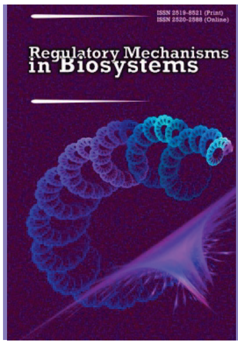

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Adaptation of gooseberry varieties to the changed agro-climatic conditions of Kyiv Polissia

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In connection with global warming, the study of plant adaptation to climate change, resistance to lack of moisture and high temperatures becomes relevant. Meteorological and phenological observations prove that a change in temperature conditions leads to an earlier start of vegetation and a lengthening of the growing season in all investigated gooseberry varieties. To assess the functional state of the photosynthetic apparatus of plants, a minimally invasive instrumental method of determining the intensity of chlorophyll fluorescence in plant leaves, adapted to work on the domestic photofluorimeter "Floratest", was used. Based on the results of the analysis of the parameters of the chlorophyll fluorescence induction curves (Fo, Fpl, Fmax, Ft) and the comparison of the coefficients for these values (Kpl, K1, K2), it was established that Fo and Kpl are the most informative. A strong correlation dependence of the indicator of the background level of fluorescence at the time of full opening of the shutter (Fo) was established. The value of Fo correlates positively with indicators of the moisture regime, negatively – with temperature indicators. Correlations between the fluorescence growth index and the variable (Kpl) showed the opposite: the largest positive correlation was observed with mean maximum temperature, the smallest with precipitation. On the basis of mathematical analysis and modeling of the obtained FIC curves and indicators of agro-climatic conditions, the values of the maximum temperature and the minimum amount of precipitation, which are critical for the functioning of the gooseberry photosynthetic apparatus, were determined. Such a study makes it possible to evaluate the course of photochemical reactions associated with the work of plant photosystems according to standard coefficients of photochemical activity, which have already been tested in numerous works of domestic researchers on a wide range of agricultural crops.

Keywords: photosynthesis; area of the assimilation surface; chlorophyll; induction of chlorophyll fluorescence; average berry weight; crop capacity; correlation.

Introduction

In connection with climate change, the industrial cultivation of plants is losing economic attractiveness, as there is a risk of a decrease in productivity due to the consumption of plant resources for adaptation to temperature changes, moisture deficit, recovery from stress and pests (Avtaeva et al., 2021; Benabou et al., 2022; Elmalki et al., 2022).

Gooseberry is one of the most valuable berry crops due to the high nutritional value of the fruits, which are a source of energy, vitamins, organic acids, and minerals. Gooseberry berries have medicinal properties, because they contain vitamins, pectin substances and trace elements. They are recommended as a dietary product because the sugars in the fruit are glucose and fructose. Gooseberry belongs to the universal berry culture, it is consumed both fresh and used for further processing. In recent years, there is a tendency for plantations to decrease, gooseberry is becoming a rare berry crop. According to the Institute of Horticulture, as of 2020, the total area of fruit-bearing gooseberry plantations in Ukraine is less than 1,000 hectares, about half of them in agricultural enterprises. When growing this crop, unfavourable agro-climatic conditions (insufficient rainfall or uneven distribution, early spring frosts, etc.) lead to a decrease in the intensity of production processes in plant leaves, and the yield of berries also decreases significantly. Among the important aspects of increasing the productivity of berry plantations is the scientifically based selection of varieties with high photosynthetic activity, adapted to certain soil and climatic conditions of cultivation. Studying the impact of agro-climatic conditions on gooseberry plants, especially during the active formation and unfolding of their productivity potential, is a relevant and important measure for increasing the effectiveness of scientific research on the selection of highly adaptive forms of the above culture. The study of changes in the induction of chlorophyll fluorescence is a sensitive and informative method of obtaining data on the functional state of plants, their reaction to the influence of environmental factors. The analysis of scientific literature showed that the study of the characteristics of the photosynthetic apparatus of wild and agricultural plants has been carried out by many scientists. Oleksiychenko et al. (2013), Vasylenko (2015), Starychenko (2016), Shepeliuk et al. (2017), Mamonova et al. (2018) studied the functional state of the pigment complex of the leaf apparatus of woody plants using the method of induction of chlorophyll fluorescence. Zelenyanska (2009) investigated the induction of chlorophyll fluorescence in the leaves of grape seedlings to determine their resistance to high air temperatures. Shavanova et al. (2014) established the effectiveness of the method of photoinduction of chlorophyll fluorescence to determine the functional state of the photosynthetic apparatus of common bitter chestnut. Kytaev et al. (2012), Kyryk et al. (2011), Lagutenko et al. (2007, 2021), Trokhymchuk & Makarova (2022) used the method of induction of chlorophyll fluorescence to diagnose the condition of fruit and berry bush crops.

Commonly accepted methods of determining the productivity of photosynthesis (net productivity of photosynthesis, dry matter content, potential yield, etc.) give only a relative characteristic of this process, therefore we investigated indicators that depend not only on the varietal characteristics of plants, but also on their provision by environmental factors. The results of such studies make it possible to evaluate the functional state of the plant as a whole at the time of study and to single out the variants most adapted to certain growing conditions.

Materials and methods

In order to study the development of young gooseberry plants during the growing season, the impact of agro-climatic conditions and the identification of varieties resistant to adverse environmental conditions, we conducted meteorological and phenological observations; determined the area of the assimilation surface, the content of chlorophyll in the leaves; changes in the induction of chlorophyll fluorescence in gooseberry leaves during the growing season were analyzed; the initial yield of 2-3-year-old plants of the above-mentioned culture was determined. The object of the study were gooseberry varieties: 'Izumrud', 'Bezshypnyi', 'Neslukhivskyi' and 'Krasen'. 'Izumrud' is an early variety, the result of breeding work of the South Ural Research Institute of Horticulture and Potato Growing, obtained by crossing 'Samorodok' and 'Pervistok Minusynska'. The bushes are medium-sized, slightly spreading. Shoots are straight, of medium thickness. Thorns are located along the entire length of the shoots. The leaves are of medium size, dark green. Fruits are green in colour, oval in shape, sweet-sour dessert taste. The weight of the berry is up to 6.5–7.5 g. The yield from the bush is about 4–5 kg and more. A variety of universal use, frost-resistant, resistant to spheroteka, high-yielding. 'Bezshypnyi' – a medium-ripening variety of Ukrainian selection. The bushes are medium-sized, medium-spreading. Shoots are straight, long, thick, without thorns. The leaves are large, green. The fruits are green with a red blush, sweet and sour, and have a pleasant nutmeg aroma. The weight of the berry is up to 5 g. The yield from the bush reaches up to 4 kg. Variety of universal use, frost-resistant, drought-resistant, high-yielding. 'Neslukhivskyi' – an early ripening variety of Ukrainian selection, obtained by crossing the 'Mliivskyi Chervonyi' and 'Slyvovyi' (authors: K. M. Kopan, V. P. Kopan, Z. A. Shestopal). The bushes are medium-sized, weakly spreading. Branches are thick, straight, very prickly. Thorns are strong, located along the entire length of the shoot. The leaves are large, green. The fruits are red in colour, with a pleasant sour-sweet taste. The weight of the berry is 6–8 g. The yield from the bush is 8 kg. A variety of universal use, frost-resistant, drought-resistant, resistant to septoriosis, relatively resistant to spheroteka, high-yielding. 'Krasen' is a medium-ripening variety of Ukrainian selection (a complex hybrid, in the origin of which representatives of European and American gooseberry species participated), bred by I. O. Mykolaichuk at the Mliiv Institute of Horticulture of the National Academy of Sciences (now the Research Station of Pomology named after L. P. Simyrenko of the Institute of Horticulture of the National Academy of Sciences). The bushes are medium-sized, semi-spreading, the tops of the branches hang in an arc. Branches of medium thickness, weakly prickly, spines are located in the middle part of the shoot. The leaves are of medium size, dark green. Fruits are brown-red. The weight of the berry is 3.8–5.2 g. The yield from the bush is up to 4.5 kg. A variety of universal use, frost resistance is average, winter-hardy, resistant to diseases, in particular to spheroteka (Lagutenko & Kitaev, 2007; Lagutenko et al., 2021).

