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DOWNY MILDEW OF CUCUMBER OF GHERKIN TYPE AND IMMUNOLOGICAL POTENTIAL OF BREEDING MATERIAL

Monograph

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ПЕРОНОСПОРОЗ ОГІРКА КОРНІШОННОГО ТИПУ ТА ІМУНОЛОГІЧНИЙ ПОТЕНЦІАЛ СЕЛЕКЦІЙНОГО МАТЕРІАЛУ

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In the course of research, we have theoretically generalized and practically solved an important scientific task on determination the peculiarities of downy mildew development, the harmfulness of the disease and relationships with Gherkin type cucumber by forming a database, which allowed us to select and introduce into the process of varietal and heterotic selection valuable for resistance to downy mildew and a complex of other traits of the initial material (parental forms), which has an important scientific and practical significance in the field of agricultural science.

For specialists in plant protection, breeding, scientific workers, lectures, postgraduates and students of biological and agricultural specialties of higher educational institutions and for all those who are interested in improving the quantity and quality of yield of cucumber of Gherkin type.

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PREFACE

In Ukraine, cucumber (*Cucumis sativus* Linneus) annually occupies about 20 % of the total area of all vegetable crops sown in the open ground, or 52.6 thousand hectares [7, 12].

The main reason that significantly reduces the quantitative and qualitative indicators of the main valuable economic traits of this vegetable crop is the high incidence of commercial crops with diseases, especially downy mildew (*Pseudoperonospora cubensis* (Berk. & M.A. Curtis) Rostovtsev) [24].

Since 1985 in Ukraine, this cucumber disease in the open ground on nonresistant varieties has constantly had a strong development, in some years the development – by the type of epiphytotia. At the same time, the shortage of commercial yield of this vegetable crop due to the defeat of this disease under the field conditions can reach the level of 50–80 % or more, seed loss – 25–70 % [12, 23].

Marketing studies have determined that the need of the population and the processing industry of Ukraine for Gherkin cucumber fruits has not been fully met yet. The main requirement for processing of this vegetable production type is given to fractions of fruit with a genetically controlled length of 9–12 cm. Gherkins belong to the group of early ripening (summer) cucumbers. They can be parthenocarpic or bee-pollinated, with a strong, medium or weak branching of a compact bush [29, 30].

One of the main reasons for significant losses of commercial yield and seeds of gherkin-type cucumber under the conditions of its cultivation in the open ground is recognized as the high susceptibility of samples to a number of diseases, in particular downy mildew (*Pseudoperonospora cubensis* (Berk. & M.A. Curtis) Rostovtsev). Unfortunately, this problem has remained relevant for Ukraine over the past few decades.

So, obtaining the initial material of a gherkin-type cucumber with a harmonious combination in the genotypes of a complex of various valuable economic characteristics (yield, quality, resistance to diseases, chemical substances content, suitability for various types of processing) and creating a modern competitive innovative product (variety, hybrid) on its basis remains a relevant and priority task for domestic agricultural science at the present time.

During the research, it was found that the nature of the dynamics of the development and spread of the main cucumber diseases in the Left-Bank Forest-Steppe is actively changing, in particular, downy mildew – from moderate to strong, angular bacterial spot disease, anthracnose, powdery mildew – from moderate to depressive. Correlation coefficients between the intensity of downy mildew spread and the values of the main abiotic factors of June – July were calculated. It is established that a specific temperature regime with a sharp fluctuation of maximum and minimum temperatures is the optimal for infection and re-infection of plants because it maximally activates the process of condensation of moisture from the air and forms the duration of preservation of drop-liquid moisture on the leaf apparatus of plants. We have identified a valuable initial breeding material of gherkin cucumber, which harmoniously combines in its genotypes traits of high resistance to downy mildew with a complex of various valuable economic characteristics. The initial breeding material (63 pieces) selected on the basis of resistance to this disease has the level of variability of the complex of the most valuable traits, and correlation dependences between them have been studied. At the same time, a group of 139 breeding samples is identified, which are promising materials for tandem selection in terms of resistance to downy mildew and with a complex of valuable economic characteristics. For the first time, correlation pleiads of the relation of cucumber resistance parameters to downy mildew with a complex of valuable traits have been constructed, and the specificity of the influence of parental components of different downy mildew resistance on the nature of inheritance of this trait by first-generation cucumber hybrids is determined.

For the first time for modern domestic breeding and technological programs, an information database (act of implementation) has been formed to determine the immunological characteristics of the collection, breeding and initial material of gherkin cucumbers of domestic and World selection (331 samples). Using the correlation analysis among the 30 main economic and approbatory characteristics we have identified a group of inert (21 pieces), with which the breeder can work individually, without caution that an artificial change in their characteristics during the breeding process for resistance to downy mildew can negatively affect the final result of the breeding process for other characteristics.

An original breeding line of gherkin-type cucumber P 57/745-11 with a high protracted genetic value for resistance to downy mildew and with a complex of economic characteristics was obtained (certificate of the National Center for Plant Genetic Resources of Ukraine no. 252). It was found out that the cultivation of 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 of crops protection from diseases is unprofitable or low profitable (-9.4 % … 44.6 %); of the medium-resistant group (score 5) – medium profitable (91.2 %); of the resistant group (score 7) – profitable (from 113.9 to 165.9 %).

1. PREVALENCE AND HARMFULNESS OF THE MAIN CUCUMBER DISEASES, CROP IMMUNITY. CONDITIONS AND RESEARCH METHODOLOGY

1.1. Botanical classification, biological and economic properties of cucumber

Cucumber (*Cucumis sativus* Linneus) belongs to the genus cucumber (*Cucumis*) of pumpkin family (*Cucurbitaceae* Juss.). In the world, the area where this vegetable crop is grown annually occupies up to 9 million hectares [152].

In Ukraine, among vegetables, cucumber is also one of the main crops, which is grown annually in both open and protected grounds in various soil and climatic zones on areas of up to 50 thousand hectares [2, 10, 103].

When developing the classification of cucumber, scientists took into account the similarity of different samples by morphological traits, suitability for growing in certain climatic zones, and a number of other botanical (approbatory) traits [79].

Developed by A.I. Filov [citation by 84], the classification of this vegetable crop is divided into 7 subspecies:

1. Wild-growing subspecies (*C. sativus* ssp. *agrestis* Gab.). Small leaves with sharply marked lobes, small fruits, extremely beautiful green colour, cylindrical, very bitter. It grows in the northern regions of India in a wild state.

2. Himalayan subspecies (*C. sativus* ssp. *himalaicus* Fil.), which includes Indian boharic and Himalayan hollow. They have very small branched stems, small spherical fruits up to 5 cm in diameter. Plants are almost bush-shaped, early ripening, fruits turn yellow very quickly.

3. Indo-Japanese subspecies (*C. sativus* ssp. *indo-japonicus* Fil.), which was formed under conditions of tropical and subtropical climates. The plants are strong, dark green, the fruits are large, with small or medium tubercles and complicated pubescence, with black (Indian) or white (Japanese) spikes. Varieties of this subspecies, especially Japanese ones, are in demand in breeding as carriers of a complex of resistance genes to the most common diseases.

4. Chinese subspecies (*C. sativus* ssp. *chinensis* Fil.). Plants are strong, with long runners and large leaves. The fruits are long, often curved, sickle-formed and serpentine. The subspecies is used in breeding

when creating greenhouse varieties, early ripening and cold-resistant forms.

5. West-Asian subspecies (*C. sativus* ssp. *occidentaliasiaticus* Fil.), varieties of which have strong plants, large stems, small or medium-sized leaves. This ecotype is characterized by high adaptability to the conditions of the continental climate, plants combine heat and cold resistance in their genotype, fruits with a thick skin, they can only be used in salads.

6. European-American subspecies (*C. sativus* ssp. *europaeo-americanus* Fil.). Plants of medium strength, with medium or small leaves. The fruits are small or medium-sized, with tubercles or rough.This subspecies includes most cucumber varieties grown in Ukraine and other regions of the world.

7. Hermaphrodite-flowered subspecies (*C. sativus* ssp. *hermafhroditus* Fil.), which is characterized by the formation of hermaphrodite flowers instead of female ones. The ovary is half-low, a turban is formed on the fruit. Pubescence is simple. Varieties of this subspecies are widely used in hybrid breeding.

According to the botanical description, cucumber is an annual herbaceous plant. The fruits of this vegetable crop are valued for their high taste, aroma and the presence of various enzymes that promote digestion. They contain (in terms of 100 g of raw matter): sugar 1.5–2.0 %, protein – about 1 %, vitamin C – 10–16 mg, vitamin PP – 0.2 mg, carotene – 0.1 mg. In terms of riboflavin content, cucumbers are superior to radishes, in terms of thiamine – red beet and common onion. In addition, the iodine content of cucumbers is higher than that of potatoes, onions and most other vegetable crops. Fruits are consumed in fresh, canned and salted forms [4, 9].

The consumption of cucumber fruits helps to improve appetite and the absorption of other foods due to the content of enzymes necessary for better absorption of B1 group vitamins, alkaline salts that reduce the acidity of gastric juice and are recommended for kidney and liver diseases. Cucumber juice is useful for rheumatic diseases, strengthens heart and blood vessels, has an antisclerotic effect, improves memory, and the high content of potassium helps to remove water from the human body, regulates and facilitates the work of the heart. In addition, cucumber (juice) is widely used in cosmetology [2, 49].

By weight, cucumber fruits are divided into tiny (weight less than 50 g), small (from 50 to 100 g), medium (101–200 g), large (201–400 g) and very large (over 400 g).

The taste qualities of the fruit (good, medium, bad) depend not only on the chemical composition, but also on the consistency of the pulp (crunching, semi-dense, dense, coarse), the thickness of the skin (thin, thick), the bitterness content in the fruit (strong, absent) and the specific aroma (strong, weak or absent).

By the duration of the growing season, cucumber varieties and hybrids are divided into early ripening, which begin to bear fruit 32–48 days after sowing in the open ground (Gherkin type), medium early ripening (50–55 days) and late ripening (56–70 days) [7, 60].

Due to the global climate changes, the cultivation of varieties and hybrids of gherkin-type cucumbers (early ripening) has become attractive in commercial vegetable growing in Ukraine today. The main advantage of which, in comparison with samples of semi-late and medium ripening group, is the genetically controlled size of the Gherkin fruit – no more than 12 cm, the compact habitus of the plant (with short runners), the maximum commercial yield on irrigation –19–23 t/ha (with twice-repeated crop rotation), with drip irrigation – 45–50 t/ha [1, 122].

1.2. Theoretical and practical significance of protracted resistance trait of cucumber of Gherkin type to the main diseases under various conditions and growing technologies

Cropping capacity and quality of Gherkin type cucumbers strongly depends on the technology of its cultivation – varieties (hybrids) do not tolerate large doses of mineral fertilizers, need stable soil moisture supply, are severely damaged by pests and diseases, and significantly reduce productivity in case of tardy harvesting. At the same time, varieties and hybrids of gherkin-type cucumber over the past 7–10 years still took a leading position in the rating of domestic producers of fresh and processed vegetable production. Their main advantage is a significant number of ovaries and gherkins, small fruits-gherkins with high pickling qualities and high commercial cropping capacity [1].

