# RESEARCH ON THE INFLUENCE OF CLIMATE CHANGE ON THE PHOTOSYNTHESIS PROCESS IN MAIZE

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**Abstract**

The general objective is the study of the photosynthesis process in corn plants, the necessary basis for the great adaptation capacity of plants to climate changes. These studies are important because they participate in the identification of solutions involved in increasing corn production and its quality. The experience was organized at the farm "*Vasile Adamachi*" within the USV Iasi, in the spring of 2021 and the analyzes on the collected physiological material were carried out in the plant physiology laboratory of the USV Iasi. The research material was represented by the hybrid DKC 4598 produced by the Bayer Group with the FAO 350-390 group. The analysis of the photosynthesis process in maize in the context of the climatic conditions specific to the growing season of 2021 was carried out by quantitatively determining of the content of photosynthetic pigments and chlorophyll fluorescence. The results obtained by the analyse of the photosynthesis process were correlated with the production obtained. The results obtained from the fluorescence analysis show us that the corn plants studied had the highest light quantification capacity in the 6 and 8 node phenophases. The recorded differences do not show an effort in the ability of the plants to adapt to the weather conditions of 2021 in North-Eastern Moldova.

**Key words**: maize, chlorophyll fluorescence, chlorophyll a, chlorophyll b, photosynthesis

Global warming is one of the main problems we face, being caused by human action in the industrial age, but also by possible astronomical developments. A serious consequence of these major climate changes is attributed to the phenomenon of desertification, which is expanding in more and more regions of the world thus, it is necessary to find effective solutions that can support agriculture even in such conditions.

In world agriculture, corn occupies the third place in area, after wheat and rice. It is found spread over all continents covering approximately 162 million hectares of agricultural land (Axinte M. *et al*, 2006; Mogârzan A., 2012). Maize culture has a high potential in Romania but also in other regions of the Globe, however, the climate changes of recent years caused, mainly by global warming, require the finding of viable solutions that facilitate obtaining relevant productions, necessary to fulfill needs in human nutrition but also in animal feed.

Due to efforts to improve corn for superior economic results, hybrids will greatly increase their production capacity in the future. In order to achieve such performances, especially against the backdrop of climate change, it is absolutely necessary to identify the most important physiological reactions to adapt to abiotic stress conditions, their knowledge being the premise of an effective forecast on the evolution of agriculture in correlation with the inevitable climate changes (Costa L.C. *et al*, 2009; László H. *et al*, 2020).

Numerous studies show that the analysis of the photosynthesis process in corn under the context of changing climatic conditions contributes to the subsequent identification of varieties with a high tolerance to temperatures that exceed the normal specific to the temperate climate zone and the water stress generated by the lack of water that affects agricultural crops in last years (Hatfield J. L. *et al*, 2011; Gurdeep S. M. *et al*, 2021; Kovak E. *et al*, 2022).

The knowledge of these ecophysiological adaptations that plants acquire due to the interaction with abiotic factors contributes to a new reorientation in the structure of agricultural crops. The adaptation of agricultural technologies to the water resource, the conservation of soil water by choosing a system of minimum works representing a new trend to meet the requirements for the conservation of water and soil resources (Hristov J. *et al*, 2020).

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## MATERIAL AND METHOD

The experience was organized at the farm "*Vasile Adamachi*" within the USV Iasi, in the spring of 2021 and was laid out according to the method of subdivided plots with three repetitions and the analyzes on the collected physiological material were carried out in the plant physiology laboratory of the USV Iasi. The research material was represented by the hybrid DKC 4598 produced by the Bayer Group with the FAO 350-390 group. The analysis of the photosynthesis process in maize in the context of the climatic conditions specific to the growing season of 2021 was carried out by quantitatively determining of the total chlorophyll content of the leaves measured with the SPAD device. We also determined the content of chlorophyll pigments and leaf flavonoids by the spectrophotometric method (Jităreanu C.D. *et al*, 2011; Jităreanu C.D. *et al*, 2020) and also during the vegetation period we monitored the fluorescence of the chlorophyll using the fluorimeter. The results obtained by the analyse of the photosynthesis process were correlated with the production obtained.

## RESULTS AND DISCUSSIONS

The general objective is the study of the photosynthesis process in corn plants, the necessary basis for the great adaptation capacity of plants to climate changes. These studies are important because they participate in the identification of solutions involved in increasing corn production and its quality.