A field study on the functioning of the photosynthetic apparatus in gooseberry leaves was conducted at the research site of the educational and research biostation "Tatarka" of the Mykhailo Drahomanov Ukrainian State University (Ukraine, Kyiv) during 2020–2021. Plant care was carried out according to the generally accepted technology of growing bushy berry crops. Records and observations were carried out on the same type, equally developed 2–3-year-old bushes. Laboratory studies were carried out in the Laboratory of Plant Physiology and Microbiology of the Institute of Horticulture (IH) of the NAAS of Ukraine (Ukraine, Kyiv).

According to natural conditions, the studied area belongs to the Kyiv Polissia, where a temperate continental climate prevails with moderately hot summers and cold winters. According to the data of the agrometeorological station of the IH of the NAAS of Ukraine "Novosilky", the year 2020 (Fig. 1) was characterized by a warm winter (the maximum average daily temperature in the first decade of February reached +8.6 °C) and a hot summer (the average daily temperature in the second decade of June exceeded the average long-term indicators by 7 °C). The spring of 2020 was marked by intense frosts (–1…–3 °C) in April during flowering and fruit setting in gooseberry plants. In the first two springs, insufficient precipitation was observed at the site (Fig. 2), which threatened a significant decrease in yield after a snowless winter. In May, prolonged rainfall (75 mm more than the average long-term data) somewhat corrected the situation and during the period of the beginning of fruit formation, the gooseberry plants were well supplied with moisture.

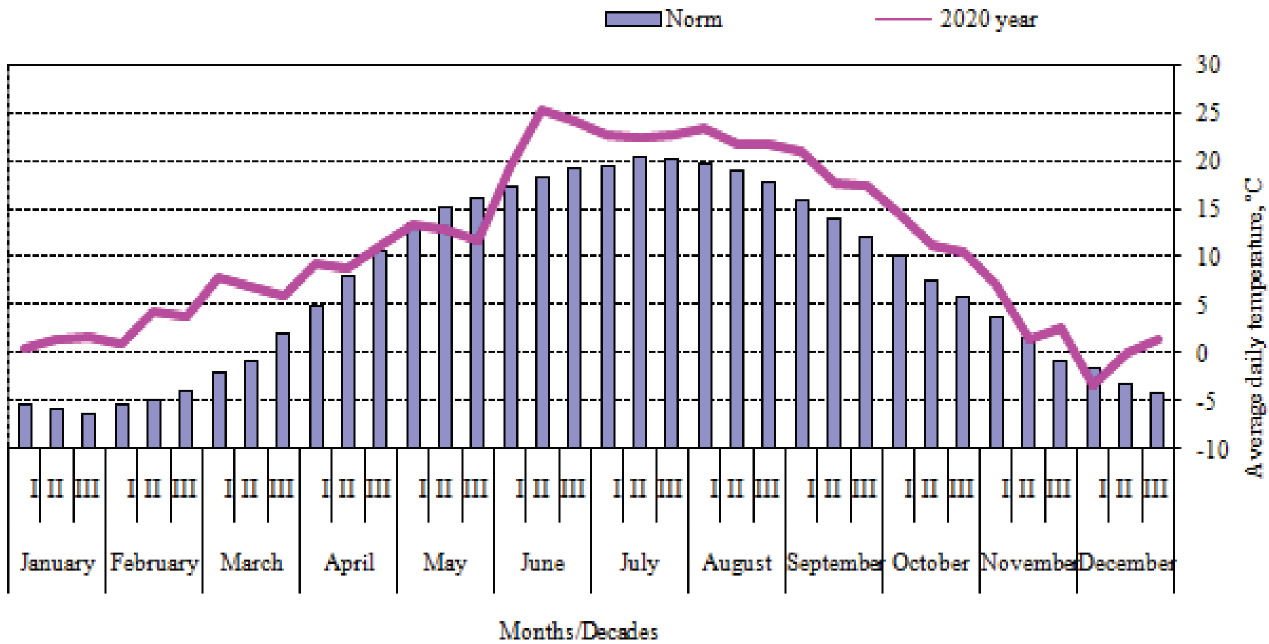

Fig. 1. The temperature regime of Kyiv Polissia (according to the weather station of the Institute of Horticulture)

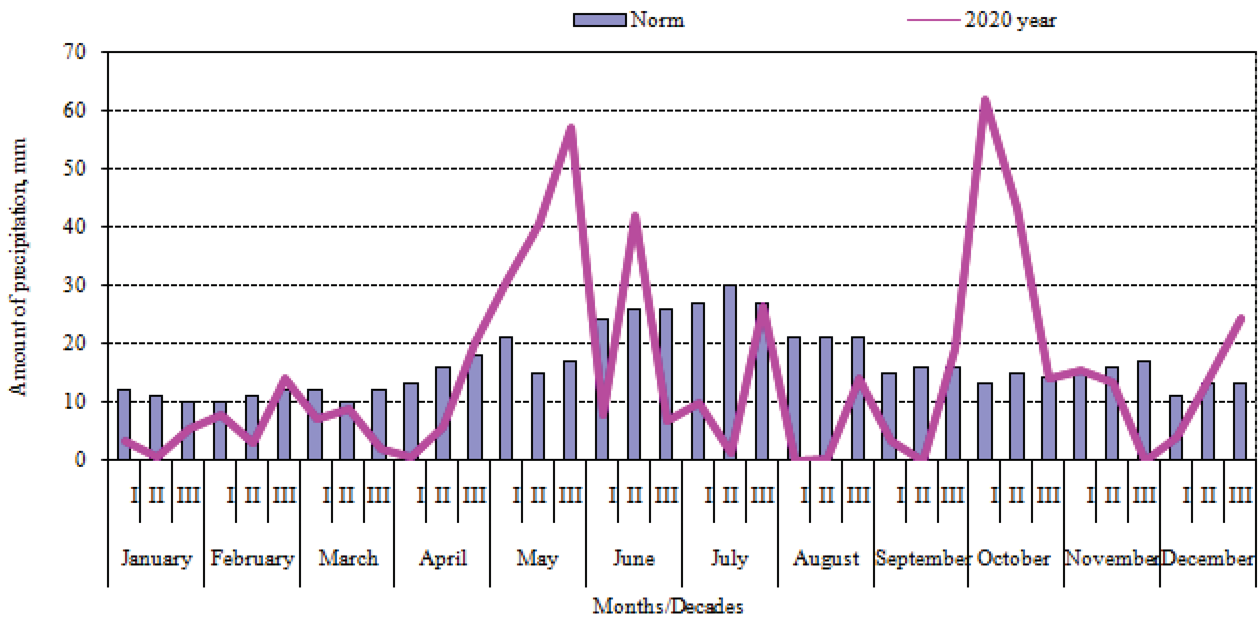

Fig. 2. Precipitation regime in Kyiv Polissia (according to the weather station of the Institute of Horticulture)

In the summer, an uneven distribution of precipitation was observed, as a result of which it was possible to distinguish separate rainy and dry periods, and in general, an insufficient level of hydration was noted. In June, 56.5 mm of precipitation fell, which is 25% less than the average long-term monthly norm. In the next two decades of July, there was almost no precipitation, and in general, only 45% of the average long-term norm fell in July. In August, precipitation fell only in the third decade in an amount that was 23% of the norm.