One of the important measures to increase the production of this vegetable crop is to increase its yield by breeding new high-yielding varieties and hybrids, developing more advanced industrial cultivation technologies, one of the basic elements of which is a comprehensive system for protecting commercial crops from diseases, pests and weeds [4, 44, 62, 101].

Until 1985, the sowing area under cucumber in Ukraine was about 70 thousand hectares, but today, due to the strong annual spread of downy mildew, they have decreased to 40 thousand hectares [33, 53].

Under the conditions of the research region, downy mildew of cucumber acquired an epiphytotic character in 1989–1990, when only 2.07–2.36 t/ha of this crop was obtained from spring–summer film greenhouses in July, and summer commercial crops completely died from the disease [92].

A sharp increase in losses of commercial products of cucumber due to losses from diseases became very relevant for many countries of the world during this period [41, 109].

As noted by G.I. Yarovoy, A.V. Kuleshov and O.M. Batova [104], who analyzed the data of 1995–2005, downy mildew on cucumber under the conditions of the region of conducting research had a spread of 9–55 % (on average for years at the level of 27.8 %) with the degree of plant damage of 2–27 % (on average for years at the level of 14.5 %).

Thus, in 1996, producers of commercial cucumber in the United States spent more than 120 million dollars on means for crops protection against downy mildew, which sharply reduced the profitability of production [147].

Earlier, back in the 80–90 years, scientists from different regions of the world found that downy mildew in addition to cucumber, affects more than 70 different plant species of the genus *Cucumis*. The disease became widespread in central Europe on cucumbers in 1984, virtually completely destroying the crops of this crop [30].

Spores of the pathogen showed a high ability to survive at fairly low soil temperatures in winter, and active mycelium – the ability to be preserved in nature for quite a long time, which is established by systematic studies for many regions of the world [37, 150, 153].

It should be noted that at that time up to 80 % of all cucumber crops in Ukraine were varieties of Nezhinsky local and Nezhinsky 12 of Nezhinsky variety type [72]. The most typical and very valuable consumer difference of varieties selected on the genetic basis of this variety type were very high pickling qualities and morphological and biometric traits of the commercial product: small (11–12 cm long) green fruit, thin tender skin of green fruit, dense pulp with small cells, black complicated pubescence, sharp expression of ribs and furrows in young fruits, medium or small seed case, high taste qualities of processed products [10, 84].

But, despite significant achievements in breeding, it was after 1985 that the global epiphytotic spread of the disease made cucumber cultivation in the former USSR unprofitable. Since this period that breeding work began in Ukraine, Belarus, Moldova and other republics of the USSR to create varieties and hybrids of open ground cucumber of a new generation – primarily with high protracted resistance to the main diseases, especially downy mildew, on the background of the maximum possible genetic improvement of a number of other valuable traits [31, 37, 57, 76].

At the same time, breeders were faced with the task of combining as much as possible in the newly created varieties (hybrids) such characteristics as a friendly yield, a long period of fruiting (gherkins), high pickling fruits qualities, early ripening, resistance to the main diseases, in particular downy mildew [21].

Therefore, for further work with resistance trait to a number of diseases, in particular to downy mildew, samples of cucumber of Far Eastern selection were involved in the breeding process, where work was already carried out to create resistant initial forms of cucumber [20]. This happened by introducing the genetic potential of cucumber originating from Japan, China, Vietnam, and India resistant to downy mildew and other diseases into domestic breeding [81, 84].

In the process of cucumber breeding for resistance to the main diseases, it was found out that the focus on creating varieties and hybrids of cucumbers only to improve the yield indicators and quality of gherkins significantly limits the choice of sources and donors of resistance to the main diseases. Without the introduction of a sufficient variety of small genes (gene complexes) into the newly created genotype, which make it possible to control resistance to the main diseases under the field conditions as much as possible, breeding in this direction is ineffective or doomed to failure [60].As a summary, it was stated that such a limited number of cucumber samples resistant to this disease led to a high uniformity of mass crops in the former USSR, which contributed to the rapid and intensive development of some phytopathogens, in particular the causative agent of downy mildew in significant areas [7, 27, 61].

As noted above, in Ukraine, downy mildew has been registered annually on commercial crops for many years. The shortage of yield from it, according to various literary sources, is from 50 to 100 % in individual years [34, 78].

Thus, according to the State Plant Protection Inspectorate of the Ministry of Agrarian Policy and Food of Ukraine [50], in 2008, downy mildew on cucumber was recorded in June on more than a third of commercial crops. Only dry hot weather in the second half of the growing season restrained its development in most areas where this vegetable crop is grown. At the same time, it was found that the most favorable weather conditions for the development and spread of downy mildew on cucumber crops annually develop in Transcarpathian, Zaporizhzhia, Dnipropetrovsk, Poltava, Kharkiv and some other regions, where the damage rates of grown samples ranged from 42–100 % with a degree of damage from 10 to 45 %.

Taking into account the difficult ecological situation in Ukraine, as well as the fact that cucumbers of Gherkin type are widely used in nutrition in a fresh form, the use of chemicals on this vegetable crop starting from the period of mass fruiting is prohibited [34, 44].

This proves that breeding in the direction of creating resistant varieties is recognized today as the most radical means of protecting cucumber plants from diseases in the world. However, we need to have information about the composition of natural populations of pathogens, their changes in space and time to successfully solve the problems of such breeding programs [31, 80, 106]. This process is long and should be constant, but production already needs real effective measures to regulate the prevalence of diseases and reduce cucumber yield losses from them [76, 111].

Today, world and domestic producers of vegetable products solve this problem with the help of integrated protection systems. They represent an ideal combination of biological, agrotechnical, breeding-genetic, chemical and organizational and economic measures aimed at the most effective and ecologically justified neutralization of the negative effects of biotic stress factors of various origins on plants [4, 6, 118].

It should be noted that already in the 90s, the scientific community admitted that humanity needs to learn how to organically manage agroecosystems by deep knowledge of general and specific rules of their formation and functioning. First of all, it was found out that both factors of immunity and methods for determining the necessity and timeliness of applying protection measures of different origin play a leading role in ensuring the natural self-regulation of artificial plant coenosis.

At the same time, it is primarily recommended to make changes in the ratio of varieties by increasing the share of growing of sustainable varieties [94, 68], and all protection measures should be carried out taking into account regional long-term and short-term forecasts, which will allow developing environmentally oriented protection systems for each region of growing of a particular product [34, 95].

It is this harmonious combination of the above factors that makes it possible to stop the increase in the use of pesticides, which will slow down the growth of pesticide environmental pollution [42, 82].

At the same time, scientists have proved that the introduction of complex (integrated) systems into production, which expect the biologization of protection with its transfer to an ecological and economic basis, is recognized as the most promising today [151]. It is separately noted that it is the use of resistant varieties (hybrids) in such integrated systems that provides the highest economic effect [23, 34, 41, 73, 159].

1.3. Peculiarities of the formation of a phytopathological complex of a cucumber of Gherkin type and gene complexes (immunity) by the resistance to the main diseases

The analyzed literature sources allowed us to establish a general and zonal list of the most common diseases of open-ground cucumber both in the research region and in the world [104].

Having analyzed the literature sources, it was determined that in the above list, diseases such as downy mildew, powdery mildew, fusarium wilt, angular bacterial spot disease, anthracnose are constantly present on cucumbers under open ground conditions [9, 33, 34, 53, 59].

At the same time, it is noted that the selection of varieties resistant to these diseases is impossible without a thorough study of the long-term and seasonal peculiarities of their pathogenesis, biology of the main pathogens and the nature of the formation of trophic connections with the plant, analysis of the influence of weather conditions on the intensity of these processes [52, 57, 58].

For the first time and most fully, the composition of diseases of many cultivated plants, including cucumber, on the territory of the European part of the former USSR in 1929 was described by A.A. Yachevsky [105].

Analysis of domestic literature has shown that the most common and harmful diseases of cucumber in open and protected ground are downy mildew, powdery mildew, anthracnose, fusarium wilt and angular bacterial spot disease [12, 34, 44].

Downy mildew or peronosporosis of cucumbers (English – Downy Mildew of Cucurbits). The causative agent of this disease is the fungal organism *Pseudoperonospora cubensis* (Berk. & M.A. Curtis) Rostovtsev. It belongs to the kingdom *Chromista* (fungal organisms), the division *Oomycota*, the class *Oomycetes*, the order *Peronosporales*, the family *Peronosporaceae* and the genus *Pseudoperonospora* [24]. In the international mycological literature, the basic name of the causative agent of this disease is *Pseudoperonospora cubensis* (Berk. & M.A. Curtis) Rostovzev. [24]. The international universal disease code is PCU [116, 160].

In addition to this name, in the scientific literature, the causative agent of this cucumber disease for specific diagnostic symptoms has been described at various times under such names – *Peronospora cubensis* Berk. & M.A. Curtis, in Berkeley (1868), *Plasmopara cubensis* (Berk. & M.A. Curtis) Humphrey (1891), *Peronospora atra* Zimm. (1902), *Pseudoperonospora tweriensis* Rostovzev (1903), *Pseudoperonospora cubensis* var. *tweriensis* Rostovzev (1903), *Plasmopara cubensis* var. *tweriensis* (Rostovzev) Sacc. & D. Sacc.(1905), *Plasmopara cubensis* var. *atra* (Zimm.) Sacc. & D. Sacc. (1905), *Peronoplasmopara humuli* Miyabe & Takah. (1905), *Pseudoperonospora celtidis var. humuli* Davis (1910), *Plasmopara humuli* (Miyabe & Takah.) Sacc. (1912), *Pseudoperonospora humuli* (Miyabe & Takah.) G.W. Wilson (1914), *Peronospora humuli* (Miyabe & Takah.) Skalický.According to the type of nutrition, this pathogen belongs to typical classical biotrophic organisms [28, 113].

For the first time, downy mildew on cucumber in the open ground was discovered in Central America in Cuba in 1868, later (1888) – in Japan, and later, in 1889 – in North America. At the beginning of the twentieth century, downy mildew was recorded on cucumbers throughout Europe and, in addition, in East Africa, Brazil, and the Java Peninsula [63].

Today, downy mildew of cucumber (pumpkin crops) in the open ground is widespread on all continents and geographical zones of cultivation – in the countries of Western, Central and Eastern Europe, Asia, Africa, North America, the Far and Middle East [64, 81].

At one time, for the first time, the mass defeat of cucumber crops by downy mildew, except for Ukraine and the former republics of the USSR, was simultaneously observed in significant, radically different soil and climatic conditions in different European countries (Czechoslovakia [136], Germany [143], Italy [113], Hungary [155], Austria [112], Sweden [126], Switzerland [156] and Greece [133].

