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BREEDING EVALUATION OF NEW GHERKIN CUCUMBER LINES TO CREATE F_1 HETEROTIC HYBRIDS

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The purpose was to evaluate new bee-pollinated open ground parental lines of gherkin cucumber. The study was conducted at the Institute of Vegetable and Melon Growing of NAAS in 2016–2020. The breeding resulted in new gynoecious gherkin lines, which correspond to the specified model: the lines are high-yielding (25.6–26.3 t/ha) and early-ripening (44 days); the marketability is 96–97%; plants are mainly with female flowers; the fruit length is 6–9 cm; the lines are resistant to downy mildew (7 points), bacterial diseases (7 points), heat-resistant; their gynoecity is 83–85%.

Keywords*: heterosis breeding, cucumber, gynoeciousline, starting material, open ground, gherkin type*

Introduction. Ukrainian vegetable growing is of great social importance and plays an exceptional role in ensuring the country's food security, and despite many problematic issues, it is developing rapidly. At the same time, many unsolved problems remain in vegetable growing, among which such problems as insufficient diversity of vegetables, low yields and low quality of vegetable products, in particular cucumbers, stand out. Solving these problems, breeders have been genetically improving the cucumber for many years to meet the demands of consumers.

The cucumber (*Cucumis sativus* L.), a representative of the Cucurbitaceae family, is one of the most important vegetables due to its rich nutrient composition and diverse uses in the culinary, cosmetic and therapeutic sectors. Cucumbers are grown and consumed all over the world, and consumers value them for their fresh and unique taste, especially for raw consumption. Fruits are a rich source of dry matter (3–6%), sugars (1.27–2.54%), fiber (0.33–0.78%), nitrogen (0.56–1.1%), pectin substances (0.24%), Ca, P, Fe, ascorbic acid, thiamin, riboflavin, and niacin [1].

Therefore, the development of new, low-cost, environmentally sustainable cucumber cultivars and hybrids remains relevant.

Literature review and problem articulation. Creation of heterotic hybrids is a priority in cucumber breeding [2]. Compared to cultivars, heterotic hybrids yield more by 15–40% or even higher and are noticeable for increased resistance to biotic and abiotic factors of the environment [3, 4]. Continuous breeding is aimed at creation of not only new cultivars and hybrids, but first of all, of starting material with a set of modeled characteristics (high marketable qualities, high yields, female type of flowering, earliness, etc.) for specific trends in breeding and adaptability to stressors [5, 6].

Creation of parental lines that, being hybridized, are capable of ensuring not only the heterosis effect in terms of performance, but also of transmitting desirable valuable economic features to hybrids is an important objective. Selection of parents for crossing is a complex process, as not every trait or property of the parents is directly transmitted to their offspring. Genes are inherited, and traits appear as a result of their expression, which forms an organism's phenotype. From review of published data, it is known that selection of parental lines based on previous indicators does not always give the expected result by itself [7], but traits can be pre-

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selected at the level of the parental genotype [8]. For planned hybridization, selection of parents should be based on complete genetic information and predominance of potential parents [9].

The importance of lines as parental forms for hybrid combinations is determined not only by their valuable economic characteristics, but also by their combining ability. In practical breeding programs, the general combining ability (GCA) and specific combining ability (SCA) of F_1 hybrids are often analyze involve the best accessions as parents in crossing designs [10–13]. The GCA characterizes expression of additive genes from the selection of parental forms, while the SCA represents the non-additive effects of genes [12]. Both additive and dominant effects of genes play significant roles in the genetic control of qualitative and quantitative traits [7, 13]. Better traits found in parents are not a guarantee that traits can be passed on to the offspring [14]. Therefore, it is important to combine lines through desired cross-combinations (obtaining recombinants).

