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ORIGINAL ARTICLE

Increase in cucumber cropping capacity and resistance to downy mildew

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The authors have specified the regional list of Gherkin-type cucumber diseases. We established that the representative population of oomycetes (fungi-like organisms) occupies the dominant position in the pathocomplex of this vegetable crop when growing under open ground conditions: downy mildew or powdery mildew (*Pseudoperonospora cubensis*). We found that the share of additional net profit in the medium resistant group of samples (score 5), compared to the susceptible group (scores 1-3), increases by 2 times; in the resistant group (score 7) it increases by 2.6 to 4.2 times. We also registered that Gherkin-type cucumber growing samples susceptible to downy mildew of the immunological group (scores 1-3) under production conditions without additional use of a comprehensive system of crops protection against diseases is unprofitable or low-profitable (-9.4...44.6%); medium resistant (score 5)-medium profitable (91.2%); resistant (score 7)-profitable (from 113.9 to 165.9%).

Keywords: Cucumber, Economic efficiency, Diseases, Prevalence, Phytopathological complex, Immunity, Selection, Variety, Hybrid.

Introduction

It is known that the success of breeding Gherkin-type cucumbers for disease resistance is primarily determined by the initial resistant material of both collection and breeding origin in crossbreeding schemes (Kartashov and Kazakova, 1988; Vitchenko and Meleshkina, 1991; Gorohovskij, Berlin, 2009). For this purpose, better to work with the most polymorphic plant populations for purposeful multiple selections of genotypes with better combination combinations of genes and gene complexes of various economic traits, including resistance traits to the major diseases (Strajstar, 1991; Dhillon, Pushpinder, and Ishiki, 1999; Tockij, 2002; Kilchevskij and Hotyleva, 2008). Thus, V.L. Nalobova, in monograph 'Cucumber breeding for disease resistance' (Nalobova, 2005) notes one of the main conclusions that considering the peculiarities of the formation of the structure of natural populations of certain types of phytopathogens in cucumber agrocenoses, breeding for the resistance of this vegetable crop to downy mildew should be carried out on a prolonged (polygenic, race-nonspecific, horizontal) type. The author emphasizes that this type of sustainability will allow scientists to conduct a more effective selection of resistant forms of cucumber and create on its basis competitive varieties and hybrids that are most in-demand today in commercial production in Ukraine (Badr and Mohamed, 1999; Blinova, 2005; Gorbatenko, Holodnyak, and Shvartau, 2011).

So, at present, a comprehensive assessment of breeding material in order to search for and select the initial forms resistant to downy mildew and further creation (selection and multiple self-pollination) on their basis an initial resistant material of Gherkin-type cucumber is highly relevant and priority for domestic agricultural science (Chaban, 1993; Skripnik and Lopotun, 2003). Scientists have determined that the breeding of cucumbers for disease resistance should be carried out stepwise, by gradually giving the breeding material resistance to the most common pathogens, by analogy with the spontaneous formation of this protracted sign in natural populations of these organisms (Efimov, Sklyarevskaya and Olhovskaya, 1978; Nalobova, 2005). World experience proves it is the use of such a theoretical approach that makes it possible to most effectively distinguish among the breeding material of cucumber of Gherkin type the initial material that is highly resistant to downy mildew against the background of a consistently high expression of other valuable traits and successfully use it in breeding programs to solve the most relevant problems of increasing its commercial production (Nalobova, 2008).

Individual traits, inherent in any living organism, are interconnected and form the so-called 'correlation pleiad or dendrite', which regulates all the processes of its vital activity. The tightness and direction of the relationships between traits in this structure are fully responsible for object integration in the environment. An important specific feature of such correlation structures is that they represent certain groups (correlation pleiades), each of which combines the most strongly related traits. This allows scientists to control the effectiveness process more effectively, especially at its final stages (Koshnikovich, Sherbinin and Timoshenko, 2008). The structure of these relationships in the adaptive breeding of vegetable crops, including cucumbers, is critical because they allow the breeder to indirectly judge the direction and tightness of the influence of one selective (working) trait on others (Nalobova, 2005).

