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Popping corn, hybrid Kneja pop 1 - a new Bulgarian selection of corn for food purposes. First message

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Abstract: The article presents original data on the newest, high-quality, Bulgarian pop corn hybrid Kneja pop 1. The hybrid was selected at the Maize Research Institute in the city of Knezha, Bulgaria. It was created by Associate Professor Dr. Georgi Yordanov, as a result of a long-term selection and genetic program for the creation of corn hybrids for special purposes of use. In 2021. it was submitted for official state testing and recognition in the IASAS system. Hybrid popping corn Kneja pop 1 has a patent Certificate for a new plant variety, Registration No. 11298 P2 and is entered in the Official Variety List of the Republic of Bulgaria. It is characterized by very good agrobiological and economic qualities of the crop, tall, productive and vibrant plants, resistant to diseases and enemies. The popcorn obtained from the grain of the Kneja pop 1 hybrid, after heat treatment, is distinguished by a very good commercial appearance and excellent tasting qualities. The cracking coefficient, K_{pop1} , reaches 40 (cm³/g).

Key words: popping corn; new Bulgarian hybrid; productivity; quality

INTRODUCTION

The popping corn - *Zea mays* L. ssp. *Everta*, unlike regular feed corn is grown primarily for human consumption. After heat treatment of the grain, delicious, dietary and nutritious popcorn is obtained from it, preferred for human consumption. Popcorn is a whole grain food, which makes it naturally rich in important nutrients. In addition to popcorn, the grain of the popped corn, after appropriate technological processing, is also used as an ingredient in some confectionery and food products. Popped corn has been known to people for many years. Open-pollinated varieties of it have been used for a long time (Jele et al., 2014; Oliveira et al., 2018). However, the main problem with them is the low productivity of the crop. To solve this problem, the heterosis effect in maize is currently used to create highly productive maize hybrids (Miranda et al., 2008; Pajic et al., 2008; Fisher & Edmeades, 2010; Hallauer & Carena, 2012; Ilchovska, et al., 2019, Olivei-

ra et al., 2018; El-Gazzar, 2021, Vulchinkova & Vulchinkov, 2021). The problem in the selection of popcorn is not only the high productivity of the plants, but also the good taste qualities of the popcorn obtained from the grain. And the highest-yielding hybrids would not be successful if their grain did not produce high-quality popcorn. In practice, with this type of corn, "tandem selection" should be conducted, including productivity + quality. This is necessary in order to satisfy the requirements of both popcorn producers, who require high yields from the cultivated varieties, and consumers of popcorn, who are mainly interested in the taste qualities, appearance and color of the popcorn. The taste qualities of popcorn mainly depend on the tenderness and fragility of their structure, the content of sugars and polysaccharides in them, the absence of coarse flakes and others. The tender texture of popcorn depends to a large extent on the volume at bursting of the kernel, also referred to as the kernel bursting ratio (K_{r1}), and is the ratio of the volume of the

popped kernels to the weight or volume of the kernels before popping. In turn, the kernel cracking rate depends on many physical and genetic factors, the most important of which are the humidity of the kernel before cracking, the method of kernel cracking, hereditary factors and others (Quinn et al., 2005; Öz & Kapar, 2011; Rossato Junior et al., 2013). Unfortunately, a negative correlation was observed between the Krorl kernel cracking ratio and grain yield in popping corn, but this could be overcome to produce hybrids with high yields and good popcorn quality (Mitev, 1984). Selection work in this regard is greatly facilitated by the fact that the selection materials are unmatched in terms of grain cracking coefficient, which is a prerequisite for successful work in this direction (Mitev, 1984). In our country, popping corn is grown on small areas. Scientific research and use of hybrids in production is quite limited (Mitev, 1984; Glogova, 2010).

The goal of our selection and genetic work was to create and study a new Bulgarian pop corn hybrid, with high quality of the grain and the popcorn obtained from it, and with good productive possibilities of sowing. The newly created Bulgarian popcorn hybrid should enrich the assortment of popcorn corn offered on our market and ensure independence from the import of this type of corn.

