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PIGMENT PROPERTIES OF NEW AND HIGH-QUALITY INBRED LINES AND HYBRIDS OF MAIZE WITH HIGH NUTRITIONAL VALUES

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This paper presents results of different studies on confirmation of a hypothesis that maize inbred lines rich in pigments and with exceptional nutritive values can be bred in order to support a medicinal standpoint of programmed need for maize in food and feed. With such an experimental approach the following maize inbreds: ZPPL 146 and ZPPL 159 and hybrids derived from them: ZP 633, ZP 735 and ZP 737 have been systematically tested. Conformational characteristics of carotenoid molecules in leaves were established by means of the resonance Raman spectroscopy. Inbread lines and hybrids which are rich in carotenoids also contain other beneficial biologically active substances.

Key words: Zea mays L., hybrid, inbred lines, carotenoids, Raman spectroscopy of leaves, delayed chlorophyll fluorescence, nutritive value.

There are reasons to consider the period 1954—2014 as a historically significant period of a great progress in the area of maize breeding, selection of maize hybrids and the production of hybrid seeds of high quality. As a result of such progress there were received more than 1400 developed grain and silage maize hybrids, as well as hybrids for the industrial processing [9, 11, 40, 42]. During this period up-to-date technical and technological prerequisites for modern process of breeding, the production of hybrid seeds and sufficient amounts of commercial seeds have been provided [13, 14, 15, 23].

Diverse interdependent studies of several scientific disciplines (biophysics, biochemistry, biotechnology, photosynthesis and Raman spectroscopy) were intermingled into the complex of the stated developmental trends with the aim to modernise and efficiently implement contemporary programmes in maize breeding and seed production [16, 21, 26, 27, 29, 38]. In addition to the exceptional results obtained in breeding of standard maize grain and silage hybrids and hybrids intended for industrial processing a relevance without delay to develop elite inbred lines and quality maize hybrids with improved chemical composition of essential bioactive compounds has arisen [6, 7, 10, 19, 22, 41].

To meet many demands and justifiable needs for quality nutrition of people (mainly children and the elderly), domestic animals, as well as for industrial processing (semi- and final products) it was necessary to select maize inbred lines with significantly richer pigment-complex properties and the exceptional nutritional value, which is achievable by increasing the carotenoid content. With such inbred lines it was possible to develop high-quality maize hybrids, which would meet established medicinal criteria regarding healthy nutrition of people, domestic animals, as well as broadly developed industrial processing, which is the objective of the present study.

Methods

Plant material. The studies were performed with the following two elite maize inbred lines: ZPPL 146 and ZPPL 159 and the hybrids developed from them: ZP 633, ZP 735 and ZP 737. The observed maize inbreds and hybrids belong to the collection of the Maize Research Institute, Zemun Polje, Belgrade. As these are inbred lines with significant breeding traits and specific chemical properties and maize hybrids with their use programmed for nutrition of people, domestic animals and for industrial processing, their traits will be separately presented in this manuscript. Fig. 1 shows the actual appearance of elite maize inbred lines with erect top leaves ZPPL 146 and ZPPL 159 and high-quality maize hybrids ZP 633, ZP 735 and ZP 737 with their ears.

Overall studies of the stated elite inbred lines and hybrids developed from them with erect top leaves encompassed several series of experiments in which new and standard methods and procedures were applied.

1. Chemical composition of maize inbred lines with significant breeding traits and high-quality maize hybrids. Methods applied to determine the grain chemical composition of maize inbred lines and hybrids are generally accepted and standardised and already described in detail in previous papers [6, 24, 31, 39, 41].