Autumn was characterized by moderately warm and fairly humid weather. September was abnormally warm, the average daily temperature ranged from +11.1 to +27.4 °C. The average daily temperature in October did not fall below +6.6 °C. The distribution of precipitation was uneven: in September, the amount of precipitation was only 23.2 mm, in October – 119.0 mm, in November – 28.8 mm.

Therefore, the agro-climatic indicators during the research significantly differed from the perennial averages, their indicators at certain stages of vegetation were unfavourable for the growth and development of gooseberry plants, they did not fully provide them with heat and moisture for crop formation.

According to the agro-soil zoning of Ukraine, the studied territory, on which our experimental site is located, belongs to the northern subprovince of the Right-bank central high province of the forest-steppe zone of chernozem typical and grey forest soils. The soil of the research area is light grey, golden, with an average content of humus, the subsoil is loam. The site is located with a slight slope (up to 1 °) of northern exposure and the depth of groundwater is deeper than 1.5 m.

To determine the assimilation surface and chlorophyll content, leaf samples were taken on 11.07.2020 in field conditions, after which work was continued in the laboratory using quantitative, morphometric, and biochemical methods. The cutting method is used to determine the leaf surface area of most agricultural crops. First, the area of the leaf plate was determined in triplicate from at least 10 leaves of the same plant. They were weighed, then with the help of a metal tube of a certain diameter with sharp edges – 10 cuttings with a total area of 45 cm^2 were selected. After weighing the cuttings, a calculation was made according to the formula: $S = (M \cdot S_1 \cdot n)/(m \cdot N)$, where S is the area of the leaf plate (cm^2); S_1 – the area of one cutout (cm^2; $S_1 = 0.785$ D, where D is the diameter of the cutout (cm)); n – number of die-cuts (pcs); M – mass of leaves (g); m – mass of cuttings (g); N – number of leaves (pieces). After the growth of the shoots was completed, the number of leaves on the accounting bushes was counted. By multiplying the number of leaves by their average size ($S_{average}$), we got the total area of leaves per bush.

Determination of the content of chlorophyll a and b in the leaves of gooseberry plants was carried out in alcohol extraction by the spectrophotometric method in three repetitions. For this, cutouts of a certain area (1–2 cm^2) were made, weighed and transferred with tweezers to separate test tubes, 5 mL of 96% ethyl alcohol were added and closed with rubber caps. The stand with test tubes was left in the dark to extract the pigments until the cutouts were completely decolorized. The spectrophotometer measured the absorption coefficients of the pigment solution for wavelengths of 663 and 645 nm.

To observe the dynamics of changes in the induction of chlorophyll fluorescence, a portable chronofluorimeter device "Floratest" developed by the State Scientific and Engineering Center of Microelectronics of V. M. Hlushkov Institute of Cybernetics (Romanov et al., 2010) was used. Selection of leaf samples for research was carried out during the phase of gooseberry fruiting and after harvesting in three terms: May 30, July 11 and August 23.

Determination of the induction of chlorophyll fluorescence was carried out at an excitation light intensity of 50–60 W/m^2. When, after adaptation in the dark, the leaf was illuminated with blue light from LEDs, red fluorescence was excited in the chlorophyll of the leaf. A fluorescent signal arrives at the photoreceptor, which converts it into an electrical signal and amplifies it. The processor module of the device receives an electrical signal from the photoreceptor, which is proportional to the fluorescence of chlorophyll. The curve CFI, induction curve or Kautsky curve is a characteristic type of curve with one or several maxima, showing the change in fluorescence intensity over time when they are illuminated (Bryon et al., 2000; Korneev, 2002).

The change in chlorophyll induction was studied in three repetitions with a three-minute measurement cycle. To assess changes in the functioning of photosynthetic processes in leaves, we analyzed the following main indicators of fluorescence photoinduction: Fo – initial fluorescence value after illumination; Fpl – a steady value of fluorescence after light adaptation of a plant leaf, which precedes a sharp increase in fluorescence intensity (the first fluorescence maximum); Fmax – the maximum value of fluorescence (and there may be several maxima); Ft – stationary level of fluorescence after 1.5–3.0 minutes after the start of illumination.

To determine the efficiency of the photosynthetic apparatus of the leaves of gooseberry plants, the coefficients Kpl, K1 and K2 were used, which were calculated according to the formulas: Kpl = (Fpl – Fpl)/(Fmax1 – Fo) – the share of centers that do not restore the primary electron acceptor QA under the saturating intensity of the exciting light (about 400–600 W/m^2); K1 = (Fmax1 – Fo)/Fmax1 – coefficient of efficiency of electron transport near the reaction centers of photosystem 2 (PS 2); K2 = (Fmax2 – Ft)/Ft – coefficient of efficiency of dark photochemical processes.

To determine the productivity of bush berries, berries were collected in the phase of full ripeness by hand, accounting was done by weighing the berries collected from the bush (kg/bush). The indicator of the average mass of berries was determined by weighing 50 berries, followed by dividing the obtained value by 50.

Statistical processing of the research results was carried out by the method of analysis of variance (ANOVA). A multiple linear regression model was used to establish a correlation between the parameters of the chlorophyll fluorescence curve and weather conditions.

The research was carried out within the framework of the fundamental topic: 22.01.03.02 F "Scientific substantiation of techniques for regulating the functional state of fruit and berry plants for the purpose of greening technologies of their cultivation" (IH of the NAAS of Ukraine) and the agreement on cooperation between Mykhailo Drahomanov Ukrainian State University and IH of NAAS of Ukraine.

Results

The passage of plants through development phases, their onset and duration depend only on the varietal characteristics of the plants and the climatic conditions of the year. In 2020, the length of the growing season in the studied gooseberry varieties ranged from 177 to 200 days. The growing season lasted the longest in the early and early-medium maturing varieties 'Izumrud', 'Bezshypnyi' and 'Neslukhivskyi' – 197–200 days, and the shortest – in the medium-maturing 'Krasen' – 177 days. In the northern forest-steppe, gooseberry vegetation usually begins in the third decade of March – early April. In 2020, the growing season began in 'Izumrud' on March 4, in 'Bezshypnyi' on March 5, in 'Neslukhivskyi' on March 6, and in 'Krasen' on March 7. Therefore, the gooseberry vegetation in the research year started two weeks earlier. In 28–30 days from the beginning of vegetation, the phases of inflorescence extension and bud separation began.

In the northern forest-steppe, according to scientists, gooseberry blooms on April 20–25, and in the case of a cold, protracted spring, in early May when the average daily temperature is +7…+18 °C. According to our observations, gooseberry flowering took place from April 13 to 18, that is, 1–2 weeks earlier. There was also a difference in flowering time between the varieties of 1–5 days – 'Izumrud' (April 13) and 'Bezshypnyi' (April 14) bloomed first, followed by 'Neslukhivskyi' (April 16), and then 'Krasen' (April 18). The flowering phase lasted 12–13 days, which is associated with significant daily fluctuations in air temperature (–1…+25 °C) during this period (second and third decades of April). The studied varieties entered the phase of flowering and ovary formation in the northern forest steppe, according to our data,as follows: 'Izumrud' – April 25, 'Bezshypnyi' – April 26, 'Neslukhivskyi' – April 29, 'Krasen' – May 1. During this period (the first and second decades of May), a decrease in the minimum air temperature to 0…+1 °C was observed, which had a negative effect on the productivity – some of the ovaries were damaged and fell off.