According to literary reports, this disease mainly affects plants of cucumber, melon, less often – watermelon, vegetable marrow and other pumpkin. First, symptoms of downy mildew appear on cotyledon or real leaves. When plants in the field are affected, round or angular spots are formed on real cucumber leaves and quickly increase in size. With the angular shape of the spots, the disease is often mistaken for bacteriosis. In wet weather, spots on the underside of the leaf are covered with a grey-purple coating of sporulation of the pathogen. Gradually, the spots increase in size and subsequently cover the entire leaf blade. Such leaves quickly turn brown, dry up and crumble [46].

The harmfulness of this disease in the open ground is very high – within a few days, especially in the presence of favorable weather conditions for the development of the pathogen, it can lead to the complete death of cucumber crops. In wet and relatively warm weather, the causative agent of the disease forms many zoospores that spread by air currents and in the presence of drip-liquid moisture on the surface of plants, within 4-6 hours (night dew, rain, fog, watering) germinate, damage and re-infect the plant [61, 81, 157].

Mathematical analysis of 10-year data under conditions of the region of conducting research we have revealed a negative connection between the amount of precipitation and the spread of the disease (B = -0.69) and the tendency to reduce its development. The result of these studies was the fact of establishing a significant negative effect of increasing air temperature (B = -1.57 and -2.59) and positive effect of air humidity (B = 0.68 and 2.07) on the dynamics of downy mildew development in agrocenoses [104].

The somewhat atypical dependence of this moisture-loving phytopathogen on the amount of precipitation is associated by different researchers with the nature of their falling out during the period when the disease develops rapidly. Light precipitation, downpours during the day, and high temperatures do not provide protracted moisture to plants, and, as a result, do not contribute to the spread of the disease [27, 38, 104].

In contrast, it was found that excessive precipitation washes away the propagules of this phytopathogen from plants. So, for the development of downy mildew in cucumber agrocenosis, moderate precipitation, the presence of dew, air humidity of more than 70 % are favorable – because these factors ensure the preservation of moisture on plants for more than 4-5 hours, which is important for activating and accelerating the pathological process. Other scientists also emphasize that the intensity of the spread and development of this disease is closely interrelated with hydrothermal conditions, in which the presence of drop moisture on the leaves is crucial. The optimal air temperature for the development of the fungus is 18...22 °C [38, 52].

The development cycle of this phytopathogenic organism in the natural environment is represented by endogenous mycelium and two types of spores: asexual (zoospores) and sexual (oospores). The endogenous mycelium of this pathogen is branched, with egg-shaped, pear-shaped haustoria, formed on cucumber plants throughout the growing season, causing their repeated re-infection. The type of lesion is passive. During the inter-vegetation period, this phytopathogen is preserved: mycelium – in seeds, oospores – in infected plant remnants [24, 53].

Asexual sporulation of the fungus – zoosporangiophores with zoosporangia (conidia), sexual – oospores. Zoosporangiophores are collected in bundles of 27 pieces, coming out through the torn cuticle with terminal branches extending at right angles. Zoosporangia are ellipsoidal, ovate, with a papillary tubercle at the apex, greyish or purple, sometimes brown, measuring 20–28 × 16–20 microns. Oospores are spherical, yellowish, 36–42 microns in diameter. Infection of plants occurs with the help of zoospores that come out of zoosporangia. Zoosporangia need drop moisture to germinate. Zoospores germinate by forming a tube through which this pathogen enters the plant through the stomata [32, 34, 36, 87, 116].

During the growing season, this phytopathogen forms several generations of conidial sporulation, which provides it with a high reproduction rate and rapid epiphytotic spread. At the same time, it is noted that the optimal temperature for germination of zoosporangia and oospores is 15 ... 20 °C [123].

In addition, the researchers found that both in the world and in Ukraine, this disease is represented in field agrocenoses of cucumber by a set of simple races or their combinative complex mixture. Although research in this area has more general biological and evolutionary significance than practical or applied [45, 120, 137, 145].

In the presence of drop moisture on the plants, the infection can pass within 2 hours. From the moment of penetration of the fungus into the tissues of the host plant to the appearance of the first disease symptoms, an incubation period passes, which, depending on weather conditions and varietal characteristics, ranges from 3 to 13 days [31, 45, 57, 126].

In addition, researchers note that losses from this disease directly depend on the stage of plant development: the earlier the infection process occurs, the higher the production loss [50].

The appearance of primary foci of downy mildew at the beginning of the flowering phase under local conditions most often led to the complete death of plants in significant areas even before the first harvest of commercial products. Severely affected plants grew brown and dried up, and only the remains of leaf petioles retained on the shoots. The absence of leaves delayed the setting and development of fruits, and fruits that managed to form to marketable sizes, did not have a typical “cucumber” taste, became wilted, the color of their skin was pale green [37, 87].

Earlier, it was already noted that if weather and climatic conditions contribute to the development of this disease, the commercial yield of commercial cucumber can decrease even by 80–100 % [53].

In Ukraine, due to the very strong (by the type of epiphytotic) nature of the development of this disease in 1985, the duration of the cucumber fruiting period was reduced to 1–2 weeks, and in some places the complete death of crops was recorded even before it began [81].

Covering significant areas of crops, this disease can cause mass death of plants as early as 8–10 days from the beginning of the pathological process, having an expression in severe damage to leaf apparatus, shedding of the ovary, yellowing and partial or complete wilting of fruits [83, 101].

So, first of all, the harmfulness of this disease is manifested in a significant decrease in the assimilation surface of leaf apparatus. So, with a weak degree of damage, the amount of chlorophyll decreases to 53 %, with an average – to 42 %, with a strong – to 13.3 %. At the same time, irreversible changes occur in the system of plant's protein complex with a gradual decrease in the synthesis of protein nitrogen, monosaccharides, and its complete cessation of complex sugars synthesis [28, 129, 140].

From the literature sources, a complex of small (*minor*) genes that recessively control cucumber resistance to the disease is known: *dm* – (downy mildew resistance), *dm-1* (downy mildew resistance-1), *dm-2* (downy mildew resistance-2), *dm-3* (downy mildew resistance-3) [26, 127].

As scientists note, even today the system of measures to protect cucumbers from downy mildew is very limited. The use of various methods, including crop rotations, fertilizers and chemical and biological means of protection, in the prevention of limiting the spread of this disease is, unfortunately, ineffective [73, 109, 116].

At the same time, it is necessary to take into account the fact that cucumber fruits (the main product of consumption) are used not only in processed, but also generally – in fresh form, so the use of chemical means of plant protection in the critical, from a phytopathological point of view, period of their development (fruiting period) is extremely limited [9, 37, 53, 114, 115].

The most effective method of protecting crops of cucumber from downy mildew today in the world is considered to be growing in field crop rotations an assortment of varieties and hybrids with high protracted resistance. At the same time, it is recognized that this type of resistance can reduce both the volume of use of chemical and biological protection products and the multiplicity of treatments for cucumber plants of Gherkin type, which will positively affect the increase in the profitability of commercial production of this vegetable crop [19, 60, 78, 117, 144].

A number of authors define such diseases as powdery mildew, angular bacterial spot disease, or bacteriosis, fusarium wilt and anthracnose to the list of less common, but annually potentially dangerous cucumber diseases when it is grown in the open ground of the designated region of Ukraine [8, 34, 44, 53, 57, 102, 104].

Cucumber powdery mildew (English – Powdery Mildew of Cucumber). The causative agent is the fungus *Erysiphe cichoracearum* DC. *f. cucurbitacearum* Poteb. It belongs to the class *Ascomycetes*, order *Erysiphales*, family *Erysiphaceae*, genus *Erysiphe* Link. The international universal disease code is Gc (ex Ec) [116, 122, 160].

The disease is widespread on cucumbers in protected and open ground in all regions of its cultivation. It also affects vegetable marrow, pumpkin, melon and other pumpkin plants in all phases of development, starting with cotyledon leaves. A sharp increase in infection 10–20 days after the appearance of the first symptoms of this disease significantly reduces the growing season of plants, which is accompanied by a noticeable shortage of general and commercial yield [109, 116].

The disease manifests itself in the form of separate white powdery spots on the upper surface of the leaves, and subsequently on the lower one. With a strong lesion, the leaves and stems are covered with a complete powdery coating – the mycelium of this fungus. The mycelium of the fungus forms haustoria, with the help of which it penetrates the plant cell. Conidiophores are formed on the hyphae of mycelium, on the limbs of which chains of oval conidia are separated [53, 79].

During the growing season of plants, the disease is spread by conidia. At the end of the growing season, small spots appear on the mycelium (powdery coating), first yellow, then brown in colour – wintering fruit bodies of the fungus (kleistothecia). According to the description of kleistothecia *E. cichoracearum* f. *cucurbitacearum* – spherical, 80–150 microns in diameter with simple or branched appendix at the apex. Bags of 5–15 pieces in kleistothecia size 58–90 × 30–50 microns, with a short leg.

As a rule, the spores are ellipsoidal or rounded, measuring 20–30 × 10–20 microns, two per bag. [38, 119].

Spores that affect cucumbers in the current year's crop rotation germinate in late spring and summer from overwintered kleistothecia. Affected leaves and stems of plants quickly turn brown and dry out. The yield and quality of cucumber fruits is reduced very much [138, 159].

The development of the disease is promoted by sharp fluctuations in temperature and humidity, as well as insufficient solar insolation of plants [116]. At the same time, depending on the specific combinative combinations of weather and climatic factors, powdery mildew in agrocenoses of open-ground melons (cucumber, melon) acts as a direct antagonist of downy mildew, primarily due to various requirements for ecological factors that form the mechanisms of harmfulness of these diseases [149, 158].

Conidia of the causative agent of this disease germinate best and infect plants at consistently high air humidity. The optimal temperature for plant damage by this pathogen is 16–20 °C. With an increase in temperature above 20 °C, the development of the disease is significantly inhibited. Powdery mildew in some (cool and humid) years can reduce the yield of cucumbers under open ground conditions by 30–45 % [142].

In the list of genes that control cucumber resistance to disease are noted the following: *pm-1* (powdery mildew resistance-1), *pm-2* (powdery mildew resistance-2), *pm-3* (powdery mildew resistance-3)and *pm-h* (*s*, *pm*) (powdery mildew resistance expressed by the hypocotyl) [127].

Today in the world and in Ukraine there is an objective need to breed cucumber hybrids of open and especially protected ground with protracted complex resistance to diseases such as downy mildew (*Pseudoperonospora cubensis* Rostow) and powdery mildew (*Erysiphe cichoracearum* DC). It is this trait that allows reducing the cost of growing them primarily by reducing the frequency of plant treatments with pesticides. At the same time, the created hybrids must be high-yielding, have high taste and technological qualities of fruits [62, 93].

Fusarium wilt of cucumber (English – Rot of Cucumber; Wilt of Cucumber).The main causative agent of the disease is a representative of fungi of the genus *Fusarium* (Schlechtend.:Fr.), namely the fungus *Fusarium oxysporum* (Schlechtend.:Fr.) f. sp. *cucumerinum* (Owen) Snyder & Hansen. This facultative parasite belongs to the division *Ascomycota*, subdivision *Pezizomycotina*, class *Sordariomycetes*, subclass

Hypocreomycetidae, order *Hypocreales*, family *Nectriaceae*, genus *Fusarium* Link. The international universal disease code is FCU [116, 160].