MATERIAL AND METHODS

Hybrid “Kneja pop 1” is a new Bulgarian, heterozygous, two-line, hybrid pop corn for food purposes. It was created at the Maize Institute by Associate Professor Georgi Yordanov (E-mail: geo.i@abv.bg). “Kneja pop 1” has a Certificate for a new plant variety, Registration No. 11298 P2 dated: 2024. 01. 25 (Patent Office of the Republic of Bulgaria) - Photo 1. The holder of the certificate is the Maize Institute - Knezha, 5835 Knezha city, Pleven region (Bg). Author: Georgi Yordanov Yordanov. By order No. RD12-3 of 17.03.2023 of the Minister of Agriculture of the Republic of Bulgaria, the Popping corn hybrid Kneja pop 1 is approved and recognized for in-

clusion in the Official Varietal List of the Republic of Bulgaria. The selection genetic work and the field experiments on the article were carried out in the selection field of the Maize Institute - Knezha city, Bulgaria, GPS coordinates: W: 43.479285 N: 24.070573, altitude 120 m, soil type typical chernozem, under conditions without irrigation during the period 2010 - 2019 year. The experimental work was carried out according to the agrotechnics adopted for the region for growing corn for grain, including soil treatments, fertilization, spraying with soil and foliar herbicide against weeds and others. The most important economic indicators of the newest Bulgarian pop corn hybrid Kneja pop 1 were studied. The hybrid was created at the Maize Institute in the city of Knezha after many years of selective genetic work on a program to create new maize hybrids for special purposes of use. Heterosis selection was used for its creation. Regional and imported maize populations with orange endosperm of the grain were used as the starting selection material, in which a selection of promising forms was carried out. Selective genetic work with these forms continued through several cycles of self-pollination and selection of desired genetic types, until complete homozygosity, distinctness, homogeneity and stability of the material were achieved. New self-pollinated, stabilized popping corn lines were thus obtained. These new self-pollinated pop corn lines were tested in randomized field trials for general and specific combinatorial ability for yield and grain quality. As a result of these tests, the parental components of the new pop corn hybrid Kneja pop 1 were selected. In 2021. it was submitted for testing and recognition at IASAS. Hybrid popping corn Kneja pop 1 is distinguished by a yellow endosperm of the grain and very good technological and productive qualities. The cracking volume reaches about 40cm³/g grain. It is characteristic that the popcorn obtained from it has an excellent taste, tenderness and commercial appearance (Figures 2 and 3).

To evaluate the more important phenological, biometric, quality and agrobiological indicators of plants and grain of the new hybrid pop corn

Kneja pop 1, it was grown in a field experiment in three replications. After reaching full maturity, the trials were manually harvested into cobs. Average cob samples were taken from each replicate for laboratory processing. The average arithmetic values, the coefficient of variation CV% and the minimum and maximum values were determined for the measured indicators according to classic statistical models (Zapryanov, 1983). To determine the taste qualities of the grain, average samples of the plowed grain were taken. It was subjected to heat treatment to obtain popcorn. Popcorn was made using hot air, without the use of fat, using a Sencor Popcorn Maker, model SPM 8023, manufacturer Czech Republic, origin China. The taste qualities of the obtained popcorn were determined by tasting and evaluated on a five-point system from 2 - weak to 6 - excellent in terms of commercial appearance, taste and aroma of the popcorn, tenderness and fragility of the popcorn.



Figure 1. Certificate for a new plant variety, Registration No. 11298P2, from 2023, for Kneja pop 1 hybrid pop corn

RESULTS AND DISCUSSION

Popping corn Kneja pop 1 is a new Bulgarian hybrid of popping corn, suitable for obtaining high-quality popcorn for food purposes. Figure 2 shows visually representative cobs and popcorn from the newly created Bulgarian pop corn hybrid Kneja pop 1.

Agrobiological description of Kneja pop 1 pop corn hybrid

Botanical affiliation – hybrid Kneja pop 1 refers to the subspecies *Zea mays* L. ssp. *Everta* – Popping corn

Vegetation period - hybrid Kneja pop 1 is medium late in vegetation period, group 550 according to FAO. Under normal agro-meteorological conditions for the development of corn, the vegetation period of the hybrid until the cobs are fully mature is 120-125 days.

Plants - the plants of Kneja pop 1 hybrid are large, vigorous, reaching a height of 250-300 cm. The stems are weakly twining, strong, well leafed with 16-18 leaves, with very good resistance to lodging for popping corn. They are resistant to economically important diseases such as *Ustilago maydis* and *Fusarium maize*, and enemies under natural growing conditions. They normally feed 1 to 2 cobs planted at a height of 130–150 cm.

Cobs - the cobs are large, conical, 21-23 cm long, with 14 rows of grains and 50 grains in a row, which provides about 700 grains in a cob. An average of 1.3 standard cobs are formed per plant.