During the research years, gooseberry plants of the 'Izumrud' and 'Bezshypnyi' entered the fruiting phase on May 14, the 'Neslukhivskyi' on May 15, and the 'Krasen' on May 18. Fruit ripening was noted after 57–60 days. The harvest was carried out in the phase of full ripeness on July 15. The length of the fruiting phase (up to 64 days) indicates that the gooseberry plants did not receive sufficient amounts of the life factors they need (in particular, moisture). In the research year, leaves began to fall in 'Izumrud', 'Bezshypnyi' and 'Neslukhivskyi' varieties on July 17, in 'Krasen' – on July 10. In conditions of insufficient rainfall (July 2020, Hydrothermal coefficient 0.3), some of the leaves of the plant were shed already in the fruiting phase in order to reduce the evaporation of moisture. In the phase of leaf fall, according to our observations, the leaves that were damaged due to lack of moisture first fell. An extension of the time period of this phase was observed. Mass fall of leaves occurred in the 'Izumrud', 'Bezshypnyi', 'Neslukhivskyi' varieties on September 25, and in the 'Krasen' on September 6, which was associated with the first long-term precipitation. Although the dates of the onset of leaf fall in plants are hereditarily fixed, our observations prove their dependence on weather conditions.

In general, in 2020, in the first half of the growing season, gooseberry plants were not sufficiently provided with heat, and in the second half, they suffered from a lack of moisture, which significantly affected the passage of gooseberry plants through the phenological phases of growth and development.

The size of the leaf plate is a biological feature of the variety and the total area of the assimilation surface depends on the length of the shoots and skeletal branches and the number of leaves located on them. Our research has established that gooseberry plants of the 'Krasen' have the smallest leaf surface area of 1846 cm^2/bush, and 'Bezshypnyi' has the largest – 3856 cm^2/bush (Table 1).

Table 1
The area of the assimilation apparatus of 2–3-year-old gooseberry plants of various varieties in the conditions of Kyiv Polissia (2020, x ± SD, n = 9)

Varieties	Foliage, pcs/bush	Leaf blade area, cm^2	Leaf surface area, cm^2/bush
Izumrud	268.2 ± 14.5^a	10.7 ± 3.1^a	2873 ± 193^a
Bezshypnyi	189.3 ± 14.6^b	20.4 ± 2.6^b	3856 ± 179^b
Neslukhivskyi	224.1 ± 14.2^c	13.5 ± 2.5^a	3024 ± 204^a
Krasen	181.2 ± 14.1^{bc}	10.2 ± 2.9^a	1846 ± 202^c

Note: values that are significantly different within a column are marked with different Latin letters (P < 0.05) according to the Tukey test results with Bonferroni correction.

At the same time, the area of the leaf surface in plants of the 'Krasen' is significantly smaller compared to the rest of the varieties due to the much smaller size of the leaf plate (10.2 cm^2) and the smaller number of leaves on the shoots (181.2 pcs/bush). In plants of the 'Bezshypnyi', this indicator is the largest and is 20.4 cm^2, although the foliage of the shoots is almost the same as in 'Krasen' (189.3 pcs./bush). The leaf surface area of the 'Izumrud' is 1.6 times greater compared to 'Krasen' due to an increase in the foliage of the shoots (268.2 pcs./bush), although the size of the leaf plate increases insignificantly (10.7 cm^2) – the difference between the indicators is within the standard deviation. In the studied plants of the 'Neslukhivskyi', the leaf surface area is 1.7 times larger compared to 'Krasen' due to an increase in the number of leaves on the shoots (224.1 pcs./bush) and a significant increase in the size of the leaf plate (13.5 cm^2). The leaf surface area of plants of the 'Neslukhivskyi' and 'Bezshypnyi' varieties is larger compared to 'Krasen' and 'Izumrud', as their biological feature is the larger size of the leaf plate.

An important role in the formation of photosynthetic productivity of plants is given to the main component of plant photosystems – chlorophyll, which ensures the absorption of photons and determines the efficiency of their energy use.

According to the results of determining the content of green pigments among the studied varieties of gooseberry, the content of chlorophyll *a* and chlorophyll *b*, as well as the total content of chlorophylls *a* and *b*, both in terms of leaf mass and their area, is higher in the 'Krasen' (Table 2).

Table 2
Quantitative indicators of the content of chlorophylls a and b in gooseberry leaves in the conditions of Kyiv Polissia (2020, x ± SD, n = 9)

Varieties	Chlorophyll, mg/g			Chlorophyll, mg/dm^2		
	a	*b*	*a+b*	*a*	*b*	*a+b*
Izumrud	1.11 ± 0.30^a	0.39 ± 0.22^a	1.50 ± 0.31^a	0.98 ± 0.27^a	0.35 ± 0.16^a	1.34 ± 0.35^a
Bezshypnyi	1.75 ± 0.21^b	0.61 ± 0.18^{ab}	2.36 ± 0.28^b	1.55 ± 0.23^{bc}	0.55 ± 0.18^a	2.10 ± 0.36^b
Neslukhivskyi	1.33 ± 0.23^{ab}	0.46 ± 0.21^{ab}	1.79 ± 0.36^{ab}	1.43 ± 0.26^{abc}	0.50 ± 0.18^a	1.92 ± 0.32^{ab}
Krasen	2.17 ± 0.14^c	0.76 ± 0.14^{ab}	2.93 ± 0.25^c	1.79 ± 0.20^{bc}	0.62 ± 0.16^a	2.41 ± 0.29^b

Note: see Table 1.

Since this variety was distinguished by the smallest area of the leaf surface, it is likely that the production processes in the leaves are intensified due to a greater amount of green pigments. In addition, this may indicate the inconsistency of growing conditions with the needs of this variety to environmental factors.

The 'Izumrud' variety was distinguished by the lowest indicators of the content of chlorophyll a and chlorophyll b, as well as the total content of chlorophylls *a* and *b*, both in terms of the mass of leaves and their area. The studied plants of this variety with low indicators of the leaf surface area are characterized by low indicators of the content of photosynthetic pigments, which indicates a high adaptation potential relative to the influence of adverse growing conditions. The varieties ‘Neslukhivskyi’ and ‘Bezshypnyi’ occupy an intermediate position in terms of chlorophyll content, which also indicates a satisfactory supply of gooseberry plants with environmental factors.

The indicator of the ratio of chlorophylls a/b in the studied gooseberry plants is in the range from 1.5 to 3.0, which indicates a sufficient level of illumination in the conditions of the experimental site. The almost identical ratio of chlorophylls *a/b* in the studied varieties shows that the gooseberry plants were in the same lighting conditions and the leaf samples were selected correctly.

Therefore, the determination of changes in the induction of chlorophyll fluorescence was carried out dynamically by monitoring weather conditions in the periods (22 days) preceding the selection of samples for research (Table 3).

Table 3
Indicators of weather conditions during the study period of induction of chlorophyll fluorescence (2020)

Time	Temperature, °C			Humidity, %			Rainfall, mm (D)
	average minimum (T_{min})	average daily (T_d)	average maximum (T_{max})	average minimum (P_{min})	average daily (P_d)	average maximum (P_{max})	
May 9–30	+6.7	+12.9	+15.9	39.0	60.6	77.7	104.4
June 20 – July 11	+18.0	+23.8	+26.2	30.4	53.9	76.3	17.8
August 2–23	+15.2	+22.6	+31.2	22.1	45.5	70.0	0.3

In the period May 9–30, the weather conditions were characterized by optimal temperature indicators (the average daily temperature was about +12.9 °C) and a sufficient amount of precipitation (32 mm).

In the period June 20 – July 11, the average daily air temperature ranged +16 … +21 °C, only 17.8 mm of precipitation fell (within this period, there was no precipitation for two weeks). That is, the weather conditions were characterized by a moderate heat regime and a small amount of precipitation.