At present, gherkin cucumbers, which almost do not overgrow, are the leaders in the cultivar rating. The genetic inheritance of this feature restrains the growth of young fruits, preventing their overgrowth. Gherkins are cucumber fruits that are not longer than 12–13 cm. Such fruits have strong texture and crispy flesh. Gherkin hybrids can be harvested before full ripening. Even and neat surface and cylindrical fruits are features of gherkin cultivars [3, 4]. These traits are important for producers, since they do not lose a significant part of the crop because of overgrown cucumbers. There is another interesting feature of such hybrids: for canning, one can harvest even pickle-sized ovaries (4-5 cm) and they will be dense and crispy. Their main advantages are large numbers of ovaries and young fruits, high yields and marketability.

The cucumber quality is determined by a whole set of features: fruit appearance (shape, color, uniformity); palatability (absence of bitterness, juiciness, aroma, crispy flesh); suitability for canning; contents of biochemically valuable substances (sugars, mineral salts, pectin substances, vitamins etc.) [15]. The interaction of alleles determining the "fruit weight" trait is intermediate between additive and cumulative, with a very weak dominance of the small-fruited form. The fruit weight is closely associated with its size. At the same time, the average fruit length in F_1 was closer to the short-fruited father. The inheritance of the "fruit length" trait was negative dominance. From the general evaluation of data on the "fruit diameter" trait, it was assumed that at least three pairs of alleles were responsible for control of the differences and heterosis was probably a result of the epistasis between the genes for the fruit length and diameter [16, 17]. However, there is a statement that the "fruit diameter" trait is inherited through overdominance controlled by at least three genes and that the "fruit length" trait is controlled by at least four genes participating in cumulative interactions [18].

Significant differences are observed in the variability of fruit texture features. Skin firmness showed a narrow range of variation, and flesh firmness did not differ significantly between cucumber types, indicating no clear differentiation of these traits. On the contrary, cucumber types differed greatly in flesh crispness, skin density, and fruit shape [8].

In breeding programs, one should take into account that the selection of one trait invariably affects a number of others, which requires elucidation of relationships between different traits. We have already noted the need to carefully study starting material for the cucumber for breeding open ground and to determine the combining ability of lines for major economically useful characteristics, such as yield, performance, earliness and marketability [19]. Our statements are confirmed by several authors who indicate the need for thorough studies of the full set of features of starting material and its use in breeding to create new gynoecious and monoecious forms [20]. Therefore, appropriate choice of parents with due account for their genetic characteristics (divergence) is a pre-requisite of any breeding program.

Based on the above considerations, heterosis studies and combining ability analyses are indispensable tools in any breeding program. They provide desirable genetic information to improve cultivars or to exploit heterosis for commercial gain.

To enhance heterosis in cucumbers, creation and use of lines are of great importance. Inbreeding (or inzucht in German) as a method of obtaining pure lines upon self-pollination of cucumber plants plays a great role in practical breeding. It allows for the genetic differentiation of a complex cross-pollinating population into individual forms, development of homozygous lines for several traits, and enrichment of an averaged population with various forms [2].

The potential of a line depends on different qualities. Quantitative signs, among which the following can be distinguished: rates of growth and formation of the assimilation apparatus, flowering type, ability to simultaneously form 2–3 or more fruits per node, fruit shape and size, etc. [21]. Maternal heredity plays an important role in the inheritance of breeding traits [7]. It was established that, to increase yields, hybridization would lead to desirable genetic improvements in the cucumber by accumulating desirable alleles from parents in the target genotype [7].

There are claims that the variability of breeding traits is influenced by environmental factors, but significant differences observed between values indicate a strong genetic control of these traits [8, 22]. Plant nutrition is a factor affecting valuable traits. Among major nutrients, phosphorus (P) plays a vital role in the transmission of early and uniform processes with organic compounds [23]. In addition, in most cucumbers, the sex is controlled by genetic and environmental factors [24].

Diseases can be controlled by fungicides, but complete and environmentally safe protection against diseases is only possible due to the resistance of host plants, which is a better and more effective option. Therefore, resistant hybrids can provide farmers with economically and ecologically sound strategies to control downy mildew [25].