### *Characterization of the climatic conditions characteristic of the study period within the „Vasile Adamachi" Iași-Copou farm*

According to the estimates presented by the IPCC (Intergovernmental Panel on Climate Change), in Romania an increase in temperature between 0.5ºC and 1.5ºC is expected in the period 2020-2029, and by 2090 it is predicted that temperatures will increase between 2ºC and 5ºC. From a pluviometric point of view, more than 90% of the related climate models for Romania forecast pronounced droughts during the summer for the period 2090-2099.

The effects of climate change on agriculture highlight the need for risk reduction decision-making in order to maintain optimal harvests and develop sustainable agriculture.

Research in the agricultural sector includes the correlation of local environmental conditions with the degree of resistance of genotypes to abiotic stress factors. In this sense, one of the most studied physiological processes is photosynthesis.

The characterization of the climatic conditions was based on the data recorded at the Copou Meteorological Station – S.C.D.V.V. Iasi.

In the N-E region of Moldova, there have been obvious changes characterized by increasing temperature variations during the seasons. The lower average annual temperature than in the rest of the regions is not due to the winters, which are not more pronounced cold than in the other areas, but to the lower averages in the summer months, which are increasingly under the influence of N-W oceanic air masses.

The summers, warm enough to ensure grain ripening, are more moderate than in the south of the country, evidenced by the reduced number of days with temperatures equal to or higher than 30ºC. The air temperature of the agricultural year 2021 registered obvious differences from the annual average in the months of April (-2.0) and July when the deviation had the value of + 2.1, and outside the vegetation period, the month of January presented the highest variation with a value of +3.7.

The maximum temperature was recorded in July (34.5°C), along with June (33.3°C) and August (33.5°C) (*table 1*).

In the climatic conditions of the year 2021, the corn hybrid under study presented a one-week delay in emergence due to lower temperatures in April, when sowing was carried out. May also showed a deviation of -0.7, which slowed down the growth rate of corn plants, which also brought some changes to the intensity of photosynthesis (*table 2*). The year 2021 was, from the point of view of precipitation, a rainy year with a positive deviation from the multi-annual average, and against the backdrop of low spring temperatures, the corn crop studied presented a physiological adaptation reaction through the lens of the photosynthesis process. This is to be described in the following through the obtained results.

The clima-diagram of the experimental period shows normal values for the April-September period.

Table 1

**Average monthly air temperatures in the agricultural year 2021 (°C)**
**Copou Weather Station – S.C.D.V.V. IASI**

| Specification | MONTHS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX |
| Monthly mean | 0.1 | -0.9 | 3.1 | 8.1 | 15.4 | 19.7 | 23.4 | 20.9 | 14.7 |
| Multi-annual Average | -3.6 | -1.9 | 3.3 | 10.1 | 16.1 | 19.4 | 21.3 | 20.6 | 16.3 |
| Deviation | 3.7 | 1.0 | -0.2 | -2.0 | -0.7 | 0.3 | 2.1 | 0.3 | -1.6 |
| Monthly minimum | -16.3 | -14.8 | -5.1 | -1.3 | 3.6 | 9.5 | 13.7 | 12.1 | 4.2 |
| Monthly maximum | 10.7 | 18.2 | 16.0 | 23.1 | 28.1 | 33.3 | 34.5 | 33.5 | 27.2 |

Table 2

**Amount of monthly precipitation in the agricultural year 2021 (mm)**
**Copou Weather Station – S.C.D.V.V. IASI**

| Specification | MONTHS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | VIII | IX | Total/Vegetation |
| Monthly mean | 28.4 | 24.6 | 50.4 | 53.2 | 68.6 | 93.6 | 87.6 | 95.4 | 10.4 | 605.8 |
| Multi-annual Average | 28.9 | 27.4 | 28.1 | 40.3 | 52.5 | 75.1 | 69.2 | 57.6 | 40.8 | 419.9 |
| Deviation | -0.5 | -2.8 | 22.3 | 12.9 | 16.1 | 18.50 | 18.4 | 37.8 | -30.4 | +185.9 |

The months of June, July and August have a high rainfall regime: 93.6 mm in June, 87.6 mm in July and 95.4 mm in August. It is noted that the highest temperatures were recorded in July, without the precipitation level decreasing much compared to the previous month. In each month of the experimental period, gradual increases in precipitation were recorded, except for September when the lowest level was recorded (10.4 mm) (*figure 1*).