The period August 2–23 was characterized by cool weather with significant temperature drops. The average daily temperature ranged +8.2 … +17.6 °C, which did not fully provide gooseberry plants with heat. The rainless period in general lasted about a month (June 26 – July 23), which negatively affected the state of gooseberry plants, which partially shed their leaves to reduce transpiration.

The shape of the curve of FIC is sensitive to changes in the state of the photosynthetic apparatus as a result of the action of both the main environmental factors and endogenous factors.

According to the results of measurements of fluorescence induction of gooseberry leaves of the ‘Izumrud’, FIC curves with a significant amplitude of fluorescence intensity were obtained, which indicates its greater adaptability to the influence of adverse environmental conditions. To assess the state of the photosynthetic apparatus of plants, a number of quantitative indicators are used, determined by the curve of FIC (Table 4).

Table 4
Dynamics of the state of the photosynthetic apparatus of ‘Izumrud’ gooseberry plants (2020, x ± SD, n = 9)

Terms of sample selection	Indicators of the fluorescence curve					Coefficients		
	Fo	Fpl	Fmax1	Fmax2	Ft	Kpl	K1	K2
May 30	416 ± 7^a	816 ± 35^a	1344 ± 130^a	1296 ± 126^a	336 ± 68^a	0.43 ± 0.01^a	0.69 ± 0.06^a	2.86 ± 0.19^a
July 11	416 ± 6^a	752 ± 34^a	1184 ± 127^a	1136 ± 124^a	528 ± 71^b	0.44 ± 0.01^{ab}	0.65 ± 0.04^{ab}	1.15 ± 0.26^b
August 23	396 ± 7^b	624 ± 36^b	896 ± 130^b	872 ± 120^b	544 ± 62^b	0.46 ± 0.01^b	0.56 ± 0.07^b	0.60 ± 0.24^c

Note: see Table 1.

The indicator of the initial level of Fo fluorescence at the beginning of the summer was 416 units, and at the end of the summer it slightly decreased to 396 units. According to our observations, the Fpl indicator of the "Izumrud" variety is significantly high at the beginning of summer, during the summer it gradually decreases from 916 to 624 relative. Two maxima of fluorescence induction, Fmax1 and Fmax2, determined by the structural and functional features of the course of photosynthesis in the leaves of gooseberry plants, were identified. In ‘Izumrud’, the Fmax2 indicator decreased during the summer from 1344 to 896 relative units. Fmax2 did not exceed Fmax1, although the background fluorescence Fo as a percentage of the maximum fluorescence flash was 34–35%. Such data significantly exceed the optimal indicator (20–25%), which may indicate a mismatch of temperature and water regimes in the reporting year of 2020.

According to our observations, the indicator of the Kpl plateau coefficient in the ‘Izumrud’ at the end of summer exceeded the threshold level of 0.45. This is associated with an increase in the share of inactive PS2 reaction centers and indicates the existing processes of leaf aging (primarily due to the negative impact of abiotic factors). However, this increase in Kpl was within experimental error. At the same time, the decrease in K1 and K2 indicators in the ‘Izumrud’ variety during the summer, especially against the background of increased Fo and Kpl indicators, indicates not only a decrease in the intensity of photochemical processes, but also destructive changes in the photosynthetic apparatus. In field studies, gooseberry plants showed premature dropping of part of the leaves to reduce transpiration.

Curves of FIC are stable and compact, which indicates sufficient supply of ‘Bezshypnyi’ plants with life factors. According to the data of the analysis of curves of FIC (Table 5), a significantly higher initial fluorescence value of Fo in the ‘Bezshypnyi’ was observed in the middle of summer – 400 relative units, while Fo in % to Fmax1 of this variety did not differ significantly in comparison with other variants of the experiment. The comparison of the above parameters of the fluorescence curve testifies to the increased potential productivity of gooseberry of the ‘Bezshypnyi’ during this period.

Table 5
Dynamics of the state of the photosynthetic apparatus of ‘Bezshypnyi’ gooseberry plants (2020, x ± SD, n = 9)

Terms of sample selection	Indicators of the fluorescence curve					Coefficients		
	Fo	Fpl	Fmax1	Fmax2	Ft	Kpl	K1	K2
May 30	384 ± 18^a	731 ± 32^a	1259 ± 152^a	1216 ± 156^a	341 ± 45^a	0.40 ± 0.01^a	0.69 ± 0.00^a	2.57 ± 0.21^a
July 11	400 ± 16^a	640 ± 29^b	992 ± 152^{ab}	965 ± 72^b	528 ± 65^b	0.41 ± 0.01^a	0.60 ± 0.00^b	0.83 ± 0.18^b
August 23	340 ± 19^b	600 ± 38^b	960 ± 159^{ab}	924 ± 68^b	324 ± 39^a	0.42 ± 0.01^a	0.65 ± 0.00^c	1.80 ± 0.16^c

Note: see Table 1.

The adapted value of Fpl fluorescence in the ‘Bezshypnyi’ cultivar at the beginning of summer was 731 relative units, which significantly exceeded this indicator in subsequent measurements. The maximum fluorescence values of Fmax1 and Fmax2 at the beginning of summer (1259 and 1216 relative units, respectively) were significantly higher than in subsequent measurements. In the ‘Bezshypnyi’, the stationary level of Ft fluorescence had a significantly higher value in the middle of summer (528 relative units), which indicates a higher level of the intensity of photosynthesis precisely during the period of intensive fruit formation. This statement correlates with the conclusions based on the Fo indicator. According to our observations, the indicator of the Kpl plateau coefficient in the ‘Bezshypnyi’ during the summer did not exceed the threshold level of 0.45 units, which indicates the lack of reaction of the photosynthetic apparatus to the influence of external factors. The value of the K1 indicator varied insignificantly and averaged 0.65 units, which indicated the stability of the structural and functional potential of leaf chloroplasts. The K2 indicator in the ‘Bezshypnyi’ at the beginning of summer had significantly higher values compared to the following measurements. Thus, electronic transport on PS2 and PS1 occurs more efficiently in young leaves of ‘Bezshypnyi’ plants.

According to the results of measurements of changes in fluorescence induction in the leaves of plants of the ‘Neslukhivskyi’ (Table 6), we observe that at the beginning of summer, the indicator of the initial value of fluorescence Fo, which was 427 relative units, was significantly higher compared to the following measurements.

The adapted fluorescence value of Fpl in the ‘Neslukhivskyi’ was also significantly higher at the beginning of summer (May 30) and was

731 relative to unit, indicating rapid saturation of inactive PS2 reaction centers in this period. The maximum fluorescence values of Fmax1 and Fmax2 at the beginning of summer in the 'Neslukhivskyi' are significantly higher (1461 and 1424 relative units, respectively) than in the following measurements. A significantly high stationary level of Ft fluorescence (584 relative units) was noted in the 'Neslukhivskyi' in mid-summer, which indicates a higher level of photosynthesis intensity during this period.

Table 6
Dynamics of the state of the photosynthetic apparatus of 'Neslukhivskyi' gooseberry plants (2020, x ± SD, n = 9)

Terms of sample selection	Indicators of the fluorescence curve					Coefficients		
	Fo	Fpl	Fmax1	Fmax2	Ft	Kpl	K1	K2
May 30	427 ± 31[a]	731 ± 26[a]	1461 ± 168[a]	1424 ± 170[a]	421 ± 71[a]	0.29 ± 0.02[a]	0.71 ± 0.00[a]	2.38 ± 0.02[a]
July 11	336 ± 24[b]	528 ± 27[b]	912 ± 177[b]	896 ± 166[b]	584 ± 76[b]	0.33 ± 0.02[ab]	0.63 ± 0.00[b]	0.53 ± 0.02[b]
August 23	364 ± 26[b]	592 ± 23[b]	980 ± 173[b]	944 ± 169[b]	324 ± 80[a]	0.37 ± 0.02[b]	0.63 ± 0.00[b]	1.91 ± 0.02[c]

Note: see Table 1.