Thus, despite the fact that artificial selection significantly increases the cucumber yield and quality, information on the inheritance of resistance will help breeders to develop programs to include resistance in new breeding lines and elite cultivars. The starting material problem is urgent in breeding research. Literature review shows that the development of lines for a given direction is the primary stage of breeding to create cucumber hybrids.

The purpose was to evaluate new bee-pollinated open ground parental lines of gherkin cucumber.

Materials and methods. The breeding studies (collection and breeding nurseries) were carried out in open ground at the Institute of Vegetable and Melon Growing of NAAS (IVMG NAAS) in 2016-2019. To obtain new forms and to create lines, we used inbreeding and individual selections in accordance with traditional breeding methods [26–29] and cultivation technologies [30]. Female (F_0) and predominantly female (F_1–F_3) plants of the most promising collection cucumber cultivars/F_1 hybrids of the Laboratory of Nightshade and Gourd Breeding of IVMG NAAS were used as starting forms. Dzherelo was taken as the check cultivar. The line trials were conducted in compliance with "Methods of the State Variety Trials of Agricultural Crops" [31].

The plant appearance was assessed in compliance with "Protocol for Tests on Distinctness, Uniformity and Stability (DUS)" [32] and "Protocol for Tests on Distinctness, Uniformity and Stability (DUS) (Vegetables and Potatoes) [33]. Valuable economic characteristics were evaluated during the growing period: bitterness of the vegetative part – in the “expanded cotyledon leaves” stage; flowering type – prior to the formation of the first fruit and during fruiting; earliness was defined as the number of days from mass emergence to the first harvest; palatability – during mass fruiting. The “female gender expressiveness” trait was to be taken into account, since it is correlated with the total performance of a plant, fruit number per plant, parthenocarpy, leaf color and size, and fruit shape, surface, pubescence, pigmentation, size, and weight. In addition to the color and shape, the fruit transportability (presence of a dense skin and a dense consistency of the fruit) was taken into account. The average yield and marketability of fruits of each accession were calculated for the entire fruiting period in accordance with the State Standard of Ukraine DSTU 3247-95 [34]. Phytopathological assessments were performed visually against natural infectious background at the peak of disease spread [35].

Data were statistically processed in Microsoft Excel 7.0, as B.A. Dospekhov recommended [36].

Results and discussion. Basing on experimental results and literature review, we created models of cucumber genotypes with specified parameters for the implementation of the gherkin cucumber breeding technology [37].

Model of the bee-pollinated open ground gherkin cucumber female line. The model parameters: the line should be early-ripening, yield 35.5–36.7 t/ha, have the marketability of 85-90%, produce high-quality fresh fruits of not longer than 8 cm with black spikes, form mostly female flowers, have two or three flowers per node and the average stem of 120–130 cm long.

Creating lines, breeders proceed from the requirements specified for new hybrids. In our case, lines are supposed to be high-yielding, early-ripening, resistant to the most harmful diseases, parthenocarpic, with the female type of flowering and a "bouquet" arrangement of female flowers, with fruits of not longer than 8 cm, with high marketability and fruit quality, and with high combining ability. Without such starting material, success in creating competitive heterotic gherkin cucumber hybrids is impossible.

Gynoecity, i.e. saturation of the population with female plants, is important for cucumber breeding. Upon development of cultivars, a low level of gynoecity is sometimes acceptable (in particular, cultivar Feniks 640), but in this case both the green yield and the seed productivity of a cultivar are significantly limited. In hybrid breeding, an insufficient level of gynoecity makes the accession unsuitable for further creation of a female line from it. However, a low level of gynoecity is quite acceptable for a male form (provided that other valuable characteristics are also present). Increased resistance to downy mildew is known to be correlated with the male type of flowering. Hence, the vast majority of male forms are monoecious.

The use of such methods as hybridization, inbreeding and selections in breeding made it possible not only to identify and fix valuable traits, but also to obtain new gynoecious bee-pollinated gherkin lines.