The pathogen affects cucumber plants in all stages of development. Infected seeds sown in the soil have low field germination. The hypocotyls of the affected sprouts rot and they die even before coming out the soil surface. On the shoots, the disease has a visual expression in two forms – directly wilting and rot of the root neck [53].

In the first form of disease symptoms, cotyledon leaves of the affected plant acquire a pale green colour, lose turgor, wither and dry up within 2–3 days.

In the second form of expression, root neck rot is most often observed in plants at excessive humidity and low soil temperature. With this course, the root neck of the plant becomes thinner and rots, the stem becomes watery and translucent. In the future, such shoots break and fall [45, 102].

In adult plants, there are also two forms of damage – direct wilting or growth inhibition (dwarfness) [130]. In this case, adult plants wither in the same way as shoots. Often individual shoots of the plant wither. Sometimes the affected plants do not die, remain dwarf, their internodes become short, and their leaves become small. Fruits from such plants are also small, or do not form, inedible [34, 44, 125]. The disease is spread through contaminated soil, plant remains, or seeds [88].

Fusarium wilt causes especially great harm to cucumbers under protected ground conditions with its permanent cultivation [130].

Today, one recessive gene (*Fcu*) has been identified in the cucumber genome, which controls resistance trait to races 1 and 2 of this pathogen in plants [26, 127].

Taking into account that the cucumber crop in protected ground is the leading one, occupies significant areas and is often grown in a permanent crop, a large number of pathogens accumulate in the soil, which inhibit the growth and development of plants and negatively affect yields. The use of pesticides in protected ground leads to their accumulation in the soil and commercial fruits. Therefore, the creation of high-yielding cucumber hybrids of protected ground with resistance to this disease is one of the important modern tasks of world and domestic breeding [48, 102].

Bacteriosis, or angular bacterial spot disease of cucumber (English – Angular Leaf Spot of Cucumber). Pathogens – the bacterium *Pseudomonas syringae* pv. *lachrymans* (Smith & Bryan) Young Dye & Wilkie (синоніми – *Bacterium lachrymans* E.F. Smith and Bryan, *Bacillus* *lachrymans* (E.F Smith and Bryan) Holland, B. Burgeri Potebnia, *Phytomonas lachrymans* (E.F Smith and Bryan) Bergey et al., *Pseudomonas lachrymans* (E.F Smith and Bryan) Carsner).It belongs to the section of Gram-negative aerobic bacilli and cocci of the class *Zymobacteria* of the order *Pseudomonadales* of the family *Pseudomonadaceae* of the genus *Pseudomonas* Migula. According to the type of nutrition – a typical facultative parasite (hemibiotroph). The international universal disease code is PSL [8, 116, 122].

Bacterial spot disease is common in both open and protected ground. Apart from cucumber, it can affect plants of melon. It appears on cotyledons, leaves, stems, and fruits. On cotyledons in the form of light brown spots. On the leaves, oily angular spots first appear, limited by the small veins of the leaf. On the underside, when the air humidity is high, they are covered with yellowish droplets, which contain a large number of bacteria. Later, the spots dry up, the tissue between the small veins falls out, the leaves become holey. With a strong lesion, the small veins themselves remain from the leaves. On the fruits, stems and petioles of leaves, small watery spots first appear, which quickly increase in size and sink down in the form of ulcers. Bacteria overwinter on plant remains in the soil [34, 107].

It is proved that the main infectious beginning of the disease is seeds, the intensity of its development is directly related to weather and climatic conditions. Usually, the first symptoms in the field are recorded from July to the end of the growing season of plants. During the growing season, bacteria are passively spread by wind, rain, irrigation water, and insects, in particular melon aphids, thrips, and spider mites, are the active vector of distribution [135]. Dry and hot weather can correct the intensity of its development and distribution in agrocenoses of open-ground cucumber [112, 150].

To date, one recessive *psl (pl)* gene has been identified in the cucumber genome, which monogenously controls the resistance of the cucumber plant to angular bacterial spot disease [26, 109, 127].

Thus, the analyzed literature sources have shown that the critical phase of this vegetable crop in the phytosanitary aspect is the phase of mass fruiting, when the use of chemical and biological plant protection products, without violating sanitary and hygienic standards, becomes extremely difficult. Cucumber is consumed fresh, usually unripe. Fruits are harvested every 2–4 days, while the minimum waiting time for most allowed using biological and chemical preparations ranges from 7 to 20 days [44, 78].

As the main conclusion, we will note that taking into account global trends and trends in breeding theory and practice, the basic task for Ukrainian scientists today is to obtain initial material of cucumber resistant to downy mildew, including Gherkin type, by working out schemes of immunological, statistical and hybridological analyses. This will allow selecting valuable resistant initial parental material (genotypes) for varietal and heterotic breeding, which will harmoniously combine a complex of valuable approbatory and economic characteristics, and effectively use it in the breeding process.

1.4. Conditions of conducting research

A generalized analysis of the literature review has showed that cucumber of Gherkin type is a heat-loving vegetable crop that requires, when grown under open ground conditions, average daily air temperatures not lower than 15 °C, relative air humidity of 75 … 95 %, soil – not lower than 60.80 % HB [46].

To obtain the maximum harvest of varieties and hybrids of Gherkin cucumber of early ripening group under open ground conditions, the sum of effective temperatures (CET) under open ground conditions is required at the level of 1200 °C, medium ripening –1250 °C, late ripening – 1400 °C, respectively.

This temperature regime is the most optimal for breeding cucumbers of Gherkin type, taking into account the precocity of the samples and the direction of our research [3, 9, 64].

The soil of experimental areas of breeding crop rotation, where field experiments were annually conducted, is podzolized chernozem, semi loamy meadow, not salined, not alkaline, low humus, with optimal water-physical properties for growing cucumbers. The level of provision of accessible (mobile) forms of phosphorus and potassium is increased. The thickness of the humus profile is up to 94 cm. The humus content in the arable layer (0–30 cm) is 3.26 %, in the sub-arable layer (30–50 cm) – 3.0 % [75].

Meteorological conditions in the region of experiments differed in seasonal diversity over the years, which is connected with the rapidly growing continentality of most of the main characteristics of the climate of Ukraine from West to East and from South to North [77].

As a result, in most of the territory of the Forest-Steppe of Ukraine, the climate in recent years has been characterized by a lack of moisture in autumn and spring periods, cold winters and hot and dry summers, with sharp daily fluctuations in minimum and maximum temperatures.

The average annual air temperature in the research area is 6.8–7.0 °C, and in the hottest month (July) – 19.3–20.4 °C. The period with temperatures above 10 °C lasts on average for 170–180 days. Spring frosts end in the third decade of April, in some years – in early May, autumn frosts – begin in the second decade of October (sometimes – in September). The amount of precipitation per year in the Left-Bank Forest-Steppe ranges from 508 (eastern part of the zone) to 622 mm (central part).The average long-term precipitation in the region during the growing season is 366 mm. The wettest months in the Left-Bank Forest-Steppe zone are June and July, during which up to 57–73 mm of precipitation falls. The early spring and early autumn periods are relatively dry. The reserve of productive moisture in the soil layer of 0–100 cm in April makes 116–138 mm, in July – 39–77 mm.

In general aspect, we will note that the meteorological conditions of the growing seasons of the conducting research went beyond the optimum for cucumber plants of Gherkin type and were determined by severe aridity, uneven precipitation, increased temperature conditions, and sharp fluctuations in day and night temperatures.

According to the meteorological post of the Institute of Vegetables and Melons growing of NAAS, an analysis of the weather conditions of the growing season in 2011 showed that the indicator of long-term precipitation for May-August was 235.7 mm. In fact, during this period, 160.5 mm fell, which was 68 % of the norm. The average daily air temperature regime for months was higher than normal by an average of 2.0–3.9 °C

May 2011 was characterized by abnormally warm and dry weather: the average daily monthly air temperature exceeded the long-term norm by 2.6 °C. Its fluctuations over decades exceeded the norm by 1,9 … 3,7 °C.

Precipitation in May fell 30 % below normal. This weather regime fell under the generalizing concept of a warm spring drought.

The general tendency of an excessively warm and dry weather regime remained in 2011 throughout the summer period.

In June 2011, the average daily air temperatures in the first and second decades were very high (2.6–3.8 °C more than normal), and in the third decade they decreased to the long-term norm – 20.6 against 20.8 °C (fig. 1.1). In the first decade, there was no precipitation, in the second – only 52 % of the norm fell, in the third (mainly in the form of downpours), the long-term norm was exceeded 3.4 times –71.5 against 21.2 mm (fig. 1.2).

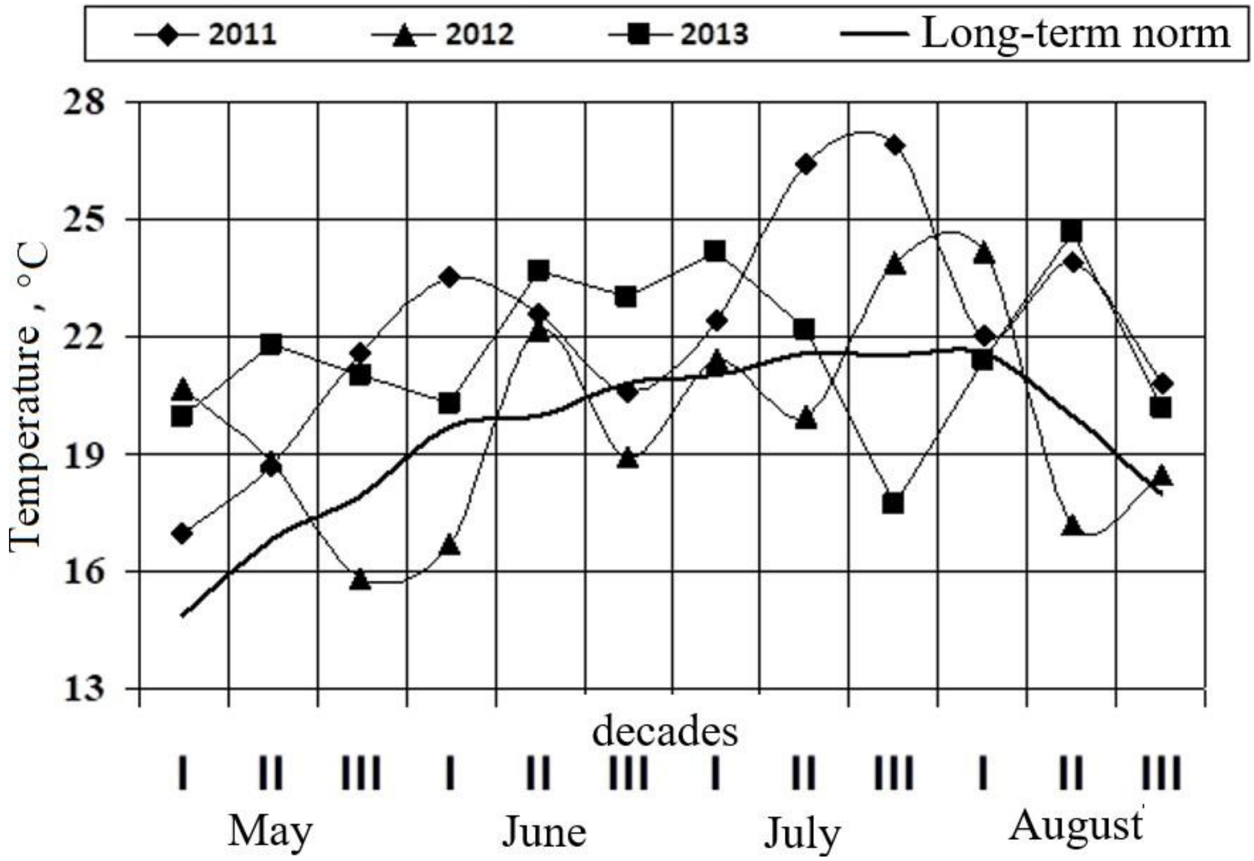


Fig. 1.1. Decadal fluctuations in the average daily air temperature (°C) (according to the meteorological post of the Institute of Vegetables and Melons growing of NAAS)

According to the analyzed literature reports it turned out that it was this combination of temperature regime against the background of excessive precipitation (air HB, %) at the end of June, to be the most specific "starting" factor for the appearance and spread of downy mildew primarily on susceptible samples of cucumber of Gherkin type.

