An increase of this index diagnoses the phenomenon of photoinhibition and testifies to the influence of stress factors on plants (**He et al., 1996; Sukhenko et al., 2019**). At the phase “the inflorescence is visible” for grape leaves Ilichevskij rannij, Kishmish tairovskij, Kometa, Muskat odesskij indicator *Ki* was higher than the optimal value, but among varieties as to the value of *Ki* a significant difference was not found. At the phase of “the beginning of ovary growth,” variety Aromatnyj as to this index differed significantly from most varieties. In the third measurement period, a significant difference in the value of *Ki* was among varieties Muskat odesskij, Kishmish tairovskij, Yarilo, Kardishah compared to the variety Ilichevskij rannij.

Thus, according to the fluorescence induction coefficient of chlorophyll (*Ki*), the potential productivity of grape plants of all varieties was at a very high level compared with data obtained by other analysis (**Zelenianska, 2009; Havryliuk et al., 2019; He et al., 2018; Bober et al., 2020**).

The coefficient of adaptability or “viability index” (*Rfd*) we used to assess the impact of growing conditions on the state of the plant. Reduction of the calculated *Rfd* to 1.47 – 1.91 c. u. indicates the negative impact of growth conditions or the possible effect of stress on the efficiency of the Calvin cycle (**Lysenko et al., 2013; El Sayed et al., 2019; Shanina et al., 2019**). In grape plants at the development phase, “the inflorescence is visible”, the average viability index among varieties was 2.49 c. u., at the phase of “the beginning of ovary growth” there was a decrease to 1.89; at the phase “the beginning of berry ripening” – up to 1.96 c. u. Plants were cultivated on a well-lit area, on a vertical trellis, the access of the sun to all parts of the grape bush is very good, so, in our opinion, the efficiency of photosynthetic processes is generally high.

The efficiency of photosynthetic processes by the coefficient of adaptability of the variety Muskat odesskij indicates a low intensity of photochemical processes in the second and third measurement period; the decrease in *Rfd* was 30.3 – 31.2%. In our opinion, it is associated with a negative effect of anthracnose on the plant; Muskat odesskij variety is more susceptible than other varieties.

The smallest changes in the viability index (5.7 – 7.2%) were determined for plants of the variety Aromatnyj.

To establish the influence of weather conditions during the growing season on the processes of photosynthesis in grape leaves, we used the indices of hydrothermal coefficient, the sum of active temperatures, the amount of precipitation (*Ki* index), except for Kishmish tairovskij, Muskat odesskij and Persej, for which a greater influence (correlation coefficient $r = 0.36 - 0.38$, moderate influence) was noted in comparison with other grape varieties (Table 2).

In general, the potential productivity of grape plants (according to *Ki* index) was weakly and moderately dependent on weather conditions during the growing season. Among the meteorological elements, the greatest influence on the efficiency of the light phase of photosynthesis in the leaves of the studied grape plants was the amount of precipitation (moderate).

The influence of weather conditions on the value of the coefficient of adaptability (*Rfd*) was greater than the value of *Ki*. The high influence of HTI on the efficiency of dark photochemical processes in the leaves of the variety Kardishah, for most varieties of grapes it was noticeable (correlation coefficient $r = 0.50 - 0.69$), only for varieties Zagadka, Kishmish tairovskij, Kometa and Yarilo it was moderate (correlation coefficient $r = 0.30 - 0.49$). The efficiency of dark photochemical processes in the leaves of most grape varieties significantly ($r = 0.50 - 0.69$) depended on $\Sigma act t \geq 10^\circ C$ during the growing season, the least dependence on these factors was observed among the varieties Aromatnyj and Yarilo. The amount of precipitation had a weak effect on the quantum efficiency of photosynthesis in the leaves of most grape varieties, but it had a moderate effect on the efficiency of photosynthesis in the leaves of Aromatnyj and Kishmish tairovskij varieties.

CONCLUSION

Analysis of changes in the induction of chlorophyll fluorescence (ICF) of leaves revealed the more efficient use of quantum energy of absorbed light by F_0 in the leaves of most varieties was noted in the phase “the beginning of berry ripening”. During the three periods of the study, the varieties Aromatnyj, Zagadka, Ilichevskij rannij, and Kardishah showed a lower content of chlorophyll molecules, which do not have a functional connection with the reaction centers (RC). According to the *Fp* index the highest intensity of photosynthesis on average for all varieties was observed in the phase “the beginning of ovary growth”, the lowest one was at “the inflorescence is visible” phase. The potential productivity of grape plants by the coefficient of ICF for all varieties was at a very high level and had a weak and moderate correlation with weather conditions during the growing season. The hydrothermal coefficient and $\Sigma act t \geq 10^\circ C$ had a weak effect on the efficiency of the light phase of photosynthesis and a noticeable one (correlation coefficient $r = 0.50 - 0.69$) on the efficiency of dark photochemical processes in the leaves of most grape varieties. Weather conditions during the vegetation in 2019 – 2020 differed from the average long-term data by a greater accumulation of heat (on average by $644^\circ C$). The influence of meteorological elements of the spring-summer

period on the onset of the vegetation phases, which in 2019 took place on average 12 days earlier than in 2020, was noted.

These data show that despite the differences in the onset of the vegetation phases and weather conditions during 2019 and 2020, the processes of photosynthesis in grape leaves are at a high level. That indicates a high potential for plant adaptation to the conditions of the northern part of the Forest-Steppe of Ukraine.

In conditions of local and global climate change, it is important to study the adaptive properties of plants to new soil and climatic conditions. In the future, it will allow expanding and changing the areas of cultivation of grapes plants. So that to provide with enough grapes, the population of Ukraine and the world.

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Funds:

This research received no external funding.

Acknowledgments:

This study is a part of the PhDs Thesis of Olena Vasylenko. The authors would like to thank for its support to the study to the Department of Horticulture them Prof. V. L. Symyrenko of National University of Life and Environmental Sciences of Ukraine (Kyiv) and to the Laboratory of Plant Physiology and Microbiology of Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (Kyiv).

Conflict of Interest:

The authors declare no conflict of interest.

Ethical Statement:

This article does not contain any studies that would require an ethical statement.

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