The introduction into industrial production of varieties and hybrids of Gherkin-type cucumber resistant to the most common diseases under growing conditions is of fundamental economic significance for obtaining stable high and high-quality commercial yields of this vegetable crop (Kartashov and Kazakova, 1988).

Materials and Methods

The key elements of field accounting were parameters such as disease prevalence (P,%) and plant damage (R,% or score) (Nalobova, 2005; Yarovii, 2006).

The prevalence index of the disease was determined using the formula:

=(a/N) • 100 …..(1)

where a is the number of sick plants, pieces;

N-total number of plants examined, pieces.

Plant damage that characterized the direct effect of the pest on the plant (sample) was determined by the formula:

R=(Σ(a • b)/N • K) • 100 …….(2)

where *(*a • b) is the sum of the plant damage degree (a) and the number of plants (b) that have the corresponding score;

N-total number of plants, pieces;

K-is the highest score on the accounting scale.

Accounting for injury of cucumber plants by spot disease, in particular downy mildew and bacteriosis, was carried out as a percentage, visually assessing the area of the affected surface of the leaf apparatus of the sample, which most optimally reflects the ranges of areas of damage during field assessments (Fig. 1) (Gannibal, Gasich, and Orina, 2011; Kirichenko and Petrenkova, 2012). When evaluating the immunological potential of the Gherkin type cucumber breeding material, the standard of susceptibility was the Nizhynsky local variety (Ukraine), the standard of resistance to varietal populations, Dzherelo (Ukraine), Phoenix 640 (Russia), hybrid, Ajax F1 (Netherlands). When assessing the degree of the injury and simultaneously determining the level of the resistance of cucumber breeding samples, the following three-point summary scale was used, where: 0 scores of the lesion scale-plants are healthy, without signs of damage (9 scores of the immunological scale-highly resistant sample); 0.1 scores-the disease affects from 0.1 to 10% of the leaf apparatus of the plant sample (score 7-resistant sample); 1 score-from 10.1 to 35% (score 5-medium resistant sample); 2 scores-from 35.1 to 50% (score 3-susceptible sample); 3 scores-from 50.1 to 100%, plants completely dry up, die (score 1-highly susceptible sample) (Fig. 1) (Nalobova, 2005; Koshnikovich, Sherbinin and Timoshenko, 2008; Chistyakova and Biryukova, 2012).

We processed data using variational, correlation, and disperse analysis (Dospehov, 1985; Bondarenko and Yakovenko, 2001; Chistyakova and Biryukova, 2012; http://www.statstutor.as.uk/resources/uploaded/pearsons.pdf). The economic effect of growing Gherkin-type cucumber samples in the field with unique resistance to downy mildew was determined according to a typical technological map for growing this vegetable crop (Bolotskih, 1988; Bondarenko and Yakovenko, 2001).

Based on the above, the purpose of this block of research was to determine the level of variability (stability) of the main traits of the cucumber of Gherkin type in obtaining new initial forms that can meet the needs and tastes of different consumers of the final innovative breeding product created-variety or hybrid.

The characteristic of the variability level of the main traits in the newly created initial material of Gherkin type cucumber was studied according to the 'Methods of examining varieties for difference, uniformity, and resistance (DUR)' (Ermakov, 1987), the chemical assessment of the quality of the fruit (dry matter content, sugars, nitrates) was carried out according to the 'Methods of biochemical plant research' (Ohorona, 2004). The main object of this research area was the initial (linear) breeding material of Gherkin-type cucumbers from nursery gardens for preliminary and competitive variety testing. In the future, all the experimental data obtained on a complex of basic economic characteristics (5 pieces) and a number of 22 approbatory traits were processed by the method of variational analysis (Dospehov, 1985). Under the weather, climatic and economic conditions that have developed today in Ukraine, an important stage in cucumber breeding is the creation of hybrids and varieties based on specially selected initial material based on resistance to the most common diseases, yield, and technological qualities. Of particular breeding value are the initial forms that harmoniously combine in their genotypes resistance to diseases with the maximum possible combination of a complex of valuable traits with the genetic ability to transmit the specified complex of traits to hybrids when crossing with the maximum possible heterotic effect (Gorohovskij and Berlin, 2009).