***Analysis of the photosynthesis process in corn in the context of the climatic conditions specific to the growing season of 2021***

The efficiency of fixing carbon dioxide in the process of photosynthesis is vital for the growth and productivity of plants, and thermo-hydric stress influences the photosynthetic capacity of plants in many ways: reducing the size and number of leaves, closing stomata, damaging the photosynthetic apparatus, decreasing the pigment content chlorophylls, inhibition of specific enzyme activity and ATP production (Burzo I., 2015).

High temperature affects the structure and functions of chloroplast components, but after recovery from moderate heat stress conditions the changes are reversible. The impact of high temperatures is greater in plants of the photosynthetic type C3 compared to those of the photosynthetic type C4 such as corn, a fact that makes this plant species have a higher tolerance to drought and heat.

The intensity of the photosynthesis process was determined by analyzing the total content of chlorophyll, the content in photoreceptor pigments in the leaves of corn plants and by determining the fluorescence of chlorophyll.

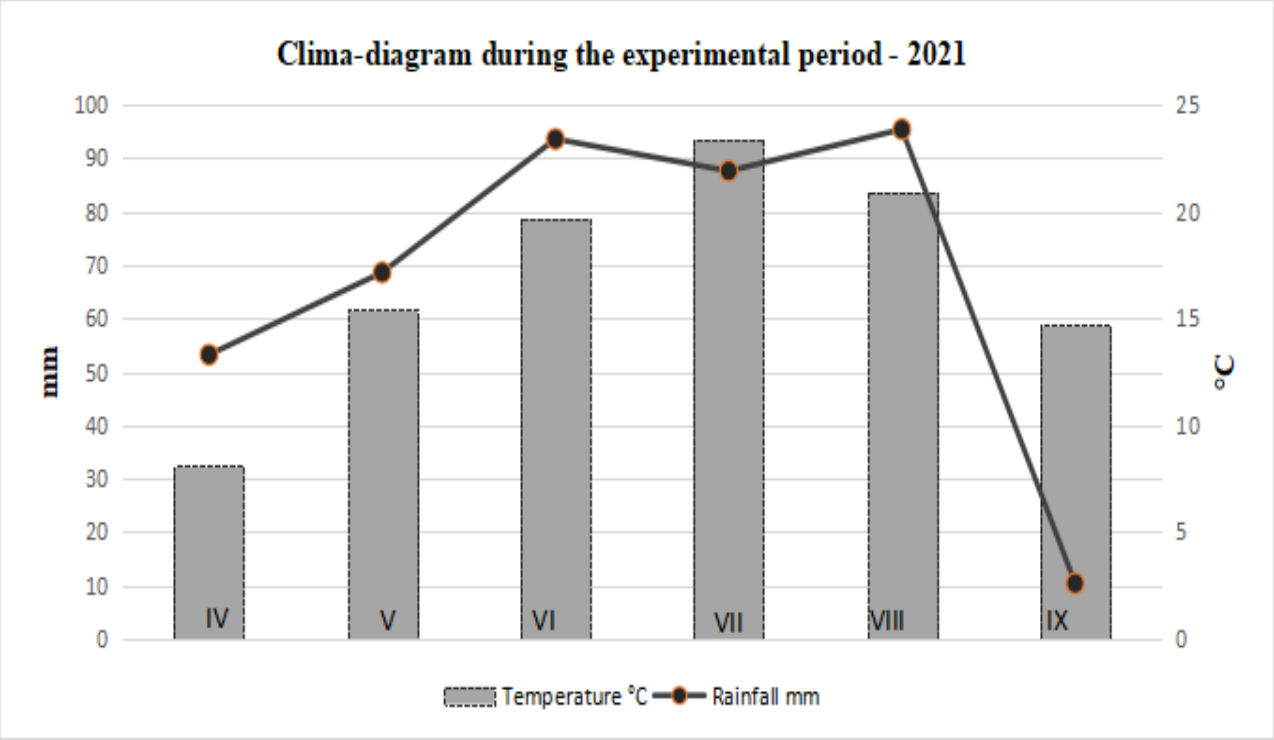


Figure 1 **Clima-diagram during the experimental period 2021**

Fluorescence is the ability of the pigment solution to show a different color depending on how it is viewed. If viewed through transparency, in direct light, it has a green color. If viewed by reflection, it is red. Thanks to this property, chlorophyll can transform the wavelength of light radiation, from short wavelength to long wavelength (Jităreanu C.D., 2002).