In July 2011, the average daily air temperature remained abnormally high. So, in the first decade it exceeded the norm by 1.4 °C, in the second – increased to 4.8 °C, and in the third decade it rose to 5.4 °C. The negative balance of total precipitation at the end of the first decade of July was 38 %, in the second – there was no precipitation at all, in the third their amount was only 6 % of the long-term norm. At the same time, precipitation was observed in the form of protracted morning, evening dew and short-term rains [67].

This combination of weather conditions in July 2011 contributed, in our opinion, to the further active spread and rapid growth of downy mildew indicators (the degree of damage and intensity of spread) in breeding crops of cucumber of Gherkin type during the critical phase of plant ontogenesis – the period of mass fruiting.

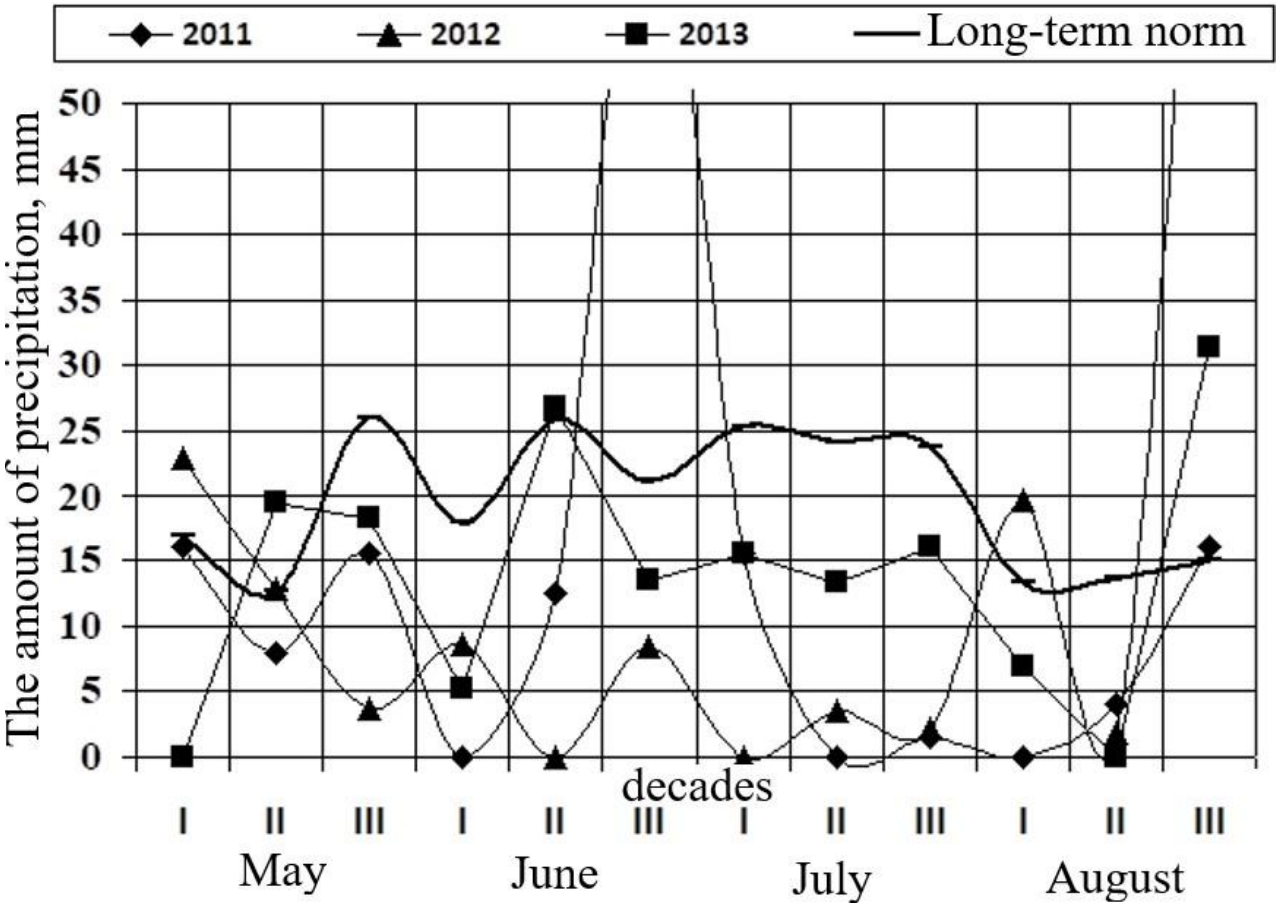


Fig. 1.2. Decadal fluctuations in the amount of precipitation (mm) (according to the meteorological post of the Institute of Vegetables and Melons growing of NAAS)

August 2011 was very warm and insufficiently provided with precipitation. The decadal temperature regime exceeded the norm by 0,4…3,9 °C. In the first decade of this month, there was no precipitation, in the second – their lack of 71 %, in the third – within the long-term norm (16 mm vs. 15 mm).

The meteorological conditions of May 2012 were usually characterized by abnormally warm and moderately humid weather. The average daily monthly air temperature during this period exceeded the long-term norm by 2.0 °C, and precipitation fell by 28.8 % below normal. So in the first and second decades of this month, the average daily air temperatures exceeded the norm by 2.0–5.8 °C, the amount of precipitation was 0.3–5.9 mm higher than normal. The third decade was cool and dry.

In June 2012, the first and third decades were cool: the average daily air temperatures were 1.9–3.0 °C lower than normal, and the second was warm – 2.2 °C higher than normal. This temperature regime was observed against the background of a strong lack of precipitation both for decades (below normal by 9.3–25.9 mm) and for the month as a whole – in the form of short-term rains, 47.9 mm or 74 % of the norm fell.

In our opinion, it was this combination of weather factors of the current year that contributed to the appearance of bacteriosis, or angular bacterial spot disease (the causative agent is the bacterium *Pseudomonas syringae* pv. *lachrymans)* on the leaf apparatus of young cucumber plants in field breeding crop rotation in the first decade of June and the spread in the second decade [24, 44, 116, 160].

The average daily temperature regime in July 2012 was within the long-term norm – 21.8 against 21.5 °C. A low temperature regime (by 1.6 °C) was observed in the second decade (cool dewy nights). At the same time the lack of precipitation remained critical. With a monthly norm of 73.3 mm of precipitation, 5.7 mm (or 7.7 % of the norm) fell. They fell out in the second (3.5 mm) and third decades.

This combination of weather factors coincided with the mass fruiting phase of most breeding samples of cucumber of Gherkin type, which provided 7–9-hour moistening of the leaf surface of plants. These fluctuations in air humidity and temperature conditions stimulated the rapid spread of the pathological process on plants. The first foci of downy mildew were detected in early July, the mass spread of the disease occurred in the second and third decades.

August 2012 remained warm, but excessively humid. The average daily air temperature for the month exceeded the norm by 0.2 °C, the amount of precipitation by 15 mm exceeded the long-term norm (65.1 mm). At the same time, virtually all precipitation fell in the third decade.

Taking into account the botanical peculiarities of cucumber of Gherkin type, all varieties and hybrids of which belong to the early ripening group, the active productive period of most of the studied samples ended approximately in the third decade of July – the first decade of August. It was during this period, against the background of a specific temperature and humidity regime, that symptoms of fruit damage by anthracnose were recorded on seed plants of Gherkin type cucumber (the causative agent is the fungus *Colletotrichum orbiculare* (Berk. & Mont.) Arx) [24, 44, 116, 160].

In general, the temperature regime of May 2013 exceeded the long-term value by 4.4 °C, the monthly precipitation was 32 % lower than normal (55.5 vs. 37.7 mm). All decades were abnormally warm: the first by 5.1 °C above normal, the second by 5 °C, the third by 3.1 °C. At the same time, the distribution of precipitation across decades also turned was diverse: in the first decade there was no precipitation, in the second it fell 6.8 mm over the norm, in the third decade – the shortage was 7.7 mm.

In June 2013, the average daily air temperature regime exceeded the long-term norm by 2.1 °C. The total amount of precipitation was 45.5 against 65 mm of normal (lack – 30 %). The first and third decades were insufficiently provided with precipitation against the background of an increased average daily temperature regime. In the second decade, against the background of an increased temperature regime (by 3.7 °C), the amount of precipitation was within the long-term norm.

The combination of the main abiotic factors turned out to be sufficient for focal spread in crops of breeding samples of fusarium wilt (the causative agent is the fungus *Fusarium oxysporum* f. sp. *cucumerinum* (Owen) Snyder & Hansen) [24, 116, 160].

We will note that under open ground conditions, the death of cucumber plants from fusarium wilt can range from 5 to 10 % [44].

The tendency as for increased temperature regime continued in the first (3.2 °C) and second (0.6 °C) decades of July. The third decade of the month was cool: the average daily air temperature indicators were below normal by 3.8 °C. At the same time, for all decades there was a quantitative lack of precipitation, which amounted to a total of 28 mm (or 38 %) for the month. Such sharp fluctuations between day and night temperatures contributed to the active condensation of drop-liquid moisture (dew) from the air to the surface of the leaf apparatus of cucumber plants.

August 2013 remained warm, but with a lack of precipitation in the first (47 % less than normal) and second (no precipitation) decades. The average daily air temperature for the month exceeded the norm by 2.3 °C, and the amount of precipitation only for the third decade was less than the long-term monthly norm by only 25 %.

Thus, the conducted analysis of the formation of abiotic stress factors in June – July 2011–2013 showed that such phases of a cucumber plant ontogenesis as flowering and fruiting of a cucumber plants account for the most unstable characteristics of their expression, which significantly deviate from the long-term regional climate norm.