The Kpl coefficient in the 'Neslukhivskyi' during the growing season fluctuated insignificantly in the range from 0.29 to 0.37 units. At the beginning of summer, there was an increase in the K1 coefficient to 0.71 units compared to subsequent measurements, but this increase was within experimental error. The coefficient of K2 in the 'Neslukhivskyi' at the beginning of summer (May 30) significantly exceeds the indicators of the following measurements and is 2.38 units. This means that electron transport on PS2 and PS1 in the leaves of 'Neslukhivskyi' gooseberry occurs more efficiently during this period.

The shapes of the curves of FIC of the 'Krasen' indicate a higher photosynthetic potential and greater adaptive capacity of plants at the beginning of summer 2020. According to the results of measurements of changes in fluorescence induction in the leaves of plants of the 'Krasen' (Table 7), we observe that at the beginning of summer, the indicator of the initial value of fluorescence Fo, which was 400 units, significantly exceeds the following measurements.

Table 7
Dynamics of the state of the photosynthetic apparatus of 'Krasen' gooseberry plants (2020, x ± SD, n = 9)

Terms of sample selection	Indicators of the fluorescence curve					Coefficients		
	Fo	Fpl	Fmax1	Fmax2	Ft	Kpl	K1	K2
May 30	400 ± 18[a]	757 ± 37[a]	1349 ± 150[a]	1301 ± 152[a]	389 ± 57[a]	0.38 ± 0.04[a]	0.70 ± 0.00[a]	2.34 ± 0.23[a]
July 11	344 ± 22[b]	496 ± 33[b]	860 ± 158[b]	848 ± 143[b]	516 ± 63[b]	0.29 ± 0.03[b]	0.60 ± 0.00[b]	0.64 ± 0.16[b]
August 23	336 ± 20[b]	488 ± 40[b]	920 ± 153[b]	868 ± 148[b]	312 ± 58[a]	0.26 ± 0.04[b]	0.63 ± 0.00[c]	1.78 ± 0.18[c]

Note: see Table 1.

In the 'Krasen', the adapted Fpl fluorescence value was also significantly higher at the beginning of summer (May 30) and amounted to 757 relative units, indicating rapid saturation of inactive PS2 reaction centers in this period. The maximum fluorescence values of Fmax1 and Fmax2 at the beginning of summer in the 'Krasen' are significantly higher (1349 and 1301 relative units, respectively) than in the following measurements. A significantly high stationary level of Ft fluorescence (516 relative units) was noted for the 'Krasen' in mid-summer, which indicates a higher level of photosynthesis intensity during this period. The coefficient of Kpl in the 'Krasen' at the beginning of summer was 0.38, which significantly exceeded the following measurements. The K1 and K2 coefficients (0.70 and 2.34 units, respectively) in the 'Krasen' at the beginning of summer (May 30) are significantly higher compared to the following measurements.

Based on the above, we note that the leaf apparatus of the 'Krasen' gooseberry is prone to the accumulation of destructive changes and premature aging under a stressful water-temperature regime. This affects the reduction of the potential of plant productivity and their economic productivity in comparison with other variants of the experiment. The actual initial performance of the 'Krasen' gooseberry variety in the accounting year 2020 also turned out to be the lowest.

The photosynthetic function of the plant is the basis of crop formation, therefore the results of assessing the state of the photosynthetic apparatus are closely related to gooseberry yield indicators (Table 8).

Table 8
Generalized indicators of the intensity of photosynthesis and productivity of young 2–3-year-old gooseberry plants depending on the variety (Kyiv Polissia, harvest July 15, x ± SD, n = 9)

Varieties	Indicators of photochemical activity					Average weight of berries, g	Yield, kg/bush
	Fo	Kpl	Fmax1	Fmax2	Ft		
Izumrud	409 ± 7[a]	0.44 ± 0.01[a]	1141 ± 131[a]	1101 ± 123[a]	469 ± 67[a]	4.64 ± 0.15[ac]	1.18 ± 0.02[a]
Bezshypnyi	375 ± 18[b]	0.41 ± 0.01[b]	1070 ± 154[a]	1035 ± 91[a]	398 ± 65[a]	4.82 ± 0.16[a]	1.16 ± 0.02[a]
Neslukhivskyi	376 ± 27[ab]	0.33 ± 0.02[c]	1117 ± 173[a]	1088 ± 168[a]	443 ± 76[a]	5.25 ± 0.21[b]	1.25 ± 0.04[b]
Krasen	360 ± 20[b]	0.31 ± 0.04[c]	1043 ± 154[a]	1005 ± 148[a]	406 ± 59[a]	4.43 ± 0.19[ac]	0.61 ± 0.01[c]

Note: see Table 1.

The increased intensity of photosynthesis corresponds to a better provision of plants with assimilates. The generalized indicators of the curves of FIC of gooseberries of the researched varieties for the growing season of 2020 did not go down below 200 relative units. This generally indicates a high functional activity of chloroplasts at the end of summer and a slowdown, compared to the expected, of the aging process of the leaf apparatus of the studied plants.

We noted an increased initial value of Fo fluorescence (409 relative units) in plants of the 'Izumrud'. This indicator, especially in combination with the increased values of maximum fluorescence Fmax, indicates a high potential performance of this variant. The maximum (Fmax1 and Fmax2) values of fluorescence in 'Izumrud' and 'Neslukhivskyi' during the studied period were higher than in the rest of the varieties, which can be determined by the genotype.

The decrease in fluorescence from Fmax2 to the Ft indicator characterizes the efficiency of dark processes. At the Ft level, photosynthesis is maximal. A greater decline of the fluorescence curve from its maximum (in practice, it is more expedient to take into account the second Fmax2 to avoid "device noise") to a stationary level, indicates a deeper oxidation of the reaction centers and a more active passage of the Calvin cycle. Accordingly, this determines and certifies the high potential productivity of the studied variety. In our study, the greatest decline in Ft (645 relative units) was noted in the 'Neslukhivskyi'. The stationary level of Ft fluorescence shows the number of chlorophylls that do not participate in energy transfer to the PS2 reaction centers. The generalized value of this indicator is increased in the 'Izumrud' (469 relative units), although the decrease in fluorescence from Fmax2 to Ft was significant and amounted to 637 relative units. Such a combination of parameters of the fluorescence curve clearly indicates a higher level of the intensity of photosynthesis of gooseberry of the 'Izumrud' compared to the rest of the studied varieties. Its economic performance in 2020 was also one of the highest.

The photosynthetic function is a component of the production process of plants. Therefore we evaluated the productivity of gooseberry varieties under the conditions of the 2020 growing season. The highest initial yield (in the second year after planting) is noted by the 'Neslukhivskyi' with a productivity of 1.25 kg/bush (with a significant difference from the 'Izumrud') and an average weight of berries of 5.25 g. The lowest indicators of the yield per bush (0.61 kg) and the average berry weight (4.43 g) were characterized by the 'Krasen'. There was a significant yield increase in 'Izumrud' and 'Bezshypnyi' compared to 'Krasen': in 'Izumrud' – 1.18 kg/bush, in 'Bezshypnyi' – 1.16 kg/bush. The average weight of berries in the 'Izumrud' was 4.64 g, in 'Bezshypnyi' – 4.82 g. All studied varieties in the first years of fruiting are characterized by large fruits. In the same soil and climatic conditions, young plants of the 'Neslukhivskyi variety (aged 2–3 years) were more productive compared to the rest of the studied gooseberry varieties. The average fruit weight in the 'Neslukhivskyi' is 1.2 times greater compared to 'Krasen', which has the lowest average fruit weight.