Fig. 1. Visual three-point scale for assessing the degree of cucumber lesion from downy mildew (photo by S.V. Bondarenko).

Studies by Medviedieva et al., (cited by Nalobova, 2005) revealed that cucumber resistance to downy mildew by a genetic basis is a polygenic trait that is inherited recessively. In order to confirm or refute this, under conditions of the Left Bank Forest-Steppe of Ukraine, we have analyzed the results of the crossing of the initial material of Gherkin type cucumber of different resistance to downy mildew and the obtained hybrid generation F_1. With the help of these studies, we have found the specificity of the dominance of downy mildew resistance trait in F_1 hybrids at different crossing combinations of different in the resistance initial (parental) material. Thus, the parental pairs involved in the hybridization process had different resistance to this disease under conditions of the natural infectious background of 2013-at the level of scores 7-1 of the immunological scale. Formula 3 determined dominance (p) of the resistance trait to downy mildew in Gherkin-type cucumber F_1 hybrids:

$$Hp = \frac{F_1 - MF}{HF - MF}, \quad .....(3)$$

where F_1 is an average indicator of the resistance trait in the hybrid combination;
MF is an average value of the resistance trait in parental components;
HF is the maximum value of the trait of the best parental form (Tockij, 2002; Shkalikov et al., 2005).
of *p:* from-to -1 is negative dominance of a trait (isOD); from -1 to -0.5-negative dominance (isD); from -0.5 to 0.5-intermediate dominance (ID), from 0.5 to 1 is positive dominance (D), from 1 to+- positive dominance or heterosis (OD). At $p=\pm1$-complete dominance of the better (+) or worse (-) expression of the trait value (Tockij, 2002).

The scale that we used to analyze the relationships between pairs of basic approbatory and economic traits was as follows: from 0 to 0.19 the relationship between traits is fragile; from 0.2 to 0.39-weak; from 0.40 to 0.59-average; from 0.60 to 0.79-strong; from 0.80 to 1.0-very strong, linear, or direct (http://www.statstutor.as.uk/resources/uploaded/pearsons.pdf). We believe that this calibration of the assessment of the correlation between breeding traits most optimally levels the uncontrolled influence of abiotic and biotic stressors and more objectively reveals the features of the genetic relationships between plant traits, in contrast to the scale (Dospehov, 1985) recommended for analyzing the results of field studies, mainly technological directions. Thus, of particular interest to us was the study of the tightness and direction of relationships between the block of main approbatory and economic traits of Gherkin type cucumber, which the breeder's research work aims, with the trait parameters of resistance to downy mildew. We paired the significant interest for indirect selection with relationship tightness at a level not lower than strong and very strong (r 0.60-1.0, see Osnovnye, 1974; Koshnikovich, Sherbinin and Timoshenko, 2008; http://www.statstutor.as.uk/resources/uploaded/pearsons.pdf). Therefore, we have calculated the economic effect of growing Gherkin-type cucumber samples under field conditions with unique resistance characteristics to downy mildew. The control when performing economic calculations was the local Nizhynsky cucumber variety-susceptibility standard (score 1 of the immunological scale, Table 1).

Experimental breeding samples when conducting comparative analysis to determine the economic effect of growing breeding material different in resistance to downy mildew were-line F_3I_1 Pavlyk (score 3 of the resistance scale), line F_5I_3 Odys (score 5), line P 57/745-11 (score 7), resistance standards-variety Dzherelo and hybrid Ajax F_1 (scores 7, Table 1).

Results

As was discovered earlier, the process of forming the basic components of the parameters of the cucumber cropping capacity under open ground conditions is caused by the influence of many factors, including the expression of the intensity and degree of plant lesion by harmful organisms, in particular downy mildew.

According to our data in recent years, the stable and moderate nature of this disease development in the research region requires versatile protection measures. At the same time, in different countries of the world, it has been repeatedly, scientifically and practically proven that the most effective in the commercial production of Gherkin-type cucumber is the cultivation of resistant varieties and hybrids.