In 2016–2020, the breeding based on the constructed models resulted in two gynoecious bee-pollinated open ground gherkin cucumber lines. The lines exceed the check cultivar in yield, marketability, fruit quality, have high combining abilities and are relatively resistant to diseases (Table 1):

Line $F_{13}I_9$ BD96-18 – early ripening (44 days prior to the first harvest of fruits). The total yield is 26.3 t/ha; the marketable yield is 25.4 t/ha; the yield for the first 10 days of fruiting is 15.4 t/ha. The marketability is 97%. In terms of yield, this line is superior to Dzherelo (check cultivar) by 30%. The dry matter content is 4.23%; the total sugar content is 2.43%. The line is relatively resistant to downy mildew (5 points). The degustation score of fresh fruits is 4.6 points. The palatability is excellent (4.9 points).

The plant forms mainly female flowers, two or three per node. The young fruit is green, cylindrical, short (<9 cm). The fruit surface has big bumps; the complex pubescence is brownish black. The average marketable fruit weight is 72 g. The line is of value and intended to be used as a female form to create competitive bee-pollinated heterotic cucumber hybrids for open ground.

Line $F_{13}I_8$ Toma-18 – early ripening (44 days prior to the first harvest). The total yield is 25.6 t/ha; marketable yield is 24.6 t/ha; the yield for the first 10 days of fruiting is 14.8 t/ha. The marketability is 96%. In terms of yield, this line is superior to Dzherelo (check cultivar) by 26%. The line is relatively resistant to downy mildew and bacterial diseases (5 points). The degustation score of fresh fruits is 4.6 points. The palatability is excellent (4.6 points).

Table 1

Valuable economic characteristics of the bee-pollinated gherkin cucumber inbred lines

Trait	Expression level		
	Check cultivar Dzherelo	Line BD 96-18	Line Toma-18
Yield and its constituents:			
Total yield, t/ha	20.3	26.3	25.6
Marketable yield, t/ha	19.0	25.4	24.6
Total yield for the first 10 days of fruiting, t/ha	8.7	15.4	14.8
Marketability,%	94	97	96
The “mass emergence –anthesis” period, days	39	39	40
The “mass emergence – fruiting onset” period, days	46	44	44
Plant height, cm	189	125	83
Fruit characteristics:			
Marketable fruitlength, cm	9–10	8–9	6–8
Fruit surface	With big bumps	With big bumps	With big bumps
Spike color	Black	Brownish black	Black
Quality (biochemical composition and technological properties):			
Dry matter, %	4.40	4.04	4.09
Total sugar, %	2.54	2.42	2.43
Ascorbic acid, mg/100 g FW	11.72	11.47	10.65
Resistance to biotic factors:			
Downy mildew, score	7	7	7
Bacterial diseases, score	5	7	5
Heat resistance, score	5	7	7
Gynoecity, %	68	85	83

The plant forms mainly female flowers, two or three per node. The young fruit is green, cylindrical, short (<8 cm). The fruit surface has big bumps; the complex pubescence is black. The average marketable fruit weight is 88 g. The line is of value as a female form to create heterotic gherkin cucumber hybrids. The line is intended to be used as a female form to create competitive bee-pollinated heterotic cucumber hybrids for open ground.

Conclusions. The studies allowed for the selection of valuable breeding gynoecious gherkin material, from which the new bee-pollinated gherkin lines were synthesized. The new lines have been included in the breeding process to create competitive heterotic gherkin cucumber hybrids. As of today, several F_1 hybrid combinations have been derived from the new lines and the breeding work with them is going on.

The lines have been submitted for registration to the NationalCenter for Plant Genetic Resources of Ukraine at the Plant Production Institute named after V.Ya. Yuriev of NAAS. Certificate No. 353 dated 06/12/2019 was issued.