So, the average decadal air temperatures in these months ranged within 16…26.9 °C, the amount of precipitation – from 0.0 to 84 mm. It should be noted that such sharp fluctuations between day and night temperatures contributed to the active formation of drop-liquid moisture (dew) on the leaf tier of plants and the duration of its retention on the plant surface [67]. It was during such periods that the optimal hydrothermal conditions for downy mildew pathogen were formed for infection and re-infection of plants in the field crop rotation.

All this led to the fact that the first foci of downy mildew on the plants of the experimental cucumber plots were recorded annually by us in late June – early July. It was from that time that the active pathological process began, the duration of which largely depended in the future on fluctuations in temperature and humidity.

So, the optimal indicators of the average daily decadal temperature of 18…22 °C against the background of the presence of droplet moisture (4–8-hour dew on the plant surface) contributed to the further re-infection of Gherkin type cucumber plants and the intensive spread of the disease on the crop in July.

The above made it possible to conduct an objective differentiation of the breeding material of cucumber of Gherkin type by the level of resistance to downy mildew (*Pseudoperonospora cubensis* Rostovtsev) during the three-year research period.

As for other diseases, namely bacteriosis, fusarium wilt, anthracnose, over the years of research, they occasionally manifested in the open ground on cucumber plants of Gherkin type and did not play a significant economic role.

1.5. Materials and methods of conducting research

The monograph summarizes and analyzes the results of research obtained by the author directly during 2011–2013 in the fields of breeding rotation of the laboratory of pumpkin crop selection of the Institute of Vegetables and Melons growing of NAAS – the branch scientific center of Ukraine for breeding and genetic research on the main vegetable and melon crops.

Phytosanitary monitoring of seasonal changes in pathocomplex of a cucumber of Gherkin type and immunological studies of the level of resistance of this vegetable crop breeding material were carried out on the original author's material in the dynamics of its creation.

The author expresses his sincere gratitude to the breeders, namely the head of the laboratory Oksana Sergienko and researcher Lina Dmytrivna

Solodovnik for the presented original breeding material and joint fruitful scientific cooperation.

When conducting research, we used the following methods of research and analysis of experimental material: field – when monitoring the phytosanitary state of crops, when collecting herbarium material and determining the immunological characteristics of the breeding material of Gherkin type cucumber under conditions of a natural infectious background; laboratory – when determining the species composition of pathogens of the most common diseases; statistical – when determining the parameters of trustworthiness, stability and variability of the obtained experimental data and the research of interrelations between a complex of economic characteristics.

Field experiments were laid down and conducted in accordance with the “Methods of field experience in vegetable growing” [33], “Methods of research work in vegetable growing and melon growing” [54], “Methods of field experience” [35], “Operational technologies of vegetable production” [65], “Methods of conducting examination of varieties for difference, uniformity and resistance (DUR)” [70], “Modern technologies in vegetable growing” [85].

Chemical assessment of fruit quality (dry matter content, sugars, nitrates) was carried out according to the “Methods of biochemical plants research” [55], the value of the “dew point” – according to the corresponding literature reference [67].

Preparation of infected plant herbarium material for microanalysis, identification of phytopathogens, and immunological assessment of cucumber breeding material under conditions of a natural infectious background were carried out according to a number of specialized recommendations and methods [5, 27, 36, 39, 40, 56, 66, 74, 96].

The general system of phytosanitary monitoring of crops of a cucumber for detecting diseases during the growing season and describing their symptoms is given in Table 1.1.

The main elements of field accounting were such parameters as the disease prevalence (P, %) and the degree of plant damage (R, % or score) [34, 60].

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

$$P = (a / N) \cdot 100, \quad (1.1)$$

where *a is the number of sick plants, pieces;*

N – total number of examined plants, pieces.

Table 1.1

Methods and scales for diseases accounting of cucumber of Gherkin type under conditions of natural infectious background

Object of observation	**Item of measurement**	**Method and scale of accounting**
Diseases complex (powdery mildew, downy mildew, anthracnose)	Prevalence,%; degree of disease development , scores or %	Visual inspection of 30–50 plants on three accounting plots, which are located evenly along the diagonal of crop. Scale for assessing the degree of leaf damage: 0 score – no signs of the disease; 1 score – spots on leaves in an amount that is not difficult to count; 2 scores – spots cover up to 1/3 of the leaf surface; 3 scores –spots cover up to 2/3 of the leaf surface; 4 scores – a significant part of the leaves die off
Diseases complex (bacteriosis)	Prevalence,%; degree of disease development , scores	The entire accounting trial or the plant as a whole is assessed by the score (according to the prevailing score). Plant damage by bacteriosis is assessed by a scale: 0 scores – no signs of damage; 1 score – the disease has an expression on 1/10 of all leaves, bacterial spots are concentrated and cover up to 1/4 of the leaf surface; 2 scores – up to 50% of the plant's leaves are affected, spots cover up to 1/2 of the leaf surface; 3 scores – more than 50% of the plant's leaves are affected, more than 1/2 of the leaf surface is covered with bacterial spots; 4 scores – all leaves of the plant are affected.

Table 1.1 (continuation)

Diseases complex (ascochytosis, anthracnose)	Degree of disease development, scores	Scale for determining the degree of damage to cucumber plants by stem form of ascochytosis and anthracnose: 0 scores – no signs of damage; 1 score – individual spots up to 1 cm on leaf petioles, on stem nodes with or without sporulation; 2 scores – individual brown or greyish-yellowish spots no more than 3 cm in length along the stem, on lateral shoots, leaf petioles with or without sporulation; 3 scores – spots 3–5 cm in size along the stem or on lateral shoots, petioles, often combined, with sporulation; 4 scores – there are numerous longitudinal spots on the main and lateral shoots, which are accompanied by cracking of tissues and the release of gum, formation of wiring at the stems and the spread of damage symptoms to the fruits.

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

$$R = (\Sigma(a \cdot b) / N \cdot K) \cdot 100, \quad (1.2)$$

where $\sum$ *(a • b) is the sum of the product of the score of plants 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 of the accounting scale.

Accounting for the lesion degree 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. 2.3) [22, 68].

When assessing the immunological potential of the breeding material of cucumber of Gherkin type, the standard of susceptibility was Nizhynsky local variety (Ukraine), the standard of resistance to varietal populations – Dzherelo (Ukraine), Phoenix 640 (Russia), hybrid – Ajax F1 (Netherlands).

0 score

0.1 scores

1 score

2 scores

3 scores

Fig. 1.3. Visual three-point scale for assessing the lesion degree of cucumber samples by downy mildew (photo by S. V. Bondarenko)

When assessing the lesion degree and simultaneously determining the level of resistance of cucumber breeding samples, the following summary three-point scale was used, where:

0 scores of 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 plants 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. 1.3) [45, 60, 93].

Experimentally obtained data were processed using statistical methods of analysis – variational, correlation and disperse [35, 54, 86, 149]. The economic effect of growing Gherkin type cucumber samples in the field with different characteristic of resistance to downy mildew was determined according to a typical technological map for growing this vegetable crop [54, 65].

Some methodological questions and intermediate calculations that had a particular specialized direction or statistically confirmed general regularities, principles, intermediate and main conclusions are given directly in the corresponding sections of the monograph.

2. PECULIARITIES OF A ZONAL PATHOCOMPLEX FORMATION OF GHERKIN TYPE CUCUMBER UNDER OPEN GROUND CONDITIONS

Monitoring studies, collecting herbarium infectious material and analysis of seasonal changes in populations of the main pathogens were carried out by us on breeding crops of cucumber of Gherkin type during 2011–2013.

During every decadal examinations, the absence or presence of symptoms expression specific to each disease on various organs of cucumber plants was determined visually according to the recommended scales and methods (see subsection 1.5).

By examinations the phytosanitary condition of agrocenoses of cucumbers under open ground conditions, it was established that the main diseases symptoms on the plants in the field looked like spots, coating (sporulation or mycelium), rot, complete or partial wilting of plants. All these symptoms had the characteristic visual signs of damage (leaf apparatus, stems, fruits).

During further incubation of the affected plant particles (selected herbarium material) in a wet chamber, the appearance of coating of mycelial hyphae on them indicated the fungal origin of the disease, exudate drops indicated the bacterial nature of the disease.

Symptoms or diagnostic signs of the disease expression on cucumber of Gherkin type and the species affiliation of disease pathogens were determined by macro-and microscopic analysis using the appropriate specialized literature (see subsection 1.5).

2.1. Diagnostics, prevalence and harmfulness of the main cucumber diseases of Gherkin type

Before proceeding to the direct presentation of the results of our research, it should be noted that when analyzing the specialized literature, it was found that the symptoms of cucumber plant damage by diseases are described differently by researchers from different regions of the world [7, 31, 53, 61, 76, 109, 160].

In accordance with this, during the route surveys of Gherkin type cucumber crops we have studied their specific diagnostic symptoms in the dynamics of development and maximum spread on the crop. Apart from that we have established the degree (R, %) and intensity of spread (P, %) of a number of diseases.

Immunological characteristic of all cucumber breeding material about a diseases complex were provided to samples at the end of the critical phase of ontogenesis for this crop – mass fruiting of plants. In the region of breeding research, this process coincides with the first and second decades of July.

Based on the experimental data obtained by us, it was primarily determined that diseases such as downy mildew, angular bacterial spot disease and fusarium wilt took part in the zonal pathocomplex of cucumber of Gherkin type under open ground conditions, with different dynamics of seasonal development.