According to literature data, chlorophyll fluorescence has so far been shown to be influenced by plant water supply, mineral nutrition and light intensity. The change in chlorophyll fluorescence properties, respectively the functioning of photosystem II (FS II) is therefore influenced by a series of abiotic factors (Petcu E. *et al*, 2014).

The measurements were aimed at determining the values of the Fv/Fm ratio in which they represent the maximum quantum yield, the indicator of the maximum efficiency of the excitation energy transfer and are calculated using the formula: Fv/Fm=(Fm-F0)/Fm, where:

F0- the minimum or initial fluorescence, which appears under conditions where the collecting antennas are open to receive light quanta.

Fm-maximum fluorescence, recorded after exposure to the excitation source (light spot of the device). In these conditions all sites of the collecting antennas are closed, saturated with light quanta (Mohammed G.H. *et al*, 1995).

By analyzing the data obtained, it is found (*figure 2*) that the fluorescence recorded the highest values (0.54 µmol) in the phenophase of 8 nodes against the background of temperatures that, although they showed a positive deviation from the normal characteristic of the studied vegetation period, did not change the reaction capacity on the photosynthetic apparatus. On the contrary, during panicle formation, the Fv/Fm ratio showed the lowest values (0.48 µmol), which highlights that the high temperatures during that period negatively influenced the ability of plants to capture light. Temperatures higher than 35ºC superimposed with the resulting excess humidity, as a result of the abundant precipitation accumulated during the panicle development period, slow down the photosynthetic activity.

From the results obtained, we evaluate the corn plants analyzed as having the highest light quantification capacity in the phenophases of 6 and 8 nodes, respectively.

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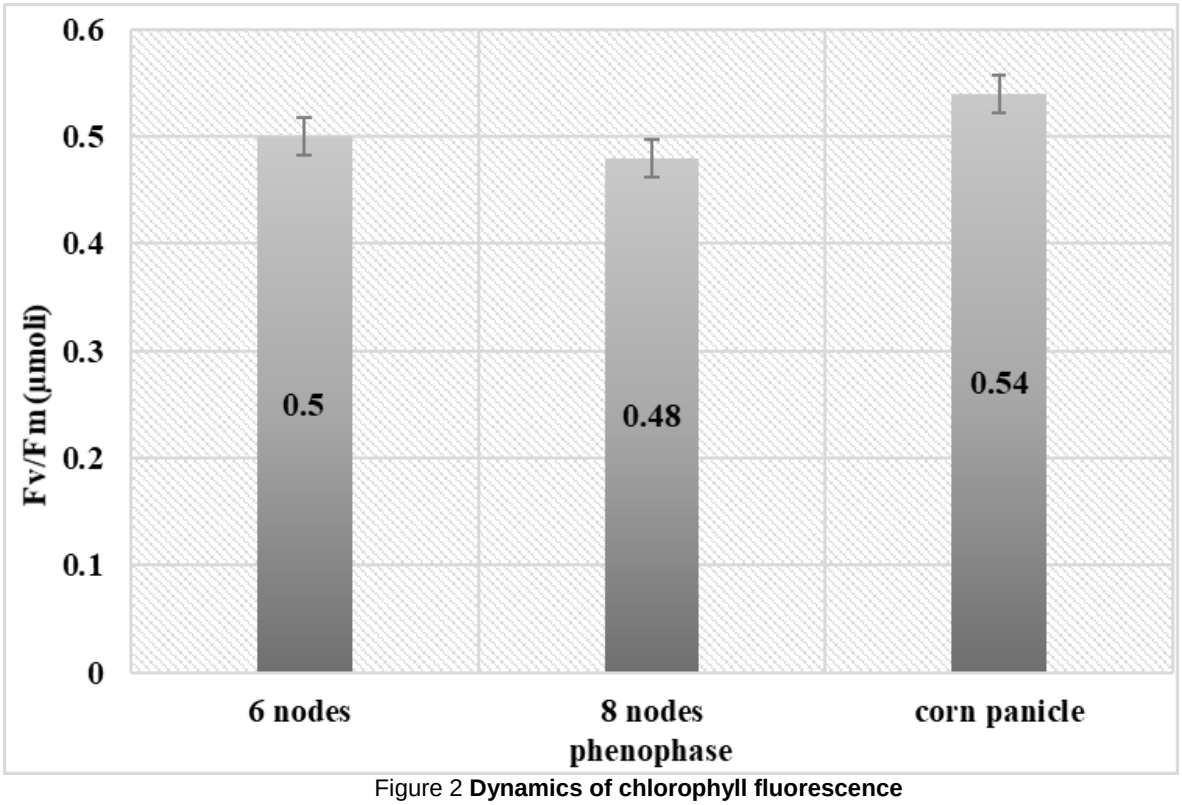



