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CHLOROPHYLL CONTENT IN MAIZE HYBRIDS

Viliana VASILEVA, Nataliya PETROVSKA, Emil VASILEV

Maize Research Institute Knezha, 5 Academic Tomov, Agricultural Academy, Bulgaria

Corresponding author email: viliana.vasileva@gmail.com

Abstract

One of the most important factors determining productivity is the photosynthesis process. The work aimed at to find the chlorophyll content in leaves of maize hybrids from two vegetation groups. Maize hybrids FAO 500-599 (Kneja 560, Kneja 564, Kneja 570A, Kneja 572 and KWS Camillo), and FAO 600-699 (Kneja 648, Kneja 649, Kneja 650A, Kneja 650 and Kneja 683) were tested in field conditions and no irrigation. Chlorophyll 'a' and chlorophyll 'b' were determined in green leaf samples 60 DAS. The total chlorophyll a+b and chlorophyll 'a' to chlorophyll 'b' ratio was calculated. Generally, the values for chlorophyll concentration were found higher for the maize hybrids FAO 600-699 group. The exceeding compared to FAO 500-599 group was for chlorophyll 'a' by 12.53%, for chlorophyll 'b' by 9.38% and for total chlorophyll by 11.47%, respectively. The chlorophyll 'a' to chlorophyll 'b' ratio was relatively similar for the hybrids from two groups. It was concluded the highest total chlorophyll concentration in maize hybrids was found in Kneja 648 (5.39 mg/g) and Kneja 560 (4.49 mg/g).

Key words*: chlorophyll 'a', chlorophyll 'b', maize, total chlorophyll.*

INTRODUCTION

Maize, often called the "Queen of the Field" is the most common fodder crop in Bulgaria and is grown for grain and silage. Maize for silage has a high energy nutritional value and is most preferred in intensive animal husbandry (Ljubičić et al., 2023; Karnatam et al., 2023).

One of the most important factors determining productivity is the photosynthesis process. Chlorophyll a and chlorophyll b are essential components of chlorophyll and thus photosynthesis. The main chlorophyll is chlorophyll a, which ensures a higher efficiency of the process of converting carbon dioxide and water into organic compounds. Both are the main components of chlorophyll and affect the capacity and speed of its photosynthetic activities. Although both are active components, chlorophyll a has significant potential for light binding, energy acquisition and sugar production, especially in photosystem I and photosystem II (Sarieva et al., 2010).

As reported by Yokoya et al. (2007) and Zhao et al. (2016), these photosynthetic pigments are responsible for collecting and transmitting absorbed light to photosynthetic reaction centres, and their concentration is linked to the effectiveness of photosynthesis. In addition, according to Zhao et al. (2016), increased content of these pigments may be one of the factors increasing photosynthetic activity.

The content of photosynthetic pigments is also one of the indicators of the reaction of plants to changes in the environment and the degree of adaptation to new environmental conditions.

The present work aimed at to determine the plastid pigments content in leaves of maize hybrids from two vegetation maturity groups (mid-late, FAO 500-599 and late, FAO 600-699, respectively).

MATERIALS AND METHODS

The experiment was conducted in the field of the Maize Research Institute - Knezha, Bulgaria under non-irrigated conditions with standard cultivation technology of growing of maize. Ten hybrids of maize from two vegetation maturity groups (mid-late, FAO 500-599 and late, FAO 600-699) were tested as follows: i) FAO 500-599: Kneja 560, Kneja 564, Kneja 570A, Kneja 572 and KXC 1395, and ii) FAO 600-699: Kneja 648, Kneja 649, Kneja 650A, Kneja 650 and Kneja 683. The sowing density was 75000 plants/ha.

For analysis to determine the content of plastid pigments, the ear leaf of the hybrids at the time of flowering of the tassel was used for each test variant. The plastid pigments content was

determined in green leaf samples 60 DAS, using the protocol of Bozova et al. (1993). Chlorophyll a, chlorophyll b, chlorophyll a+b, carotenoids, total plastid pigments content [chlorophyll (a+b) + carotenoids], (mg/g FW) was found. The chlorophyll 'a' to chlorophyll 'b' ratio was calculated.

Minimum and maximum values, coefficient of variation (CV%), standard deviation (SD) were determined. Pearson's correlation coefficient (r) was used to determine the strength and direction of the linear relationship between indicators.