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BREEDING EVALUATION OF NEW GHERKIN CUCUMBER LINES TO CREATE F1 HETEROTIC HYBRIDS

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The **purpose** was to evaluate new bee-pollinated open ground parental lines of gherkin cucumber.

Materials and Methods. The breeding studies (collection and breeding nurseries) were carried out in open ground at the Institute of Vegetable and Melon Growing of NAAS in 2016-2019. To obtain new forms and to create lines, we used inbreeding and individual selections in accordance with traditional breeding methods and cultivation technologies.

Results and Discussion. Basing on experimental results and literature review, we created models of cucumber genotypes with specified parameters for the implementation of the gherkin cucumber breeding technology. The breeding based on the constructed models resulted in two gynoecious bee-pollinated open ground gherkin cucumber lines: $F_{13}I_9$ *BD96 - 18* and $F_{13}I_8$ *Toma - 18.* The lines are early- ripening (44 days) and well-yielding (25.3–26.6 t/ha), exceeding the check cultivar (Dzherelo) by 20-30%. They are relatively resistant to downy mildew (5 points). They are noticeable for excellent palatability. Their plants form mainly

female flowers. Their young fruits are cylindrical, green, and short (8 cm). The lines are intended to be used as female forms.

Conclusions. The new lines have been included in the breeding process to create competitive heterotic gherkin cucumber hybrids. As of today, several F_1 hybrid combinations have been derived from the new lines and the breeding work with them is going on. The lines have been submitted for registration to the NationalCenter for Plant Genetic Resources of Ukraine at the Plant Production Institute named after V.Ya. Yuriev of NAAS. Certificate No. 353 dated 06/12/2019 was issued.

***Key words**: heterosis breeding, cucumber, gynoeciousline, starting material, open ground, gherkin type*

СЕЛЕКЦІЙНА ОЦІНКА НОВИХ ЛІНІЙ ОГІРКА КОРНІШОННОГО ТИПУ ДЛЯ СТВОРЕННЯ ГЕТЕРОЗИСНИХ ГІБРИДІВ

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Мета дослідження. Оцінка новостворених бджолозапилювальних батьківських ліній огірка корнішонного типу для відкритого ґрунту.

Матеріали і методи.Селекційні дослідження (колекційний і селекційний розсадник) проводились впродовж 2016–2019 рр. в умовах відкритого ґрунту на науково-дослідній базі Інституту овочівництва і баштанництва НААН. Для отримання нових форм і створення ліній використовували інцухт, індивідуальний відбір у відповідності до загальноприйнятих методів селекції та технології вирощування.

Обговорення результатів. За результатами експериментальних досліджень і аналізом джерел літератури, сформовано моделі генотипів огірка з заданими параметрами для реалізації технології селекції огірка корнішонного типу. Відповідно до розроблених моделей результатом селекційної роботи для умов відкритого ґрунту – створено дві гіноеційні бджолозапилювальні лінії огірка корнішонного типу для відкритого ґрунту – лінія $F_{13}I_9$ БД96 – 18 та лінія$F_{13}I_8$ Тома – 18. Лінії ранньостиглі (44 доби), урожайні (25,3–26,6 т/га), що на 20–30 % перевищують стандарт Джерело. Відносно стійкі проти пероноспорозу (5 б.). Мають відмінні смакові якості. Рослина переважно жіночого типу цвітіння. Плід – зеленець циліндричної форми, короткоплідний (8 см). Лінії призначені для використання у якості материнської форми.

Висновки. Нові лінії включені у селекційний процес зі створення конкурентноздатних гетерозисних гібридів огірка корнішонного типу. З використанням нових ліній на сьогодні створено ряд гібридних комбінацій першого покоління з якими продовжується селекційна робота Лінії передані для реєстрації до НГЦРРУ Інституту рослинництва ім. В.Я. Юр’єва НААН. Отримана довідка № 353 від 12.06.2019 р.

***Ключові слова:** гетерозисна селекція, огірок, гіноеційна лінії, вихідний матеріал, відкритий ґрунт, корнішонний тип*