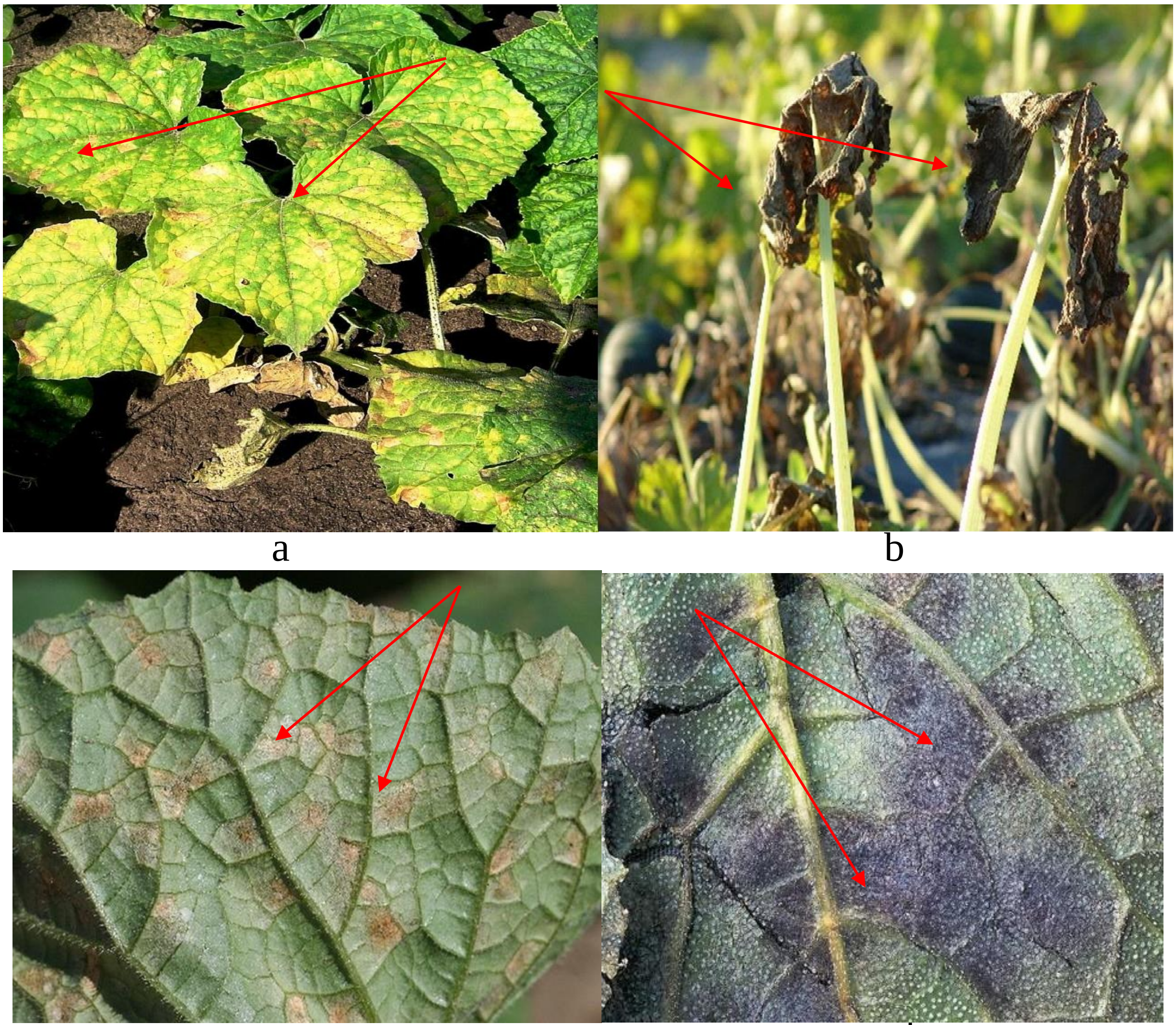
The original description of zonal (regional) specific diagnostic symptoms of these diseases on cucumber plants of Gherkin type in the open ground (taking into account the biological peculiarities of its growing) during the research period is given below.

Thus, based on the obtained results of phytosanitary monitoring, it was established that in the field, downy mildew on cucumber plants developed first on the upper surface of leaf plates in the form of angular, first light yellow, and then light brown spots.

In the future, these spots quickly increased in size and later merged. This period lasted under open ground conditions from 1 to 8 days. The severely affected tissue of such leaves in the sun rapidly dried up, became brittle, the leaves twisted and fell off. With this course of the pathological process, only leaf petioles remained on the stems of severely affected plants (fig. 2.1 A, B).

Our research found out that in the future, the rapid loss of leaf mass directly affected the process of forming the fruits setting that were on the plant earlier (before the lesion), their further physiological development. Thus, in plants severely affected by downy mildew (scores 3, 4) (see fig. 1.3) the formed fruits had slight colouration, were necrotic, and did not have a characteristic cucumber taste or smell.

When the leaf surface of plants is strongly moistening both in the field and in laboratory conditions (wet chamber), on the lower surface of the affected leaves, namely in places of spots from the outer surface (see fig. 2.1 A) there was an active sporulation of this fungi-like organism – an abundant greyish-purple coating of sporulation was formed (fig. 2.1 c, d) [119].



a b

c d

Fig. 2.1. Specific diagnostic symptoms of downy mildew expression on cucumber plants are characteristic spots on the upper surface of the leaf blade (a), the outer look of leaves at severe lesion (b), the beginning of sporulation (c) and its active phase, (d) – the view from the underside of the leaf blade.

When conducting a microscopic analysis in the laboratory, we have found that this process is a consequence of asexual sporulation of the fungi-like organism *Pseudoperonospora cubensis*, which in this representative of oomycetes is represented by zoosporangia and zoospores (fig. 2.2) (see section 1) [121].

As it noted above, the second place in the pathogenesis of this vegetable crop in the region of research in years was occupied by such disease as bacterial leaf rust (the causative agent is the bacterium *Pseudomonas syringae* pv. *lachrymans*).

The characteristic diagnostic symptoms of this disease on cucumber plants of Gherkin type are shown in fig. 2.3.

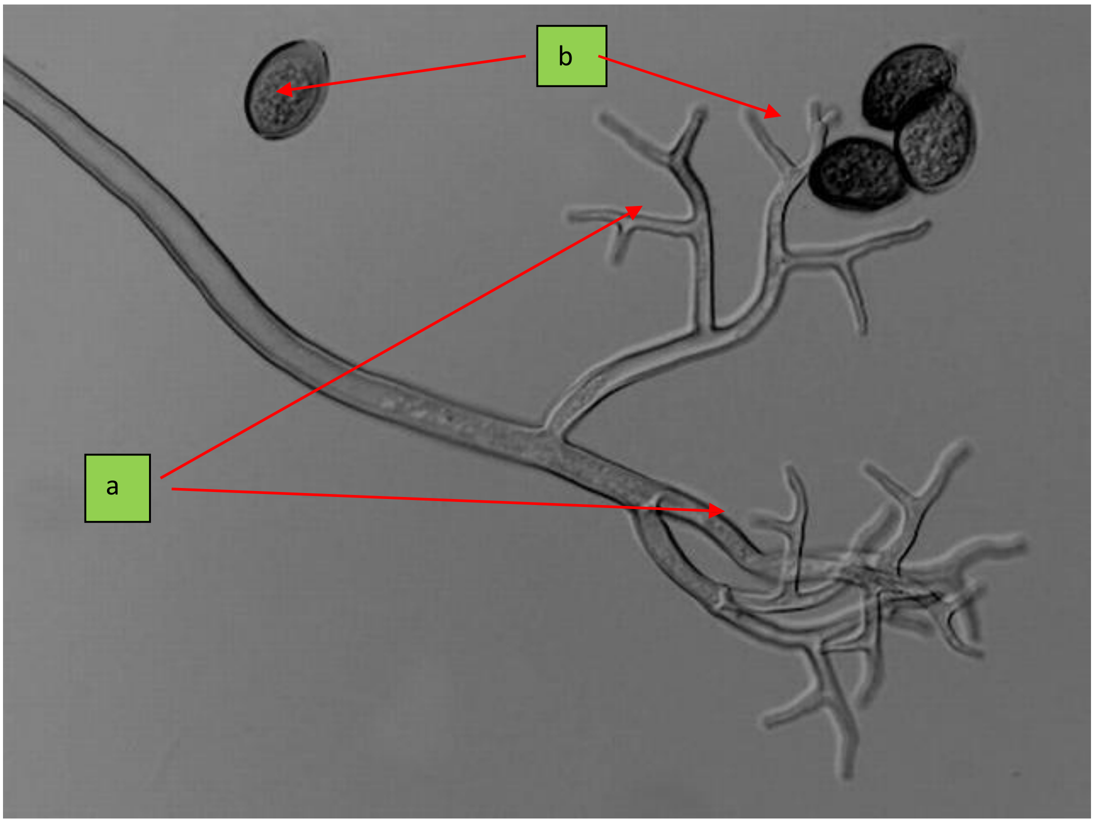


Fig. 2.2. Zoosporangia (a) with zoospores (dark balls – b) of the fungi-like organism *Pseudoperonospora cubensis* (wet chamber, washout, Lumam M1 microscope, UFO DS-8330 camera, 2012)

Initially, on physiologically young plants that were beginning to bloom, on the leaf apparatus, the disease had a characteristic expression in the form of small, irregular in shape, slightly greasy greyish-brown marginal spots (like sunburns). At the same time, the colour of tissues that were not damaged by the pathogen did not change and remained rich green (fig. 2.3 a).

Gradually, on severely affected leaves, the spots merged and became angular due to the restriction of their size by leaf veins. The affected tissue discoloured, and the leaves themselves looked like "burned". Limited by the veins, the affected tissue then quickly dried out, rotted and destroyed, which made the leaf surface parchment-like and holey (fig. 2.3 b).

Among other diseases of cucumber of Gherkin type in the open ground, we have recorded plants with characteristic symptoms of fusarium wilt (the main causative agent is the fungus *Fusarium oxysporum* f. sp. *cucumerinum*) [34, 44, 116, 130] (fig. 2.4).

It should be noted that when cucumber plants were affected by fusarium wilt in the field, we met two forms of visual specific symptoms of its expression – when the entire plant or a significant number of lateral shoots directly withered (fig. 2.4 A).

a)


b)


Fig. 2.3. Characteristic diagnostic symptoms of angular bacterial spot disease expression on cucumber plants of Gherkin type: a – physiologically young plants; b – severe lesion by bacteriosis

a)

b)


Fig. 2.4. Specific diagnostic symptoms of fusarium wilt expression on cucumber plants: a – most of the plant has wilted, b – the plant is underdeveloped, dwarf, the internodes are short, the leaves and fruits are small, drying out

Often, if the second type of pathogenesis of this disease occurred, the cucumber plant had a visually noticeable suppressed physiological state (dwarfism), the shoots remained underdeveloped, the internodes were short, the leaves and fruits were small and without turgor (fig. 2.4 b).

When analyzing the specific seasonal combination of weather and climatic factors, it was found that the main indicators of harmfulness – the intensity of spread (P, %) and the degree of lesion (R, %) of cucumber samples of Gherkin type by a diseases complex, in particular downy mildew, under open ground conditions directly depended on two basic components:

– firstly, it depends on the peculiarities of the meteorological factors combination at the end of June and in July, which falls on the critical phase of ontogenesis of this vegetable crop – the period of plants mass fruiting (table. 2.1);

– secondly, it depends on the level of reaction expression of field (protracted) resistance to downy mildew of the studying cucumber breeding material (fig. 2.5).

As can be seen from the indicators given in the table 2.1, the variability of the intensity value of development or prevalence (P, %) of downy mildew in different by the resistance of the breeding material of Gherkin type cucumber in the years of research ranged from 24 to 100 %.

At the same time, the calculated weighted average population indicator of downy mildew prevalence ($\bar{X}$weighted average population indicator = 63 %) on breeding crops of cucumber of Gherkin type in the critical phase of ontogenesis (the end of the first decade of plants mass fruiting) confirmed the annual high intensity of the natural infectious background of this disease and the objectivity of the obtained characteristics of the resistance level to it of breeding material [11, 16].

As a comparative analysis showed, calculated by us the weighted average population intensity indicator ($\bar{X}$weighted average population indicator**)** of development (prevalence) of downy mildew in the cucumber crops of Gherkin type annually amounted to more than 63 %, angular bacterial spot disease – 10 % (less by 6.4 times), fusarium wilt – 3 % (less by 20 times) (Table 2.1).

Thus, according to our research, it was established that the individual share of the contribution to the overall process of zonal pathocomplex formation of open ground cucumber of Gherkin type (the frequency of occurrence of a biological object [128]) of such a disease as downy mildew was 82% in the years of research, angular bacterial spot disease – 13.2%, fusarium wilt – only 4.8 % (fig. 2.6, table 2.1).