A correlation between indicators of agrometeorological conditions in the fruiting phase and some indicators of the functioning of the photosynthetic apparatus, which significantly affect the level of productivity of gooseberry plants, was revealed. Based on the obtained correlation relations between the indicator of the background level of fluorescence at the time of full opening of the shutter (Fo) and weather factors (Fig. 3a), a predictive model of the indicator of the background level of fluorescence at the time of full opening of the shutter from weather factors was built:

$$Fo = 789.2498 - 13.8441 \times T_{max} - 1.4907 \times D \qquad (r = 0.8832) \qquad (1)$$

where, Fo – is the indicator of the background level of fluorescence at moment of full opening of the shutter (relative unit); T_{max} – average maximum temperature (°C); D – the amount of precipitation (mm).

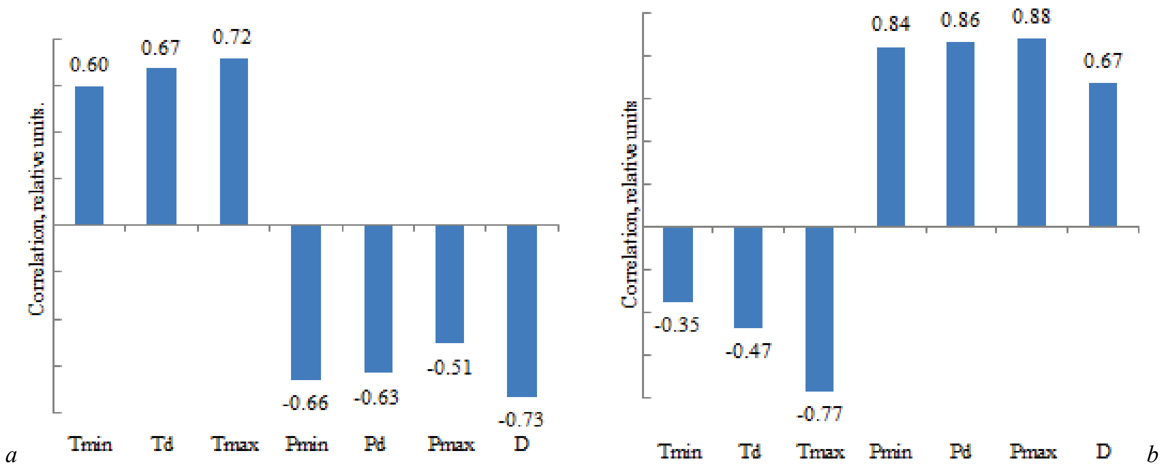

Fig. 3. Correlation relations: *a* – between the indicator of the background level of fluorescence at the time of full opening of the shutter (Fo) and weather factors; *b* – between the index of increasing fluorescence to variable (Kpl) and weather factors: Tmin – average minimum temperature, Td – average daily temperature, Tmax – average maximum temperature (°C); Pmin – average minimum humidity, Pd – average daily humidity, Pmax – average maximum air humidity (%); D is the amount of precipitation (mm)

The value of the indicator of the background level of fluorescence at the time of full opening of the shutter (Fo) at the level of 384 relative unit and above is determined by the average maximum temperature of 29.2 °C and below and the corresponding amount of precipitation.

A strong negative correlation (–0.77) was established between the indicator of the background level of fluorescence at the moment of full opening of the shutter (Fo) and the maximum daily temperature. A strong positive correlation at the level of 0.7–0.9 between Fo and the moisture regime was also determined, which indicates the activation of production processes in gooseberry leaves when the plants are sufficiently supplied with moisture.

On the basis of established correlation ratios between the index of increasing fluorescence to variable (Kpl) and weather factors (Fig. 3b), a predictive model of the index of the ratio of increasing fluorescence to variable (Kpl) from weather factors was built:

$$Kpl = 0.6610 - 0.0078 \times T_{max} - 0.0024 \times D \quad (r = 0.8498) \qquad (2)$$

where, Kpl – the ratio of increasing fluorescence to variable fluorescence (units); T_{max} – average maximum temperature (°C); D – the amount of precipitation (mm).

The ratio of increasing fluorescence to variable (Kpl) at the level of 0.38 relative unit and more determined by the average maximum air temperature not higher than 35.5 °C and the amount of precipitation 66.8 mm and below. Thus, the established indicators can be used to assess the impact of the environment on the photosynthetic apparatus and the potential productivity of gooseberry plants.

The conducted correlation analysis determined a strong negative correlation (ranging from –0.5 to –0.7) between Kpl and indicators of the hydration regime. This fact indicates that the lack of precipitation during the fruiting period leads to a violation of the internal energy conversion and distribution of electrons in the reaction centers of photosystem 2 (PS2).

Discussion

The intensity of passage of gooseberry plants through phenological phases of development depends on the agro-climatic conditions of the growing season (Lagutenko & Zahorodnya, 2012; Lagutenko et al., 2021). At the onset of unfavourable conditions, the plants of this culture, adapting to the lack of moisture at the end of summer, dropped some of the leaves, and in some places also the fruits, which led to the premature end of the fruiting phase and stretching in the time of the defoliation. Partial premature falling of leaves indicates their accelerated aging. The latter reduces the accumulation of assimilates by gooseberry plants in the second half of the growing season and shortens the time of functioning of the photosynthetic apparatus as a whole (Lagutenko & Nasteka, 2011). The variety 'Krasen' with the shortest duration of the growing season was noted as the least adapted to the influence of adverse conditions.

The concentration of chlorophylls in the leaves is an important sign of the state of the photosynthetic apparatus, in particular, an indicator of the plant's provision of all life factors (illumination, temperature, humidity, elements of mineral nutrition). The maximum content of chlorophylls is noted in the leaves during the transition of plants from vegetative to generative transformations (Lazár, 1999). Chlorophyll content was determined in gooseberry leaves at the beginning of the fruiting phase. All variants of the experiment contained chlorophylls in a concentration sufficient for normal functioning. Among the researched varieties, 'Krasen' with the smallest leaf surface area adapts to environmental conditions by increasing the content of chlorophyll.

At the same time, the number of photosynthetic pigments only partially reflects the performance of the photosynthetic apparatus. More informative regarding the last feature is taking into account the share of reaction centers involved in production processes (Lichtenthaler & Babani, 2004). Photosynthetic activity determines biological productivity and shows the crop's potential for yield. Many researchers have established that the intensity of photosynthesis is influenced by many factors: feeding regime, lighting, air temperature, damage to plants by pests and diseases (Kyryk et al., 2013; Shavanova et al., 2014; Syvoded et al., 2018; Havryliuk & Kondratenko, 2020). Such studies are quite possible with the use of modern photofluorimeters of the "Floratest" type. When assessing the state of the photosynthetic apparatus in dynamics (during the growing season), the interpretation of the obtained results significantly depends on the period of leaf ontogenesis (Nesterenko et al., 2006). The initial level of Fo fluorescence depends entirely on the loss of excitation energy during migration and the share of chlorophyll molecules that do not participate in photosynthetic processes. According to literature sources (Kytaev & Kryvoshapka, 2012), most plants experience a decrease in the functional activity of chloroplasts in August, which is reflected in the Fo indicator. The next indicator the adapted (Fpl) value of fluorescence informs about the rate of saturation of inactive reaction centers of PS 2, which is responsible for the decomposition of water and the release of oxygen (Stirbet & Govindjee, 2011). Domestic and foreign research scientists note that this photosystem is most sensitive to environmental factors, such as extreme high and low temperatures, excess light, overmoistening, drying, increasing the salt content in the nutrient medium (Nesterenko et al., 2006; Zelenyanska, 2009). An increase in the share of inactive reaction centers can also occur in connection with the aging of leaves (Bukhov et al., 1997). The same conclusions were confirmed in our research. In the studied varieties of gooseberry, this indicator was on average from 580 to 731 during the growing season unit and was larger in the 'Izumrud'. The increase in fluorescence intensity from Fo to the Fpl level is due to energy saturation of reaction centers that do not transfer an electron to the electron transport chain (ETC), i.e., it characterizes the efficiency of the transfer of captured energy to the subsequent ETC (Vasylenko et al., 2015). The highest increase was observed in gooseberry plants of the 'Izumrud' (322 relative units), and the smallest (220 relative units) in 'Krasen'. This can be explained by the more intensive evaporation of plants of the first of these varieties due to higher productivity.