Figure 2 **Dynamics of chlorophyll fluorescence**

Based on the data provided by this device, the effect of certain environmental factors on the total chlorophyll content of the leaves can be appreciated. Since the chlorophyll content present in the leaves is closely related to the mineral nutrition of the plants, it has been proven that the value of the chlorophyll content increases proportionally with the amount of N in the leaves, the high values indicated by SPAD highlighting a nutritionally healthy plant.

The total chlorophyll content analyzed in the 6-node phenophase showed the lowest values (30.6 SPAD), in the following phenophases the chlorophyll content increased progressively, the maximum values being reached at the appearance of the panicle (66.7 SPAD) (*figure 3*).

According to the data from the specialized literature, the hybrid under study follows the same pattern of corn plants subjected to optimal growing conditions. Although the year 2021 recorded higher than normal temperatures and a water regime rich in precipitation, the total chlorophyll content evolved typical of crop plants, the values gradually increasing with the maturing process of the leaf system. In the process of photosynthesis, the absorption of light energy and its transformation into chemical energy is carried out with the help of photosynthetic systems. The photosynthetic system consists of a complex of photosynthetic pigments, having an absorption center and a reaction center, making up the photosynthetic unit.

Chlorophyll a 431-433 nm and chlorophyll b 453-454 are components of the absorption center and chlorophyll a 662-663 nm and chlorophyll b 616-617 nm are components of the reaction center (Toma L.D. and Jitareanu C.D., 2007)

The content of assimilatory pigments was assessed by the light energy absorption intensity using the 1% acetone extract of pigments determined spectrophotometrically and expressed in absorbance units. The spectrophotometric analysis of the pigment content in the corn stalks was carried out when the plants had 6 nodes, 8 nodes, respectively at the appearance of the panicle.