Grain - the grain - is orange-yellow, medium-sized, and hard. The popping volume reaches about 40cm³/g kernel, with a popping ratio of 1 to 34. It is characteristic that the popcorn produced from it has an excellent taste, tenderness and commercial appearance. (Figures 1 and 2)

Popcorn - the popcorn from the Kneja pop 1 hybrid grain when heat treated produces very nice creamy white, large and crispy popcorn with a good commercial appearance and very good taste qualities. (Figure 1) They are suitable both for direct fresh consumption and for caramelizing, glazing and other culinary purposes.

Productivity - the productivity of the hybrid is stable – 5500-6000 kg/ha of standard grain under non-irrigated conditions of crop cultivation.

The studies of the most important phenological, biometric, quality and agrobiological indicators of the plants and the grain of the new pop



Figure 2. Cobs and popcorn from Kneja pop 1 hybrid pop corn



Figure 3. Presentation of the main appearance of the cobs and popcorn characteristic of the Kneja pop 1 hybrid

corn hybrid Kneja pop 1 show the following results. Table 1. Some more important phenological indicators of hybrid pop corn Kneja pop 1 are presented. The indicators Days from plant emergence to panicle flowering, Days from plant emergence to emergence of cob silk and Days from plant emergence to full plant maturity were studied. The table shows the average indicators of the signs from the measurements made, as well as their minimum and maximum measured values. For an objective comparison of the variation of the different signs in value, this and the following tables present their coefficients of variation, CV%. Figure 1 shows a diagram of the dynamics of the occurrence of the individual phenophases of the pop corn hybrid Kneja pop 1. It takes 61 to 64 days, an average of 62.7 days, from the emer-

gence of the plants of the hybrid to the beginning of the flowering of its panicles, and until emergence of silk on the cob from 62 to 65 days, or an average of 63.7 days.

The difference between the flowering of the panicles and the appearance of silk on the cob is on average one day, which ensures one good pollination of the hybrid. Popping corn hybrid Kneja pop 1 reaches full plant maturity when the cobs can be harvested in 120 – 126 days, or an average of 123.3 days from the beginning of seed germination. From the results presented for the occurrence of the individual phenological phases of hybrid Kneja pop 1 can be concluded that it belongs to the group of mid-late hybrids of maize. From the presented results for the occurrence of the individual phenological phases of the hybrid, it can

Table 1. Measured phenological parameters of Popping corn hybrid Kneja pop 1

Parameters	Measure	Mean value	Coefficient of variation CV%	Variation of the parameter	
				MIN	MAX
Days from plant emergence to panicle flowering	Days	62.7	2.44	61	64
Days from plant emergence to emergence of cob silk	Days	63.7	2.40	62	65
Days from plant emergence to full plant maturity	Days	123.3	2.48	120	126

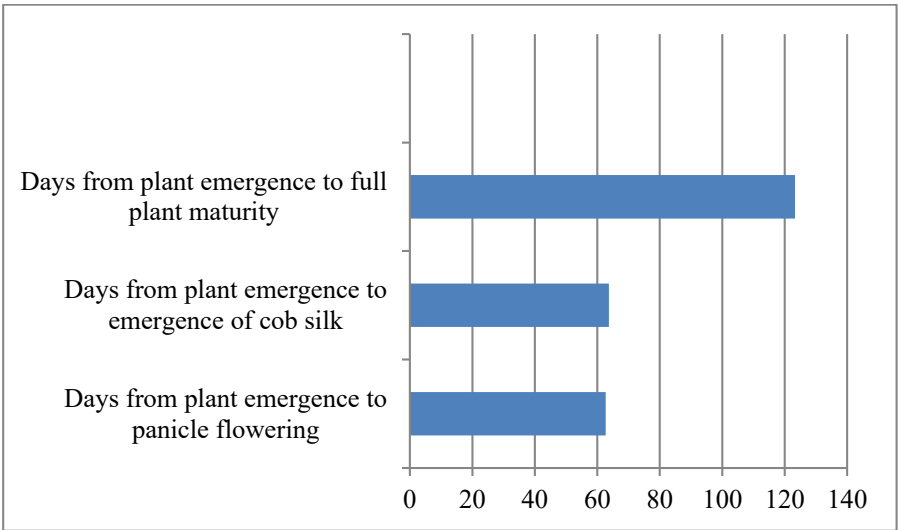


Figure 4. Diagram of the dynamics of the Phenological phases of Popping corn hybrid Kneja pop 1

be concluded that it belongs to the group of mid-late hybrids of corn.