Based on the difference between the fluorescence levels Fo and Fmax, the potential efficiency of photochemistry of PS2 in the dark-adapted state is estimated, which is determined by the recovery of Qa and the achievement of the maximum fluorescence level (Walker, 1981). The share of Fo as a percentage of Fmax refers to production processes in chlorophylls, rather than to the entire process of photosynthesis as a whole, because this indicator reveals the efficiency of capture of solar radiation by chlorophyll acceptors. The difference between Fo and Fmax1 parameters was significant (Fo was 33.6–35.0% of Fmax1) in all studied varieties, which indicates the shading of gooseberry bushes. In our study, the analysis of weather condition in the previous period (May 9–30) proves the predominance of cloudy days. At the same time, considering this indicator in combination with other sections of the fluorescence curve (Fo in relative unit, Fmax, decrease of fluorescence intensity to a stationary level), it is possible to assert the high productivity potential of gooseberries, especially 'Izumrud' and 'Neslukhivskyi'.

The Fmax1 indicator characterizes the number of active pigments involved in the transfer of energy to reaction centers. In conditions of insufficient lighting, there is an increase in light-absorbing and antennal chlorophylls in the leaves, which is accompanied by an increase in this indicator. The Fmax2 indicator is determined by the illumination of the leaves and depends on the absorption of ATP in the process of induction of the Calvin cycle, which is related to the concentration of reduced NADP+ (Lichtenthaler & Babani, 2004). The decline of chlorophyll fluorescence from the maxima of Fmax1 and Fmax2 to the stationary level of Ft is caused by the activation of dark photochemical reactions (the Calvin cycle) and the gradual oxidation of carriers of the ETC (Vasylenko et al., 2015).

The calculated parameter Kpl shows the number of Qb-non-reducing PS2 complexes, the proportion of which increases under stress (Korneev, 2002). Due to this, the presence of a viral infection in plants can be diagnosed by the level of Kpl (Vasylenko et al., 2015). The Kpl index was 0.41–0.44 in the varieties 'Izumrud' and 'Bezspynyi', which may indicate the presence of stress in the plants. While in 'Nesluhivsky' and 'Krasen' it was within 0.31–0.33.

High plant productivity can be achieved by optimizing the entire complex of conditions necessary for the normal flow of the photosynthesis process. For an effective production process in the leaves of plants of a temperate climate, the optimal air temperature is considered to be 20–25 °C. According to our research, an increase in the average daily temperature up to 29.2 °C for gooseberries is a stress factor in environmental conditions, and a temperature of 35.5 °C and above is critical for the synthesis of organic matter. Under dry conditions, the synthesis of chlorophyll is delayed due to a general disturbance of metabolism. A decrease in the amount of precipitation during the month to a level below 66.8 mm for gooseberry plants can lead to significant stress and destructive changes in the photosynthetic apparatus. Deterioration of weather conditions during the fruiting period of young gooseberry plants adversely affected the state of the photosynthetic apparatus, which was confirmed by their low yield.

Conclusions

According to the results of phenological observations, the growing season of gooseberry was extended in the research year, its duration in the studied varieties was from 177 to 200 days. In connection with the abnormally early onset of climatic spring, the gooseberry vegetation began two weeks earlier, and the prolonged warm autumn contributed to the extension of the vegetation by another two weeks. According to the results of determining the area of the assimilation surface of the leaves, it was found that it is the largest in gooseberry plants of the 'Bezshypnyi' and is 3856 cm^2/bush. This indicator is due to this variety having the largest area of the leaf plate, which is its biological feature. The 'Krasen' is characterized by higher indicators of the content of chlorophyll a and chlorophyll *b*, as well as the total amount of chlorophylls *a* and *b*, both in terms of the mass of leaves and their area, which may indicate the intensification of production processes due to a greater number of green pigments.

The FIC method is quite informative for evaluating the efficiency of the photosynthetic system and studying the impact of adverse weather factors. The researched varieties of gooseberry differ significantly in terms of indicators of induced changes in chlorophyll fluorescence, which reflects the processes of energy conversion at the initial stages of photosynthesis. To evaluate the productivity potential and functional stability of the photosynthetic apparatus in relation to gooseberry culture, the following sections of the fluorescence curve turned out to be the most informative: background fluorescence Fo in % to Fmax1, the intensity of the fluorescence decline from the second fluorescence flash Fmax2 to the stationary level Ft (in relative units of the unit), the actual intensity of the stationary level of fluorescence Ft. According to the set of indicators of the curve FIC, gooseberry varieties more adapted to environmental conditions were determined: 'Izumrud' and 'Neslukhivskyi'.

Among the investigated varieties, 'Neslukhivskyi' is characterized by the largest initial yield (1.25 kg/bush). The average weight of their berries varies from 4.4 to 5.2 g. This is due to the higher berry weight (5.25 g), which is a characteristic feature of this variety. However, this level of yield is low compared to the indicated potential yield, as noted by its authors. Based on the above, it can be concluded that gooseberry of the 'Neslukhivskyi' is characterized by a very high productivity potential of the photosynthetic apparatus, but its real economic productivity is extremely dependent on the temperature and water regime during the formation and ripening of the berries.

A correlation between indicators of agrometeorological conditions in the fruiting phase and some indicators of the functioning of the photosynthetic apparatus, which significantly affect the level of productivity of gooseberry plants, was revealed. The values of indicators of the background level of fluorescence at the moment of full opening of the shutter (Fo) and the ratio of increasing fluorescence to variable (Kpl), which are determined by the main elements of the formation of high gooseberry productivity, can be predicted on the basis of weather factors – the average maximum temperature and the amount of precipitation.

The results of field observations and laboratory experiments prove the need to adapt gooseberry cultivation technology for effective regulation of temperature and moisture conditions, especially in periods with unfavourable weather conditions of vegetation. To obtain high and stable yields of berry products, it is important to select varieties or hybrids resistant to droughts and high temperatures. Gooseberry varieties 'Neslukhivskyi' and 'Izumrud', which were distinguished by a high level of fluorescence induction, even in the adverse conditions of the 2020 growing season, and are characterized by high indicators of potential productivity, are recommended by us for wider introduction into production. These same varieties are potentially valuable carriers of a rare combination in one genotype of high intensity of photosynthesis and at the same time significant functional resistance of the pigment complex to the main adverse agro-climatic factors. Gooseberry varieties 'Neslukhivskyi' and 'Izumrud' should be investigated for the perspective of involvement in the selection process to obtain forms of gooseberry more highly adapted to growing conditions and high-yield forms of gooseberry.

The authors declare no conflict of interest.

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