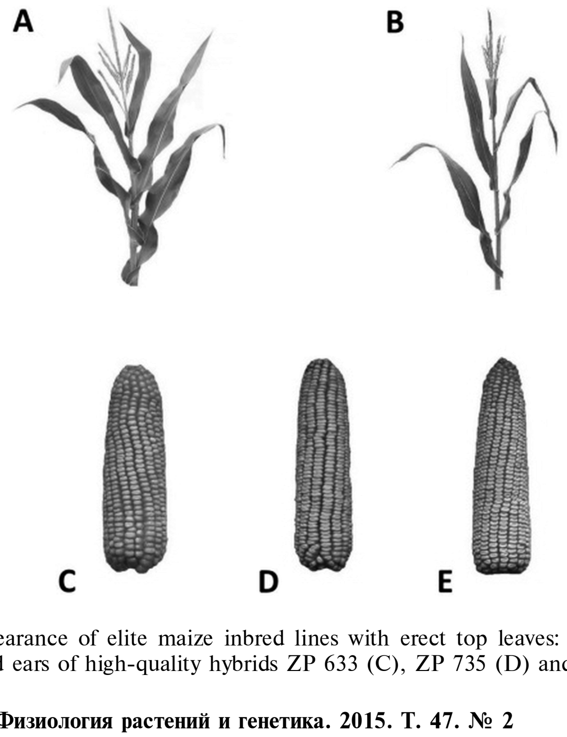

Fig. 1. Actual appearance of elite maize inbred lines with erect top leaves: ZPPL 146 (A) and ZPPL 159 (B), and ears of high-quality hybrids ZP 633 (C), ZP 735 (D) and ZP 737 (E)

2. Resonance Raman spectroscopy method applied to maize inbred lines. Measures of resonance Raman spectroscopy of maize inbred line leaves were done in accordance with the procedure and the method described in our previously published manuscripts [32, 33, 34, 35].

3. The measure of the angle and the leaf area of maize inbred lines. This series of experiments was related to studying the erect position of top leaves in maize inbred lines. A specially designed protractor was used to measure the angle between the position of the above-ear leaf and the position of the plant stalk on maize inbred lines. The leaf area was measured by the LI-3000 portable leaf area meter (LI-COR Biosciences, USA). Measures of the angle between the above-ear leaf and the stalk and the leaf areas were carried out on 126 plants for each inbred line during the three-year period. These methodical procedures had been described in previously published papers [27, 31].

4. Photosynthetic fluorescence measurements. This series of the experiments was related to photosynthetic fluorescence measurements, including thermal processes of delayed chlorophyll fluorescence (DF), critical temperatures (phase transitions) and activation energies. The test maize inbreds grown in the experimental field of the Maize Research Institute, Zemun Polje, were brought to the laboratory between 7 a.m. and 8 a.m. Plants sampled in the field were transversally cut in the ground internode. In the laboratory, plants were internode lengthwise placed in water. Prior to the fluorescence experiment, all plants were kept under the black ball glass for two hours. A segment of intact above ear leaves was taken from such plants and placed into a chamber of the phosphoroscope. The intact leaf segments were kept in the chamber (in the dark) for at least 15 minutes, and then thermal processes of DF were measured. These tests were performed on 118 plants of each inbred line. An improved, non-invasive photosynthetic fluorescence method was applied for these measurements. This method was developed at the Maize Research Institute and was described in the previously published papers [28, 29, 31, 36, 38].

5. Functional dependence of the yield. Agronomic and morphological traits of high-quality maize hybrids for various locations in South-Eastern Europe. Numerous and long-term studies of yields (t ha^{-1}) of the three high-yielding and high-quality grain and silage maize hybrids (ZP 633, ZP 735 and ZP 737) were performed in many different locations in Serbia and other countries of South-Eastern Europe. Standard methods for contemporary maize production, tinning and processing were applied in these studies [6, 22, 43].

6. Presentation of breeding and seed production properties of elite inbred lines. As prospective inbred lines with efficient photosynthesis, rich pigments and outstanding nutritive qualities were observed, a broader presentation of their respective breeding, seed production and technological traits, properties and parameters gained by use of standard methods of ranking is given.

7. Medical opinions on need for human nutrition with maize. Empirical efforts to acquire knowledge about the need for maize diet in human nutrition were initiated a long time ago, perhaps 300—400 years ago. Much later, in the 1950s, scientific literature related to this topic emerged, primarily in medicinal institutions. However, the authors of this study became interested in this topic in the early 1990s [25].