Table 2 shows the measured biometric parameters of plants of hybrid popping corn Kneja pop 1. The total height from the base to the top of the panicle reaches 300 cm, on average 285 cm. According to this indicator, the hybrid approaches those of fodder corn hybrids. This shows a high manifestation of heterosis in terms of plant height. In most varieties of popping corn, the plants are much weaker than those of forage corn. Tall plants of the hybrid are also associated with higher cob setting. The height from the ground surface to the topmost cob of the popping corn Kneja pop 1 plants reaches 150 cm, on average 142 cm. The higher planting of the cobs is a prerequisite for their protection from fungal diseases and enemies, due to the better aeration and the further distance from the moist soil surface. Although the popping corn Kneja pop 1 plants are tall, they are strong and resistant to lodging. In most varieties of popping corn, according to our observations, there is a problem with high values of crop establishment. The diameter of the stems, measured in the milk-wax phase of the plants,

varies from 26 to 30 mm, on average 28 mm, which ensures their good resistance. Plants of the hybrid form 14 to 18 large leaves, which provides a large photosynthetic surface of the crop. This is a prerequisite for high productivity of the hybrid. The tall and well-foliated plants of the hybrid provide a large residual biomass that can be used for animal feed.

Tables 3, 4 and 6 present the results of the measurements of the biometric and quality indicators of the cob, grain and popcorn obtained during heat treatment of the grain of the hybrid popping corn Kneja pop 1. As can be seen from the obtained data and also from the images presented on Figures 1 and 2, the cobs of the hybrid are large, conical. The length of the cobs reaches 210 cm, on average 190 cm. The diameter of the cob varies from 34 to 42 mm, or an average of 38 mm, and the number of grain rows in the cob is on average 16 rows. Pop corn has significantly smaller cobs and kernels than regular feed corn. For it, the quality indicators of the grain and especially of the popcorn obtained from it are more important.

The grain of the hybrid popping corn Kneja pop 1 is hard, with a glass shard and a small pro-

Table 2. Measured Biometric parameters of plants of hybrid Popping corn Kneja pop 1

Parameters	Measure	Mean value	Coefficient of variation CV%	Variation of the parameter	
				MIN	MAX
Total height of plants	cm	286.7	5.33	270	300
Staking height of the upper cob	cm	141.7	7.35	130	156
Diameter at base of stem	mm	28.0	7.14	26	30
Number of green leaves	number	16.0	12.50	14	18

Table 3. Measured Biometric parameters of the cob of Popping corn hybrid Kneja pop 1

Parameters	Measure	Mean value	Coefficient of variation CV%	Variation of the parameter	
				MIN	MAX
Cob length	cm	193.3	7.90	180	210
Cob weight	g	138.3	9.10	125	150
Cob diameter	mm	38.0	10.53	34	42
Number of rows in the cob	number	16.0	12.50	14	18

portion of a soft, floury structure. These characteristic morphological features are related to the specific capabilities of the popping corn kernel to explosively increase its volume when thermally affected. The greater proportion of the floury part in the structure of the grain leads to a weaker increase in the volume of the popcorn obtained from the grain of the popping corn. Usually, the varieties with this type of grain are higher yielding, but with a lower quality of the popcorn obtained from it. As can be seen from the presented research results, the grain of the hybrid popping corn Kneja pop is hard, orange in color, averaging 83% of the weight of the cob. The total number of grains obtained from one cob is high - on average 635 pieces, which can vary from 615 to 650 pieces, according to the conditions for shaping the cob during the vegetation of the plants. This shows that the hybrid popping corn Kneja pop1 has a high reproductive rate.

In this regard, the results of the study of the productive and economic indicators of the hy-

brid, presented in Table 5, are important. With an average grain weight obtained from one cob of 116g and a cob weight of 138g, the yield of standard grain per hectare of hybrid popping corn Kneja pop1 reaches average 5.0 t/ha, at a seeding density of 45000 pl/ha. Considering that the price of the grain of the popping corn is several times more than that of the grain of the ordinary fodder corn, such productivity of the hybrid popping corn Kneja pop1 ensures a very good profitability of its cultivation. The agrobiological indicators of the varieties used are also important for the successful development of the popping corn crop. In general, popping corn is characterized by lower agrobiological indicators than regular feed corn. This type of corn has weaker stems, with a greater number of side branches, resulting in a higher % of plant stems lying down. As can be seen from the presented results, the hybrid popping corn Kneja pop1 is characterized by a low degree of plant establishment. Plant lodging varies from 4 to 5% under normal growing conditions. The

Table 4. Measured Biometric parameters on the grain of Popping corn hybrid Kneja pop 1