However, today, the domestic consumer makes an obligatory condition for breeders-for commercially successful introduction into production of any newly created varietal and hybrid material, is a resistance trait to the main diseases, in particular, downy mildew with an agrotechnical varietal scheme of rational reduce additional costs for the system of integrated protection under maximum preservation of its effectiveness.

As noted earlier, it is the trait of protracted resistance of Gherkin-type cucumber to the causative agent of downy mildew under the field conditions that allows reducing the pesticide load on plants without special critical yield losses by reducing the number of crops treatments and increasing the waiting terms between them (Gavrish, 2001; Koshnikovich, Sherbinin, and Timoshenko, 2008).

The introduction into industrial production of varieties and hybrids of Gherkin-type cucumber resistant to the most common diseases under growing conditions is crucial for obtaining stable high and, high-quality commercial yields of this vegetable crop (Kartashov and Kazakova, 1988). Therefore, we have calculated the economic effect of growing Gherkin-type cucumber samples under field conditions with unique resistance characteristics to downy mildew. The control when performing economic calculations was the local Nizhynsky cucumber variety-susceptibility standard (score 1 of the immunological scale, Table 1). Experimental breeding samples when conducting comparative analysis to determine the economic effect of growing breeding material different in resistance to downy mildew were-line F_3I_1 Pavlyk (score 3 of the resistance scale), line F_5I_3 Odys (score 5), line P 57/745-11 (score 7), resistance standards-variety Dzherelo and hybrid Ajax F_1 (scores 7, Table 1).

The total cropping capacity of the local Nizhynsky susceptible variety (control variant) was 7.2 t/ha in the selection crop, attracted to the economic evaluation of the breeding samples from the nursery garden for competitive variety tests, depending on the level of resistance to downy mildew-from 11.9 (line F_3I_1 Pavlyk) to 28.6 t/ha (Ajax F_1 hybrid) (boharic conditions). At the same time, the yield obtained due to the present resistance to downy mildew, compared to the susceptible control, ranged from 4.7 to 21.4 t/ha for these breeding samples (Table 1). It should be separately noted that this indicator for the original line P 57/745-11 and the resistance standard (Dzherelo variety) was almost at the same level (within the average error)-13.2 against 14.2 t/ha (Table 1).

In the future, the economic analysis showed that an increase in the value of the field resistance expression in samples of the susceptible group by one gradation of the score of this feature assessment scale (Nizhynsky local variety-line F_3I_1 Pavlyk) allows, against the background of an increase in additional costs for growing, harvesting, packing, transportation, temporary storage and sale, to obtain additional products from the field for 8695 UAH/ha.

With a further score increase in Gherkin-type cucumber resistance in breeding samples of Gherkin type cucumber, the cost of additional products obtained per unit of area in samples of the medium-resistant group (score 5) increased by 2 times (line F_5I_3 Odys). In the highly resistant group (score 7), this growth increased to 2.9 to 4.5 times (line P 57/745-11-hybrid Ajax F1).

An important generalizing indicator of economic efficiency from the introduction into breeding practice and production of the immunological measure developed of Gherkin-type cucumber, in the narrow sense of this concept (line, variety, hybrid), is the profitability indicator (P,%). It was calculated by dividing the total value of the obtained products of the line, variety, hybrid (profit) by the total production costs when it is growing (cost price).

Table 1. The economic effect of growing Gherkin-type cucumber samples different in downy mildew resistance, 2012.

S.No.	Indicators	Calculation algorithm	Breeding sample				
			Line F_3I_1 Pavlyk	Line F_5I_3 Odys	Dzherelo standart	Ajax F_1 standart	Line P 57/745-11
1	Resistance	CP	3	5		7	
2	Cropping capacity of susceptible standard Nizhynsky local (control), t/ha	CP1			7.2		
3	Cropping capacity of breeding samples, t/ha	CP 2	11.9	17.4	21.4	28.6	20.4
4	Amount of additionally obtained yield, t/ha	CP 3=CP 2-CP 1	4.7	10.2	14.2	21.4	13.2
5	Selling price of products, UAH/ton*	CP 4			1850		
6	The cost of additional obtained products, including, at the expense of resistance, UAH/ha	CP 5=CP 3 × CP 4	8695	18870	26270	39590	24420
7	Total costs of growing and harvesting a susceptible standard Nizhynsky local	CP 6			14701 [65, 85]		

	(control), UAH/ha						
8	Costs of growing and harvesting additional yields of breeding samples of different resistance groups, UAH/ha	CP 7	523	2134	3496	5196	2939
9	Additional net profit, including at the expense of resistance, UAH/ha	CP 8= CP 5-CP 7	8172	16736	22774	34394	21481
10	Growth of net profit values between different resistance samples, times	CP 9	1	2.05	2.78	4.2	2.62

*Calculations were made at the selling price of 1.85 UAH /kg (in 2012 prices).