Results and discussion

1. Chemical composition of maize inbred lines with significant breeding traits and high-quality maize hybrids. Results of overall studies of grain chemical compo-

TABLE 1. Results of the analysis of grain chemical composition of maize inbred lines and hybrids

Grain chemical composition of maize inbred lines and hybrids	Range of the chemical composition in the literature*	Average chemical composition in the literature*	Average chemical composition of maize inbred lines and hybrids				
			Inbreds		Hybrids		
			ZPPL 146	ZPPL 159	ZP 633	ZP 735	ZP 737
Moisture (%)	7—23	16	10.24	10.12	9.90	9.84	10.15
Starch (%)	61—78	71.7	67.80	66.26	68.23	64.39	67.86
Protein (%)	6—12	9.5	10.22	12.57	11.11	12.27	11.57
Fat (oil) (%)	1—5.7	4.3	7.53	5.38	6.11	5.82	7.16
Ash (%)	1.1—3.9	1.4	1.48	1.45	1.51	1.54	1.47
Cellulose (%)		3.0	2.26	2.33	2.37	2.43	2.00
Yellow pigment (μg β-carotene/g d.m.)**	—	—	19.0	18.10	27.30	21.90	21.60
Total carotenoids (mg/kg)	12—36	26	33.2	31.8	32.4	28.3	27.8

*Source: [45].
** Done by the AACC method: AACC, 1995. Pigment. Methods 14—50.

sition of observed maize inbred lines and hybrids are presented in Tab. 1. Obtained results relate to important chemical constituents and are supplemented with results of chemical compositions of vitamins, dietary fibres and other biogenic and medicinal compounds.

2. Resonance Raman spectrum of leaves of maize inbred line ZPPL 146. Fig. 2 presents a typical example of a leaf resonance Raman spectrum of the maize inbred line ZPPL 146.

The following six characteristic resonance Raman spectral bands were established within the 900—1800 cm^{-1} interval of Raman frequencies: 962, 1026, 1160, 1187, 1206 and 1520 cm^{-1}. Four spectral bands with smaller intensity (I_{962}, I_{1026}, I_{1187}, I_{1206}) were caused by conformational changes of phosphates, glycose, amides III. The remaining two spectral bands with significantly higher intensity (I_{1160}, I_{1520}) are regularly analysed in relation to the conformational changes in the carotenoid molecule. It is common to analyse the differences in the intensities of spectral bands (I_{1520} and I_{1160}), and even

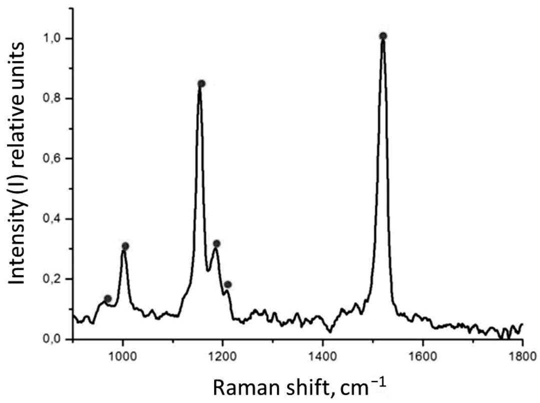

Fig. 2. Resonance Raman spectrum of the leaf of the maize inbred line ZPPL 146

more often the differences in their ratio (I_{1520}/I_{1160}) are analysed. Fig. 2 presents the resonance Raman spectrum of the leaf of the inbred line ZPPL 146 with dominant spectral bands (I_{1520} and I_{1160}) that reveal the carotenoid molecules placed in the non-polar phase of the thylakoid membrane of the leaf. In this paper the effort was made to emphasise the application of resonance Raman spectroscopy in studying important vital functions of leaves of maize inbred lines, especially under agroecological conditions atypical for the maize growing region. Carotenoid molecules (β-caroten, $C_{40}H_{56}$, with the activity of vitamin A, but also two xanthophylls: cryptoxanthin $C_{40}H_{56}O$ and zeaxanthin $C_{40}H_{56}O_2$), since localised in non-polar phase of the thylakoid membrane of maize inbred leaves, showed to be a very suitable natural probe, capable to contribute to registering not only higher and more significant, but also smaller and finer conformational changes. These changes in the molecular structure of carotenoids may be expressed in the form of bending, stretching, compressing and physical disruption of chemical bonds, which is caused by intensive actions of environmental factors, first of all of unfavourable critical temperatures. In the end each conformational change in the carotenoid molecule unconditionally changes the function not only of the carotenoid molecule but also of the thylakoid membrane in leaves of maize inbred lines. Conformational changes in chemical bonds $- C = C -$ are reflected in the spectral band at 1520 cm^{-1}. In addition, conformational changes in chemical bonds $= C - C =$ are reflected in the spectral band at 1160 cm^{-1} [1] (Fig. 2).