Parameters	Measure	Mean value	Coefficient of variation CV%	Variation of the parameter	
				MIN	MAX
Number of grains in a row	number	40.3	10.02	36	44
Total number of grains in the cob	number	635.3	2.75	615	650
Weight of grain in the cob	g	115.7	7.80	105	125
% of grain in the cob	%	82.3	2.53	80	84
1000 grain weight	g	180.7	5.57	170	190

Table 5. Measured Agrobiological parameters on the grain of Popping corn hybrid Kneja pop 1

Parameters	Measure	Mean value	Coefficient of variation CV%	Variation of the parameter	
				MIN	MAX
Production of standard cobs	t/ha	611.7	8.19	550	650
Production of grain	t/ha	5.00	10.54	4.45	5.50
Cobs on one plant	number	1.4	40.3	1	2
Laying the plants	%	5.0	40.0	3	7
Grain moisture at harvest	%	16.3	9.35	15	18
% side branches	%	14.0	25.75	10	17

number of side branches reaches an average of 16%, and they are poorly developed and do not have a significant impact on the productivity of the hybrid. But productive possibilities for grain yield in popping corn are not the most important indicator. Popping corn is primarily grown for human popcorn consumption.

A high grain yield, without high quality of the popcorn obtained from it, cannot ensure a good acceptance by consumers of a given variety. That is why even lower productive hybrids will be in demand if they offer high quality popcorn obtained from them.

The quality of popcorn depends on many indicators. First of all, these are the taste and aroma of popcorn, the tenderness and fragility of the popcorn structure. As additional extras, these are the good commercial appearance, shape and color of the popcorn as specific customer requirements. The taste qualities of popcorn, in turn, depend on the specific combination of proteins, starches and fats in the grain, the aroma of popcorn, the content of sugars and others. The tenderness and fragility of the popcorn structure depends largely on the Kpop1 kernel bursting ratio, the higher it is, the more tender and brittle the popcorn is usually. But, the thinner shell of the grain, the small size

of the remaining tips of the grain and others are also of great importance. As can be seen from the results presented in Table 6. For the quality assessment of popcorn obtained from hybrid popping corn Kneja pop1, they are characterized by excellent indicators. The color of the popcorn is a soft creamy white. The predominant shape of the popcorn, when thermally treated with hot air, in a machine of such a principle, is the butterfly type and the rose type. The kernel cracking coefficient, Kpop1 of the hybrid is very high – 40 cm³/g. The commercial appearance of freshly obtained popcorn is excellent. The results of the tasting evaluation of the popcorn obtained from hybrid popping corn Kneja pop1 also show excellent values. The taste evaluation of popcorn, although subjective, is very important for consumers and consumers of popcorn. This type of evaluation gives the most realistic idea of the quality of the popcorn, which cannot be achieved by means of machine measurement of their individual indicators.

Table 6. Quality parameters of the grain, cob and popcorn from Kneja pop 1 hybrid

Parameters	Assessment
Quality parameters of the grain and cob	
Grain type	Hard
Grain color	Orange
Cob shape	Conical
Color of the cob spindle	White
Quality parameters of the popcorn	
Popcorn color	Creamy white
Popcorn shape	Rose and butterfly
Crack factor, Kpop1	40 (cm ³ /g).
Commercial type	6 (Excellent)
Taste and aroma	6 (Excellent)
Tenderness and fragility	5.5 (Excellent)



Figure 5. Diploma for the winner of the popcorn hybrid Kneja pop 1 in the competition for innovations at the international agricultural exhibition “AGRA-2023” (February 21-24, 2023 at the international fair - Plovdiv)

For good results, the pop corn hybrid Kneja pop 1 was awarded with a Diploma for the winner of the competition for innovations at the international agricultural exhibition “AGRA-2023” (February 21-24, 2023 at the international fair - Plovdiv) - Figure 5.

CONCLUSIONS

- At the Maize Research Institute - Kneja city, a new, high-quality hybrid Popping corn Kneja pop 1 has been created, as a result of a long-term selection-genetic program to create corn hybrids for special purposes of use.

- Hybrid popping corn Kneja pop 1 is characterized by very good agrobiological and economic qualities of sowing, tall, productive and vibrant plants, resistant to diseases and enemies.

- The popcorn obtained from the grain of Kneja pop 1 hybrid, after heat treatment, is distinguished by a very good commercial appearance and excellent tasting qualities. The cracking coefficient, Kpop1, reaches 40 (cm³/g).

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