RESULTS AND DISCUSSIONS

For the hybrids in the FAO 500-599 group, chlorophyll content ranged between 2.16 and 2.88 mg/g FW for chlorophyll a and between 1.12 and 1.61 mg/g FW for chlorophyll b, respectively (Table 1). The highest chlorophyll a, chlorophyll b and total contents were found for plants of hybrid Kneja 560 (2.88 mg/g FW, 1.61 mg/g FW and 4.49 mg/g FW, respectively). Relating the values to the group average, the chlorophyll content for hybrid Kneja 560 was 9.17% higher for chlorophyll a, 15.66% higher for chlorophyll b and 11.41% higher for chlorophyll a+b. Our results related to chlorophyll a are in agreement with those of Łącka et al. (2021) and for chlorpphyll a and chorophyll b with Vulchinkova et al. (2018).

On average, the highest coefficient of variation was found for carotenoid content (CV% 24.42) for hybrids in the FAO 500-599 group.

Table 1. Plastid pigment content (mg/g FW) in maize hybrids of FAO 500-599 maturity group

Hybrids	Chl a	Chl b	Chl a+b	Carotenoids	Total
Kn 560	2.88	1.61	4.49	0.347	4.837
Kn 564	2.79	1.43	4.22	0.266	4.486
Kn 570A	2.71	1.43	4.14	0.250	4.390
Kn 572	2.16	1.12	3.28	0.204	3.484
KXC1395	2.65	1.37	4.02	0.192	4.212
Max	2.88	1.61	4.49	0.347	4.837
Min	2.16	1.12	3.28	0.192	3.484
Average	2.64	1.39	4.03	0.250	4.282
SD	0.281	0.177	0.453	0.061	0.501
CV%	10.65	12.69	11.25	24.42	11.69

For hybrids in the FAO 600-699 group, chlorophyll content ranged between 2.55 and 3.54 mg/g FW for chlorophyll a and between 1.24 and 1.85 mg/g FW for chlorophyll b, respectively (Table 2). The highest chlorophyll a, chlorophyll b and total contents were found for plants of hybrid Kneja 648 (3.54 mg/g FW, 1.85 mg/g FW and 5.39 mg/g FW, respectively). Relating the values to the group average, the chlorophyll content for hybrid Kneja 648 was 17.37% higher for chlorophyll a, 20.4% higher for chlorophyll b and 18.41% higher for chlorophyll a+b. Higher values compared to the group average were also found for plants of hybrid Kneja 650A, by 8.42% for chlorophyll a, by 0.7% for chlorophyll b and by 9.18% for chlorophyll a+b, respectively.

For hybrids in the FAO 600-699 group, chlorophyll content ranged between 2.55 and 3.54 mg/g FW for chlorophyll a and between 1.24 and 1.85 mg/g FW for chlorophyll b, respectively (Table 2). The highest chlorophyll a, chlorophyll b and total contents were found for plants of hybrid Kneja 648 (3.54 mg/g FW, 1.85 mg/g FW and 5.39 mg/g FW, respectively). Relating the values to the group average, the chlorophyll content for hybrid Kneja 648 was 17.37% higher for chlorophyll a, 20.4% higher for chlorophyll b and 18.41% higher for chlorophyll a+b. Higher values compared to the group average were also found for plants of hybrid Kneja 650A, by 8.42% for chlorophyll a, by 0.7% for chlorophyll b and by 9.18% for chlorophyll a+b, respectively.

On average, for the hybrids of the FAO 600-699 group, the highest coefficient of variation was found for carotenoid content (CV% 21.18).

Table 2. Plastid pigment content (mg/g FW) in maize hybrids of FAO 600-699 maturity group

Hybrids	Chl a	Chl b	Chl a+b	Carotenoids	Total
Kn 648	3.54	1.85	5.39	0.312	5.702
Kn 649	2.55	1.24	3.79	0.189	3.979
Kn 650A	3.27	1.7	4.97	0.342	5.312
Kn 650	2.99	1.52	4.51	0.271	4.781
Kn 683A	2.73	1.37	4.1	0.259	4.359
Max	3.54	1.85	5.39	0.342	5.702
Min	2.55	1.24	3.79	0.189	3.979
average	3.02	1.54	4.55	0.270	4.830
SD	0.400	0.245	0.645	0.058	0.697
CV%	13.25	15.98	14.17	21.18	14.43

In general, the plastid pigment content was found higher in the hybrids of the FAO 600-699 maturity group as follows: by 12.53% for chlorophyll a, by 9.38% for chlorophyll b, by 11.47% for chlorophyll a+b, by 8.30% for carotenoids, and by 11.29% for total plastid pigments content (chlorophylls+carotenoids).