3. The measure of the angle and the area of the above-ear leaf. Results on the measures of angles between the above-ear leaf and the stalk, as well as, the average leaf areas are presented in Tab. 2. Based on obtained results on the measures of angles it can be stated that the observed maize inbred lines with significant breeding traits belong to the group of recently developed inbred lines with erect top leaves and a trait of a photosynthetic model.

Observed maize inbred lines represent good heterotic pairs, have good combining abilities for grain yield and silage, their propagation is well and they are highly yielding inbreds. These inbreds are rich in pigments and have extraordinary nutritive qualities.

4. Photosynthetic fluorescence measurements. The exact temperature dependence of the delayed chlorophyll fluorescence (DF) intensity for the thylakoid membrane of elite maize inbred lines with erect top leaves. The experimental measures of changes in the stationary DF level in dependence on the temperature, ranging from 25 to 60 °C, were performed. Dynamics of temperature dependence for observed new maize inbred lines with erect top leaves is presented in Fig. 3.

TABLE 2. Angle between the above-ear leaf and the stalk and leaf area of maize inbred lines with efficient photosynthesis

Maize inbred line	FAO maturity group	Heterotic origin of inbred line	Angle of the above-ear leaf, degree		Leaf area of the above-ear leaf	
			$\bar{X}$	σ	$\bar{X}$	σ
ZPPL 146	650—700	BSSS, USA Zemun Polje	20.8°	1.21	3762.7	238
ZPPL 159	550—600	Local population from Argentine (S13) crossed to the inbred PE25-10-1, Zemun Polje	21.30°	1.23	2378.1	241

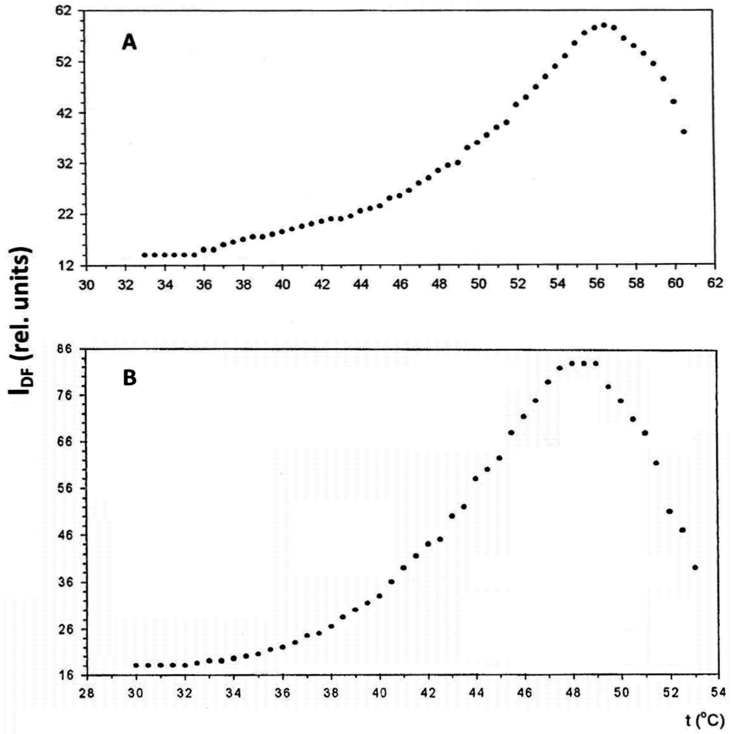

Fig. 3. Dynamics of changes in the intensity of the delayed chlorophyll fluorescence (IDF) of thermal processes in dependence on the effects of temperatures in chloroplasts and the thylakoid membranes of the intact above-ear leaf of the maize inbred lines ZPPL 146 (A) and ZPPL 159 (B) with significant breeding properties and erect top leaves