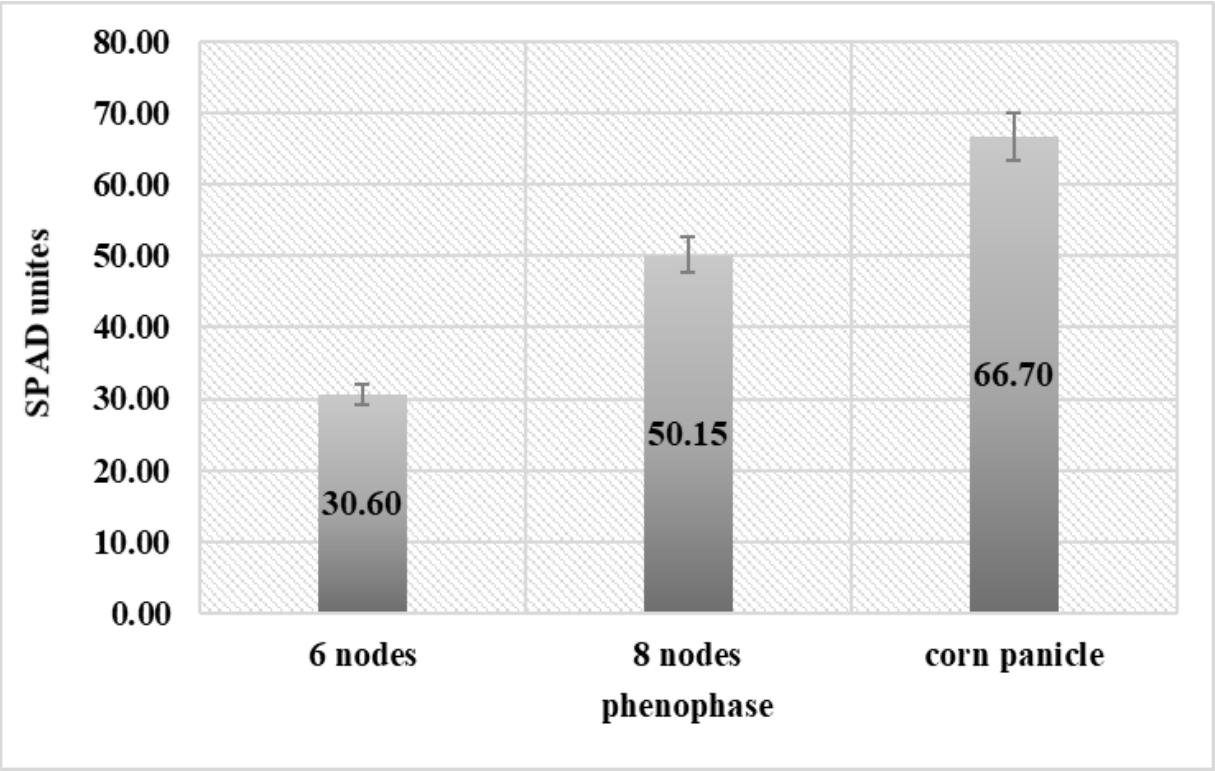


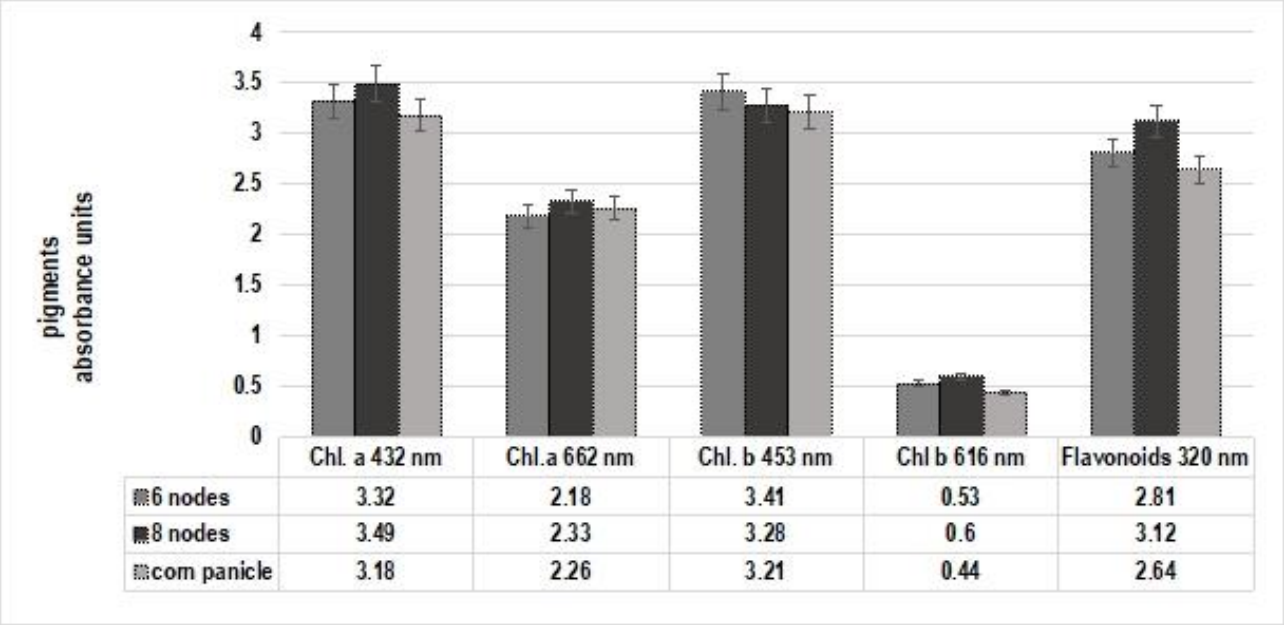

Figure 3 **Dynamics of the total chlorophyll content**

According to the obtained data, the highest values of the 432 nm chlorophyll content, component of the absorption center, were recorded in the 8-node phenophase (3.49 u.a), and the lowest at the appearance of the panicle (3.18 u.a), the latter values correlating with the high temperatures of the analyzed period (*figure 4*). Thermal stress causes changes in the composition of thylakoid membranes, inhibiting the absorption of light energy.

Analyzing the content of chlorophyll b 454 nm, a slight change is noted (*figure 4*), the highest value being recorded in the phenophase of 6 nodes (3.41 u.a), but the lowest value is maintained at the appearance of the panicle (3, 21 u.a), a period that coincides with temperatures exceeding 30ºC, highlighting an inhibitory effect on the photosynthesis process.