Figure 1 presents data on the percentage of plastid pigments content in the tested hybrids. It

can be seen that chlorophylls occupied a part of 92.83 to 95.44%, while that of carotenoids ranged from 4.56 to 7.17%. The highest coefficient of variation was found for carotenoids content (CV% 21.92). Their percentage as a proportion of total plastid pigments content was higher for hybrids of FAO 500-599 maturity group.

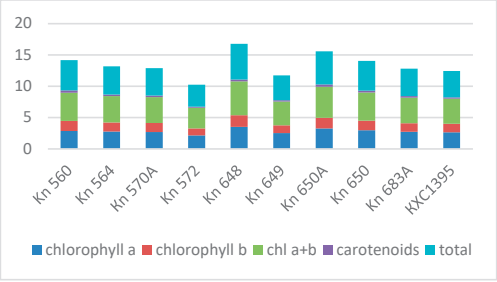

Figure 1. Plastid pigments content (mg/g FW) in maize hybrids of two maturity groups (FAO 500-599 and FAO 600-699), (CV% 13.50 for chlorophyll a, CV% 14.71 for chlorophyll b, CV% 13.82 for chlorophyll a+b, CV% 21.92 for carotenoids and CV% 14.05 for total content)

Szulc and Bocianowski (2011) found that "stay-green" hybrids are genetically more stable than classical hybrids. "Stay-green" maize hybrids compared to conventional hybrids are characterized not only by higher chlorophyll content, but also by significantly better ability to form higher yields of both grain and silage (Szulc et al., 2021). Chlorophyll content is a relatively more stable trait compared to carotenoid content (CV% 21.18 and 21.92 vs. CV% 11.25 and 14.17, respectively). Ghimire et al. (2015) demonstrated that chlorophyll content was positively correlated with grain yield.

Figure 2 shows the chlorophyll a to chlorophyll b ratio. The chlorophyll a to chlorophyll b ratio was relatively similar for the hybrids from two maturity groups (1.900 for FAO 500-599 against 1.971 for FAO 600-699), CV% (2.931 for FAO 600-699 against 3.430 for FAO 500-599). This indicator is considered genetically determined, which explains the low variation, SD=0.07 and CV% 3.57, respectively.

Some relationships between the plastid pigments content were calculated. Pearson's correlation coefficient (r) was used to determine the strength and direction of the linear relationship between the parameters (Table 3 and Table 4).

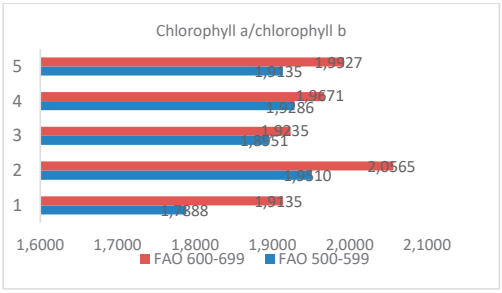

Figure 2. Chlorophyll a to chlorophyll b ratio in maize hybrids of two maturity groups (FAO 500-599, CV% 3.324; FAO 600-699, CV% 2.931)

The following correlations were found for the hybrids in the FAO 500-599 maturity group (Table 3): a significant positive correlation between chlorophyll a and carotenoids (r=0.683), a strong positive correlation between chlorophyll b and carotenoids (r=0.818), and between chlorophyll a+b and carotenoids (r=0.742). A very strong positive correlation was found between chlorophyll a and chlorophyll b (r=0.962), between chlorophyll a and chlorophyll a+b (r=0.994), and between chlorophyll b and chlorophyll a+b (r=0.986).

A moderate negative correlation was found between chlorophyll a and chlorophyll a/b (r= -0.447). A significant negative correlation was found between chlorophyll a+b and chlorophyll a/b (r= -0.539), as well as between chlorophyll b and chlorophyll a/b (r= -0.673) and a strong negative correlation between chlorophyll a/b and carotenoids (r= - 0.828).