The Arrhenius plot for the determination of critical temperatures and conformational changes in chloroplasts and the thylakoid membrane of the prestigious maize inbred lines with erect top leaves. The Arrhenius plot is based on the linearisation of the exact DF temperature dependence of observed maize inbred lines. Critical temperatures (phase transition temperatures) at which conformational changes occur in chloroplasts and the thylakoid membranes are determined by the application of the Arrhenius plot. Results of the Arrhenius plot application to observed elite maize inbred lines are presented in Fig. 4.

Activation energy and critical temperatures in the thylakoid membranes of the observed elite maize inbred lines with erect top leaves. Detailed studies on the thermal processes of DF, and especially on the analysis of experimental thermal curve, encompassed not only the temperature dependence and the Arrhenius plot, but also the estimation of values of activation energies (E_a) for critical temperatures (phase transition temperatures) in chloroplasts and the thylakoid membranes of the observed elite maize inbreds. Obtained results are shown in Tab. 3.

5. Functional dependence of the yield. Agronomic and morphological traits of high-quality maize hybrids for various locations in south-eastern Europe. High-yielding and high-quality maize hybrids: ZP 633, ZP 735 and ZP 737 are mainly intended for grain and silage production under agroecological conditions of South-Eastern Europe. According to our studies and experience gained by practice, the hybrid ZP 633 is very suitable in the human diet. However, hybrids ZP 735 and ZP 737 are exclusively used in nutrition of domestic animals through high-quality silage of grain and whole plants. These hybrids are

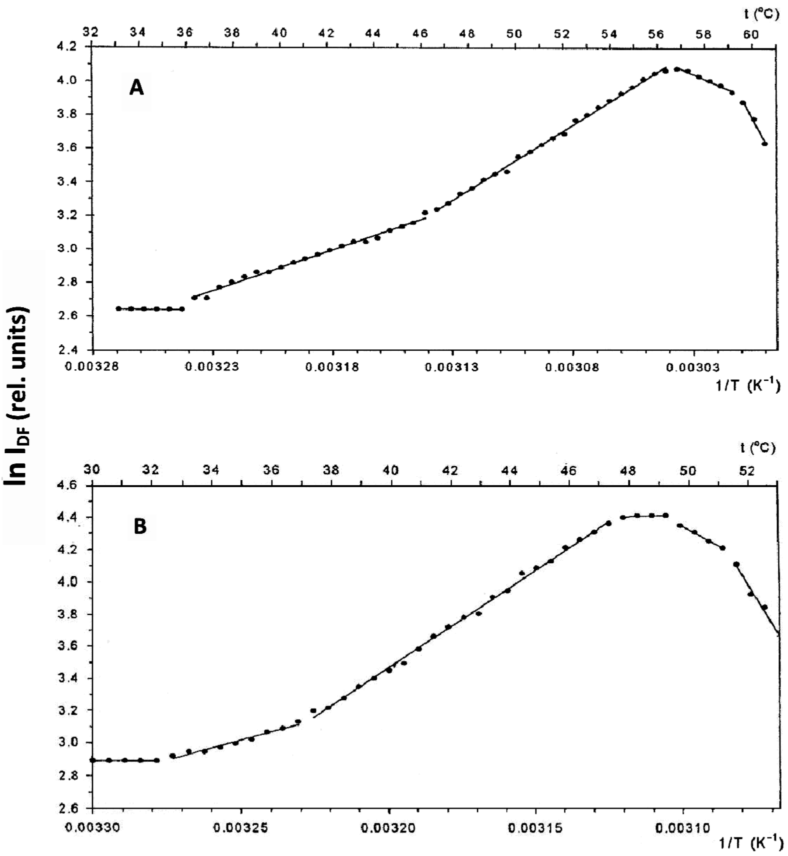

Fig. 4. The Arrhenius plot for the determination of critical temperatures and conformational changes in chloroplasts and the thylakoid membranes of the above-ear leaf of maize inbred lines ZPPL 146 (A) and ZPPL 159 (B) with significant breeding properties and erect top leaves

used to a significantly smaller extent in industrial processing of semi- and final products intended for diverse purposes. Their important agronomic and morphological traits are presented in Tab. 4 and 5.