As can be seen from figure 4 chlorophyll at 663 nm, the main component of the absorption center in photosynthetic systems, with a role in capturing light energy and transferring it to the reaction center recorded a maximum of 2.33 u.a in the 8-node phenophase and a minimum at the 6-node phenophase (2.18 u.a) and at panicle emergence (2.26 u.a). The values demonstrate a specific adaptation behavior of corn plants to the climatic conditions of that period different from a normal year. Photosystem II and the photoreceptor antenna are more sensitive to the action of high temperatures, that is why a slight inhibition of the photosynthesis process is observed against the background of temperatures that reach 40ºC at certain times of the day. During the period of stem elongation - 8 detectable nodes, the content of chlorophyll b 616 nm (component of the reaction center), showed higher values (0.6 u.a) in corn plants than in the case of the other two phenophases analyzed (*figure 4*).

The same trend is maintained; the lowest content of chlorophyll b 616 nm being registered at the emergence of the panicle.




| | Chl. a 432 nm | Chl.a 662 nm | Chl. b 453 nm | Chl b 616 nm | Flavonoids 320 nm |
|---|---|---|---|---|---|
| 6 nodes | 3.32 | 2.18 | 3.41 | 0.53 | 2.81 |
| 8 nodes | 3.49 | 2.33 | 3.28 | 0.6 | 3.12 |
| corn panicle | 3.18 | 2.26 | 3.21 | 0.44 | 2.64 |

Figure 4 **Dynamics of chlorophyll and flavonoid content**

The analysis of the content of photosynthetic pigments highlights a behavior specific to the vegetation period under the influence of abiotic factors, the recorded differences do not highlight an effort in the ability of the plants to adapt to the meteorological conditions of 2021.

An important category of pigments that was also analyzed is the flavonoid pigments (320-325 nm), which have the function of protecting the plant from stress factors.

According to the obtained results, the highest content of flavonoid pigments was registered at the appearance of the panicle (3.42 u.a) (*figure 4*). This stage is very important in the development of corn plants because the plants show their ability to reproduce, to perpetuate the species, being is a critical moment. Despite the unfavorable conditions during this period, heavy rains and higher-than-normal temperatures specific to the studied vegetation period, the hybrid under study demonstrates a good adaptability precisely through the high content of flavonoids during this critical period. The appearance of the panicle mostly coincided with the appearance of silk, this is due either to favorable climatic conditions or, in the present case, to the great ability to adapt to unfavorable environmental factors, so that the plants manage to compensate through different physiological mechanisms certain shortcomings.

The production obtained in maize is conditioned by its production elements: the number of developed cobs/plant, the length of the cob, the number of rows of grains per cob, the number of rows of grains per row and MMB.

In the DKC 4598 hybrid, out of 50 analyzed plants, 42 had 2 cobs/plant, that is, an average of 1.84. The cobs were very well developed reaching an average weight of 384 g (*table 3*).

The average number of rows of grains per cob recorded was between 16 and 20 with a minimum number of 36 grains and a maximum of 40 grains/row. Cob length showed values between 19.4 cm and 22.5 cm, and the recorded MMB was 386 g. Drought and heat can significantly reduce the survival time of pollen and implicitly, delay the appearance of silk. In these conditions, the synchronization between the release of pollen and the appearance of silk is essential for the formation of the set of grains, securing production and ensuring profit. The data obtained show that the studied hybrid has a very good production capacity even against the background of a year with positive thermal deviations in July, August and September and with excess humidity in June and July.

Table 3

**The main production elements of the hybrid DKC 4598**

| No. medium cobs/plant | Cob lenght(cm) | No. of rows/cobs | No.of grains/row | MMB |
|---|---|---|---|---|
| 1.84 | 19.4 (min) | 16 (min) | 36 (min) | 386 |
| | 22.5 (max) | 20 (max) | 40 (max) | |

## CONCLUSIONS

From the results obtained at the fluorescence analysis, we evaluate the corn plants studied as having the highest light quantification capacity in the phenophases of 6 and 8 nodes respectively.

The analysis of the content of photosynthetic pigments and stomatal conductance shows a specific behavior to the vegetation period under the influence of abiotic factors, the recorded differences do not highlight an effort in the ability of plants to adapt to the meteorological conditions of 2021 in N-Eastern Moldova.

The obtained data highlight that the studied hybrid has a very good production capacity even against the background of a year with positive thermal deviations in the months of July and August and with excess humidity in June and July.

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