Table 3. Correlations between plastid pigments content in maize hybrids of FAO 500-599 maturity group

	Chl a	Chl b	Chl a+b	Chlo a/b
Chl a	0.962	0.994	-0.447	0.683
Chl b		0.986	-0.673	0.818
Chl a+b			-0.539	0.742
Chlo a/b				-0.828

In the studies of Łącka et al. (2021) the next correlations were observed between contents of: chlorophyll a and carotenoids (r=0.778), contents of chlorophyll b and carotenoids (r=0.807), contents of chlorophyll a+b and carotenoids (r=0.785), chlorophylls a and b (r=0.990), chlorophylls a and a+b (r=1.000). The significant negative correlations were observed between contents of: chlorophylls a and a/b (r=-0.678), chlorophylls b and a/b (r=-

0.767), chlorophylls a+b and a/b (r=-0.698) as well as contents of chlorophyll a/b and carotenoids (r=-0.711).
The following correlations were found for the hybrids of FAO 600-699 maturity group (Table 4): strong positive correlation between chlorophyll a and carotenoids (r=0.873), between chlorophyll b and carotenoids (r=0.890), and between chlorophyll a+b and carotenoids (r=0.880). A very strong positive correlation close to the functional correlation was found between chlorophyll a and chlorophyll b (r=0.999), between chlorophyll a and chlorophyll a+b (r=0.999), and between chlorophyll b and chlorophyll a+b (r=0.999).

Table 4. Correlations between plastid pigments content in maize hybrids of FAO 600-699 maturity group

	Chl a	Chl b	Chl a+b	Chlo a/b
Chl a	0.999	0.999	-0.954	0.873
Chl b		0.999	-0.964	0.890
Chl a+b			-0.958	0.880
Chlo a/b				-0.967

A very strong negative correlation was found between chlorophyll a and chlorophyll a/b (r= -0.954), between chlorophyll b and chlorophyll a/b (r= -0.964) and between chlorophyll a+b and chlorophyll a/b (r= -0.958).

CONCLUSIONS

When determining the content of plastid pigments (chlorophylls and carotenoids) in the leaves of maize hybrids of two vegetation maturity groups (mid-late, FAO 500-599 and late, FAO 600-699), it was found that the highest chlorophyll a, chlorophyll b and total contents for plants of hybrid Kneja 560 (2.88 mg/g FW, 1.61 mg/g FW and 4.49 mg/g FW, respectively). For the hybrids of the FAO 600-699 group, the highest chlorophyll a, chlorophyll b and total contents were found for plants of hybrid Kneja 648 (3.54 mg/g FW, 1.85 mg/g FW and 5.39 mg/g FW, respectively). Higher than the group average values were also found for plants of hybrid Kneja 650A, respectively by 8.42% for chlorophyll a, by 10.7% for chlorophyll b and by 9.18% for chlorophyll a+b.
In general, the plastid pigment content was higher in the hybrids of the FAO 600-699 maturity group as follows: by 12.53% for chlorophyll a, by 9.38% for chlorophyll b, by 11.47% for chlorophyll a+b, by 8.30% for carotenoids and by 11.29% for total plastid pigment content (chlorophylls+carotenoids). The percentage contribution of carotenoids as a proportion of total plastid pigment content was higher for hybrids in the FAO 500-599 group, reaching 7.17% versus 6.44% for hybrids in the FAO 600-999 group.
For the hybrids of FAO 500-599 maturity group a very strong positive correlation was found between chlorophyll a and chlorophyll b (r=0.962), between chlorophyll a and chlorophyll a+b (r=0.994), and between chlorophyll b and chlorophyll a+b (r=0.986) and a strong negative correlation between chlorophyll a/b and carotenoids (r= - 0.828).
For the hybrids of maturity group FAO 600-699, a very strong positive correlation close to the functional correlation was found between chlorophyll a and chlorophyll b (r=0.999), between chlorophyll a and chlorophyll a+b (r=0.999), and between chlorophyll b and chlorophyll a+b (r=0.999). A very strong negative correlation was found between chlorophyll a and chlorophyll a/b (r=-0.954), between chlorophyll b and chlorophyll a/b (r=-0.964) and between chlorophyll a+b and chlorophyll a/b (r=-0.958).

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