According to data presented in Tab. 4 and 5 observed hybrids belong to long-season hybrids with modern architecture and the stay-green trait. Moreover more than 50 % of grain of these hybrids are in the silage mass, which is very important for silage quality. The embryo content in grain amounts to above 10 %, what is especially important for quality of nutritive

TABLE 3. Changes in activation energies (E_a) and critical temperatures (t, °C) in the course of thermal processes in chloroplasts and the thylakoid membranes of the intact above-ear leaf of inbreds with significant breeding properties and erect top leaves

ZPPL 146		ZPPL 159	
E_a, kJ/mol	t, °C	E_a, kJ/mol	t, °C
—	34.5	—	32.5
41.00	46.0	42.1	37.0
74.86	56.5	101.2	47.5
50.70	59.5	6.2	49.0
225.50	—	81.1	51.0

TABLE 4. Agronomic traits of observed high-quality maize hybrids

Hybrid designation	ZP 633	ZP 735	ZP 737
Hybrid type	SC	SC	SC
FAO maturity group	550—650	750—850	750—850
Plant height (cm)	250	280	290
Ear height (cm)	120	130	135
1000-kernel weight (g)	380	370	370
Kernel type	semi-dent	dent	dent
Sowing density of silage hybrid (1000 plants ha^{-1})	60—70	70—75	70—75
Leaf position on plant	semi-erect to erect	semi-erect to erect	semi-erect to erect
Tolerance to drought	good	good	good
Tolerance to diseases	good	good	good
Leaf appearance at harvest	stay green	stay green	stay green
Hybrid growing regions (altitude, m)	300—400	250—400	250—400
Hybrid silage yield (t ha^{-1})	60—65	70—80	70—80
Hybrid grain yield (t ha^{-1})	7.819*	8.108**	12.732**

* Hybrid yield achieved in 30 locations in Serbia in the 2008—2011 period.
** Hybrid yield achieved in 6 locations in Greece in the 2006—2009 period.

TABLE 5. Ear morphological traits of observed high-quality maize hybrids with a grain structure

Morphological traits of ear	Hybrid designation		
	ZP 633	ZP 735	ZP 737
Grain moisture (%)	18	19	20
Ear length (cm)	22	25	25
Ear weight (g)	252.30	286.42	226.70
Rows per ear	16	18	18
Kernel row number	700	800	850
Kernel weight on ear (g)	228.36	248.35	200.40
% grain pericarp on ear	5.32	6.55	4.60
% grain embryo on ear	11.28	12.06	10.70
% grain endosperm on ear	83.40	81.39	84.70

values of hybrids in nutrition of people (especially of children and the elderly) but also in nutrition of domestic animals, as well as for industrial processing of semi- and final products.

6. Brief survey of breeding and seed production traits of elite maize inbred lines with efficient photosynthesis. Observed maize inbred lines with significant breeding traits ZPPL 146 and ZPPL 159 have been used in breeding for the last 5—6 years. Due to it, relevant observations of their total traits, performances and parameters are presented in Tab. 6.

7. Medical opinions on need for human nutrition with maize enriched with pigments and other nutrients. Maize is one of the potential energy sources. This

TABLE 6. Relevant breeding and seed production traits of maize inbred lines with efficient photosynthetic functions