So, when growing in production variety testing, the overall profitability level of different in resistance groups breeding samples (P,%) of Gherkin-type cucumber was calculated using the following formula (Bondarenko and Yakovenko, 2001).

$$P = \frac{C-CP}{CP} \bullet 100, \quad (4)$$

Where C is the total cost of the products sold, UAH/ha,

CP-cost price of sold products, UAH/ha.

Based on the calculated data, we have found the profitability level of the Gherkin-type cucumber breeding material of different quality in field resistance to downy mildew under production conditions from the collection and nurseries gardens of competitive (production) variety testing (Table 2).

Thus, based on results of the economic effect evaluation, we found that growing Gherkin-type cucumber samples susceptible to downy mildew of the immunological group (scores 1-3) under production conditions, without additional use of a comprehensive system to protect crops from this disease, is unprofitable (-9,4%-44,6%) (Kompleksna, 2012).

Growing samples of the medium-resistant group (score 5) without applying a system of protection measures against diseases, on the example of the F_5I_3 Odys line, which is resistant in this parameter, shows an average level of profitability of 91.2%. Cultivating cucumber samples resistant to the downy mildew pathogen under production conditions makes it possible near research that was conducted to get profitability at the level of 113.9 to 165.5% without using intensive technologies to protect this crop (Table 2). Thus, the economic analysis convincingly proved that under the conditions of mandatory completion of all standard technological methods of growing Gherkin type cucumbers under open ground conditions of the Left Bank Forest-Steppe of Ukraine, one of the resistant most important is the trait of sample resistance as a key factor in the increase in cropping capacity and the increase in the economic effect of this vegetable crop production.

Table 2. Profitability (%) of growing Gherkin-type cucumber samples different in resistance to downy mildew, 2012.

		Initial breeding sample (variety, line, hybrid)					
S.No	**Indicators**	**Nizhynsky local standard**	**Line Pavlyk F_3I_1**	**Line Odys F_5I_3**	**Line P 57/745-11**	**Dzherelo standard**	**Ajax F_1**
1	Resistance	1	3	5	7		
2	General immunological characteristics	susceptible		medium-resistant	resistant		
3	Selling price of products, UAH/ton	1850					
4	Total cropping capacity, t/ha	7.2	11.9	17.4	20,4	21,4	28,6
5	Total cost of sold products (revenue), UAH/ha	13320	22015	32190	37740	39590	52910
6	Costs of growing products, including additional UAH/ha*	14701	15224	16835	17640	18197	19897
7	Total level of profitability,%	- 9.4	44.6	91.2	113.9	117.5	165.9

*-the calculation was made according to a typical technological map of growing cucumbers under open ground conditions.

Conclusion

The regional list of Gherkin-type cucumber diseases has been specified. We established that the dominant position in the pathocomplex of this vegetable crop when growing under open ground conditions is occupied by the representative population of oomycetes (fungi-like organisms): downy mildew or powdery mildew (*Pseudoperonospora cubensis*). We found the share of additional net profit in the medium resistant sample group (score 5), compared to the susceptible group (scores 1-3), increases by two times, in the resistant group (score 7)-increases 2.6 to 4.2 times.

We revealed that the Gherkin-type cucumber sample growth susceptible to downy mildew of the immunological group (scores 1 to 3) under production conditions without additional use of a comprehensive system of crop protection from diseases is unprofitable or low-profitable (-9.4...44.6%); medium-resistant (score 5)-medium-profitable (91.2%); resistant (score 7)-profitable (from 113.9 to 165.9%).

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