Breeding and seed production traits	Brief description of breeding and seed production traits of maize inbred lines	
	ZPPL 146	ZPPL 159
Heterotic origin	BSSS, SAD, Zemun Polje	Local population from Argentine (S13) crossed to the inbred PE25-10-1, Zemun Polje
FAO maturity group	650—700	550—600
Grain yield ha^{-1} in kg at 14 % moisture		
a) dry land farming	3500	2000
b) irrigation	5000	3000
Number of plants ha^{-1} at harvest		
a) dry land farming	50000	50000
b) irrigation	60000	60000
Stalk properties	Stalk is moderately high with prolific trait. Tassel has elongated central branch with fewer side branches	Stalk is short. Tassel has closed side branches that shed long
Stalk resistance to lodging	Inbred is resistant to lodging	Inbred is resistant to lodging
Erect position of above ear leaves	first leaf < 20.8° second leaf < 17.9° third leaf < 15.3°	first leaf < 21.3° second leaf < 18.1° third leaf < 15.4°
Does the leaf remain green until harvest?	Leaf did not remain green until harvest	Leaf remained moderately green until harvest
What is tolerance of inbreds to stress factors (drought and high temperatures, etc.)?	Inbred is tolerant to drought and high temperatures	Inbred is tolerant to drought and high temperatures
Kernel traits and cob colour	Semi-dent type, orange kernels, while cob is white	Semi-flint, orange kernels, while cob is red
% grain moisture at harvest	20—25	20—25
Dry down rate in the stage of grain maturing	Dry down rate is fast, but hybrids are suited for silage	Dry down rate is not fast, but hybrids are suited for silage
Is harvest of the inbred easy?	Harvest is easy	Harvest is easy
What does emergence look like?	Inbred emerges well	Inbred emerges well
What does early growth of the inbred look like?	Early growth is moderate	Early growth is moderate
Is grain of hybrids developed from this inbred suitable for nutrition of ruminants and nonruminants?	Grain is suitable for nutrition of ruminants, nonruminants, human nutrition and for industrial processing	Grain is suitable for nutrition of ruminants, nonruminants, human nutrition and for industrial processing
What is the carotene content in inbred grain?	a) 33,2 (mg/kg) b) 19,00 (μg βCE/g d.m.)	a) 31,8 (mg/kg) b) 18,10 (μg βCE/g d.m.)
Is the inbred suitable for developing silage hybrids?	Inbred is very suitable for developing silage hybrids	Inbred is very suitable for developing silage hybrids
Is digestibility of the hybrids developed from this inbred good?	Hybrids developed from this inbred have good digestibility of the whole plant and of milled grain	Hybrids developed from this inbred have good digestibility of the whole plant and of milled grain

raises the question of what it is that makes maize so useful and likeable for nutrition. Maize contains very little fats, and at the same time it contains many carbohydrates. Moreover maize contains many plant fibres and therefore it lowers the levels of blood cholesterol and blood sugar, which lowers the risk of colon cancer [12]. At the same time, maize provides vitamin B, folic acid and magnesium, which positively affects brain functioning. In addition, vitamin C originating from maize will make you awake. It should also be known that excessive levels of some amino acids might cause heart diseases. This condition occurs due to the lack of folic acid in the organs. For these reasons, the use of maize in the diet results in successful protection of the heart [12, 18]. In addition, folic acid is essential for the proper foetal nervous system development, hence maize is recommended for diets of women who intend to become pregnant, as well as pregnant women in the first three months of their pregnancy. Furthermore, cooked maize on cobs can be consumed, as well as cooked maize added to various meals and salads. Of course, maize can be consumed in the form of corn bread, polenta, tortillas and popcorn (with a minimum addition of oil). In each of these forms, maize is very beneficial for normal growth and development and metabolism functions [20, 25]. Beside the stated, the most often medicinal benefits are based on the role of carotenoids. They protect plants from damages caused by photo-induced free radicals. Carotenoids, as precursors of abscisic acid, give kernels the yellow colour [19, 44]. It is important to point out to a special role of carotenoids as antioxidants in prevention of cardiovascular diseases, cancer and cataract [12, 18].

As already said, a great success has been achieved in maize breeding and the production of high-quality commercial and hybrid maize seed for the last 60 years. The number of plants per area unit has been significantly growing since 1978. This trend in maize breeding was referred to as a «plant density» programme and it further directly affected the yield increase of high quality of hybrid maize seed, as well as commercial seed [37, 38]. Somewhat later, a programme on the development of maize inbred lines with erect top leaves (inbreds with efficient photosynthesis) was established. It was considered that these inbreds were the closest to the proposed efficient photosynthetic model [30]. Almost at the same time, a programme on the development of maize inbred lines rich in pigments and with other chemical properties and extraordinary nutritive values was established [6, 10, 12, 18, 19, 20, 21, 23, 41].

This study was an attempt to answer the following questions by using different tests and analyses: is there a reliable and dominant trait of maize inbred lines rich in the pigment complex that would be the basis for the development of new high-quality maize hybrids that would be suitable for food, feed and industrial processing of semi- and final products? The analysis of presented overall results, obtained in the series of experiments, give the positive answer to this question. Consequently, prestigious maize inbred lines (ZPPL 146 and ZPPL 159) and high-quality hybrids developed from them (ZP 633, ZP 735 and ZP 737) are the best confirmation of the stated. Selected inbred lines and hybrids developed from them are rich in pigments, have significant nutritive values, especially of carotenoids that give kernels their yellow colour [4], that are used in the nutrition of poultry. Carotenoids positively affect health of both, people and animals [5, 12, 18, 41]. This aspect of observed maize inbred lines and hybrids will get priority within the heathy diet of people and animals.

According to the presented numerous and diverse results on studies of inbred lines with significant breeding traits (ZPPL 146 and ZPPL 159) and high-quality maize hybrids developed from these inbreds (ZP 633, ZP 735 and

ZP 737) that are rich in pigments and have exceptional nutritive values, the following can be it concluded:

Selected maize inbred lines (ZPPL 146 and ZPPL 159), rich in carotenoids, yellow pigments, also have significant amounts of other relevant bioactive compounds.

Observed inbred lines have erect top leaves and are classified into a group of maize inbreds with significant properties of photosynthetic model and are tolerant to high temperatures.

Spectral bands pointing to conformational characteristics of molecules of carotenoids but also other compounds (phosphates and amides III) were established by the application of the resonance Raman spectroscopy method to the leaf of maize inbred lines.

Relevant traits, properties and parameters of observed maize inbred lines that can be used in the process of selection are presented.

These prestigious maize inbred lines were used to develop high-quality maize hybrids (ZP 633, ZP 735, ZP 737) that are recognisable for their quality in human nutrition (children and the elderly), that are confirmed by medical observations related to their use in food, feed and industrial processing.

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ВЛАСТИВОСТІ ПІГМЕНТІВ НОВИХ ІНБРЕДНИХ ЛІНІЙ ТА ГІБРИДІВ КУКУРУДЗИ ВИСОКОЇ ПОЖИВНОЇ ЦІННОСТІ

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Викладено результати досліджень, які підтверджують правомірність гіпотези про те, що інбредні лінії кукурудзи з підвищеним вмістом пігментів і високими поживними якостями можуть бути основою для отримання гібридів, що повною мірою відповідають сучасним вимогам до продуктів харчування та кормів. У цьому плані всебічно вивчено інбредні лінії кукурудзи ZPPL 146, ZPPL 159 й отримані на їх основі гібриди ZP 633, ZP 735, ZP 737. Конформаційні характеристики молекул каротиноїдів у листку отримано за допомогою резонансної раманівської спектроскопії. З'ясувалося, що інбредні лінії і гібриди з високою концентрацією каротиноїдів містять у зернівках й інші корисні біологічно активні речовини.

СВОЙСТВА ПИГМЕНТОВ НОВЫХ ИНБРЕДНЫХ ЛИНИЙ И ГИБРИДОВ КУКУРУЗЫ ВЫСОКОЙ ПИТАТЕЛЬНОЙ ЦЕННОСТИ

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Представлены результаты исследований, подтверждающие правомерность гипотезы о том, что инбредные линии кукурузы с повышенным содержанием пигментов и высокими питательными качествами могут быть основой для получения гибридов, в полной мере соответствующих современным требованиям к продуктам питания и кормам. В этом плане всесторонне изучены инбредные линии кукурузы ZPPL 146, ZPPL 159 и полученные на их основе гибриды ZP 633, ZP 735, ZP 737. Конформационные характеристики молекул каротиноидов в листьях получены с помощью резонансной рамановской спектроскопии. Оказалось, что инбредные линии и гибриды с высокой концентрацией каротиноидов содержат в зерновках и другие полезные биологически активные вещества.

Ключевые слова: Zea mays L., гибрид, инбредные линии, каротиноиды, рамановский спектр листа, замедленная флуоресценция хлорофилла, питательная ценность.