Table 2.1

The intensity of development or prevalence (P,%) of the main diseases, open ground cucumber – the end of the first decade of fruiting, %

Year	Downy mildew	Angular bacterial spot disease	Fusarium wilt
	LV $\nu_{min} \div \nu_{max}$*	**LV $\nu_{min} \div \nu_{max}$**	**LV $\nu_{min} \div \nu_{max}$**
2011	25,5 ÷ 100	0,0 ÷ 5,0	0,0 ÷ 5,0
2012	29,0 ÷ 100	0,0 ÷ 34,0	0,0 ÷ 1,0
2013	24,0 ÷ 100	0,0 ÷ 20,0	0,0 ÷ 10,0
In total by years	24,0 ÷ 100	0,0 ÷34,0	0,0 ÷ 10,0
$\bar{X}$ weighted average population indicator*	63,0	10,0	3,0
Frequency of occurrence	82,0	13,2	4,8

Note: * here and in the future, LV $\nu_{min} \div \nu_{max}$ is the limit of trait variation (the smallest ÷ the largest), $\bar{X}$ weighted average population indicator is its weighted average population value.

In the future, we determined that between such valuable economic characteristics of cucumber of Gherkin type as the total crop capacity, yield for the first fruiting decade, the period of mass fruiting and the basic indicators of downy mildew harmfulness (lesion degree, intensity of spread) on breeding samples with different expression of reactions, the correlation interrelation was medium and close, but opposite in the direction of action (see section 3).

It should be emphasized separately that a certain number of breeding samples that did not have field (protracted) resistance to downy mildew under conditions of a natural infectious background had stable crop losses at the level of 60-80%, in some years (2011) were characterized by the complete death of all plants on the experimental plots even before the beginning of fruiting phase [18].

At the same time, we have found that from 80 to 100 % of plants of susceptible and highly susceptible groups (1–3 scores of the immunological scale) could not reach the critical for this vegetable crop in the research region phase of ontogenesis– the period of mass fruiting (see fig. 2.5 and section 3) [90].

Fig. 2.5. The immunological reaction of a control breeding sample susceptible to downy mildew (Nizhynsky local variety, the last on the right, 2011)

Taking into account this fact, we consider it necessary to specifically focus on the peculiarities of seasonal dynamics of the development of the main zonal diseases of Gherkin type cucumber under open ground conditions for all years of research.

Thus, in 2011, the first specific diagnostic signs of cucumber plants lesion by downy mildew under open ground conditions in field crop rotation (fig. 2.1) were recorded by us during route surveys of breeding crops in the third decade of June (formation phase of runners). The mass spread of the disease in plants of breeding crop rotation occurred in the first half of July (Table 2.2).

In addition, in 2011, during a phytopathological examination of breeding crops, we recorded individual cucumber plants with characteristic symptoms of lesion by angular bacterial spot disease and fusarium wilt, but these diseases did not become widespread under open ground conditions (Table 2.1, Table 2.2).

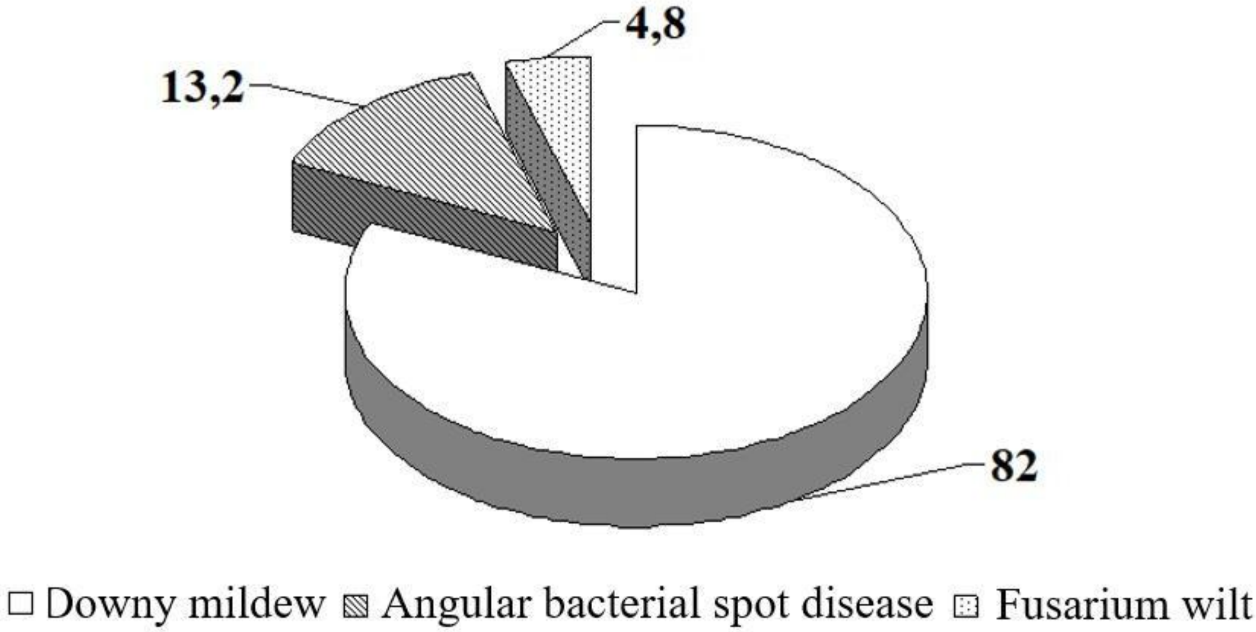


Fig. 2.6. Zonal pathocomplex of open ground cucumber of Gherkin type, individual share of the main diseases contribution, summarized for 2011-2013, %

Table 2.2

Characteristics of the development of the main cucumber diseases of Gerkin type under open ground conditions of the Left-Bank Forest-Steppe of Ukraine

Year	Disease	Beginning (appearance of the first lesion signs)	Mass spread of the disease
2011	downy mildew	III decade of June	I–II decade of July
	fusarium wilt	II decade of June	--
	angular bacterial spot disease	III decade of June	--
2012	downy mildew	I decade of July	II–III decades of July
	fusarium wilt	III decade of June	--
	angular bacterial spot disease	I decade of June	II decade of June
2013	downy mildew	III decade of June	I decade of July
	fusarium wilt	III decade of June	--
	angular bacterial spot disease	III decade of June	--

As we noted above (see section 1), the hydrothermal conditions of June – July 2012 were specific (abnormal) and by the indicators of temperature regime and moistening regime did not meet the standard values of the long-term climate norm for the zone of conducting research.

The first visual lesion signs of cucumber samples of Gherkin type by downy mildew in the breeding crop rotation on the experimental plots in 2012 were recorded in the first decade of July. Mass disease development on the leaf apparatus of plants of control cucumber samples (as a priori – in the field crop rotation) was in the second decade of July (Table 2.2).

In addition, under the field conditions, on some breeding samples this year were visually recorded specific symptoms of damage to cucumber plants by diseases such as angular bacterial spot disease (for the first time – in early June, en masse – in the second decade of this month) and fusarium wilt – focal. Occasions of individual plants damaged by fusarium wilt pathogens in experimental areas were noted in the third decade of June (Table 2.2, fig. 2.7).

Fig. 2.7. Characteristic specific falling out of cucumber plants on experimental plots when they are affected by fusarium wilt, 2013.

The study of seasonal changes in the zonal pathocomplex of cucumber of Gherkin type on breeding crops in 2013 showed the following.

The beginning (third decade of June) and further spread of this fungi-like organism against the background of a rapid increase in the intensity indicators (P, %) and degree of lesion (R, %) of breeding crops of Gherkin type cucumber were usually recorded by us in the first decade of July.

It was this time period that coincided in most breeding samples with the critical ontogenesis period of this vegetable crop – namely, the phase of mass fruit formation in experimental plants of different breeding origin (Table 2.2).

These facts once again clearly confirmed the presence of an annual hard natural infectious background of downy mildew in the research region (basic breeding and genetic center of Ukraine), which indicates a high representativeness of the conducted assessments of cucumber breeding material by the protracted resistance trait.

In the future, to confirm the above conclusion about the constant dominance of such disease of Gherkin type cucumber as downy mildew in the open ground in the region, we have combined the experimental data obtained by us with 16-year research results of other authors [104].

Comparison of long-term changes in the list of cucumber diseases, the nature of their dynamics, variability of basic indicators of harmfulness in the open ground with the obtained experimental data is summarized in Table 2.3.

Thus, according to summary data, the nature of downy mildew development for the period from 1990 to 2005 is characterized as moderate, only in some years – as strong. At the same time, the indicator of development intensity (P, %) in agrocenoses of open ground cucumber fluctuated at the level of 8.9 – 54.6 % (weighted average population indicator or $\bar{X}$weighted average population indicator – 27.8 %), the value of lesion degree of plants (R,%) – at the level of 2.2–27.4 % ($\bar{X}$weighted average population indicator – 14.5 %) (Table 2.3).

During the period from 2011 to 2013, against the background of global climate changes, the weighted average population intensity indicator of downy mildew prevalence on the crops increased more than 2 times – from 27.8 to 63.1 %. Accordingly, the limits of the maximum values of this indicator also increased – from 24 to 100 %. The maximum indicator values of the lesion degree of samples also increased – from 27.4 to 75 %. The weighted average population value ($\bar{X}$weighted average population indicator) of this indicator increased 2.5 times – from 14.5 to 35.6 % (Table 2.1, 2.3).

All this gives us reason to say that during the period from 1995 to 2013 in the region of research, the nature of downy mildew development on cucumber crops in the open ground gradually changes its character from moderate to consistently strong (by the type of epiphytotia) (Table 2.3).

Unlike downy mildew, our summary data of long-term changes in the dynamics of cucumber disease such as angular bacterial spot disease showed that against the background of a gradual decrease in the weighted average population value of development intensity (P) by more than 2 times (9.8 vs. 22.1 %), the average value of lesion degree of plants (R) in crops in recent years have been gradually increasing – from 11.1 to 17.4 % (more than 1.5 times) (Table 2.1, 2.3).

Table 2.3

Characteristics of zonal ecologically and adaptive changes in the development intensity (P) and lesion degree (R) of cucumber by a diseases complex (Left-Bank Forest-Steppe of Ukraine, Kharkiv region), %

Disease	1990–2005 pp. [104]			2011–2013 pp.		
	$\frac{LV\ \nu_{min} \div \nu_{max}}{\bar{X}}$ weighted average population indicator		The nature of the disease development *	$\frac{LV\ \nu_{min} \div \nu_{max}}{\bar{X}}$ weighted average population indicator		The nature of the disease development *
	P	R		P	R	
Downy mildew	8,9÷54,6 27,8	2,2÷27,4 14,5	M - S	24,0 ÷ 100 63,1	2,5÷75,0 35,6	S
Angular bacterial spot disease	4,0 ÷ 42,2 22,1	1,0÷20,0 11,1	M	0,0 – 34,0 9,8	2,1÷50,0 17,4	M
Powdery mildew	1,0÷38,0 13,2	0,1÷9,0 3,9	M	The disease has not been diagnosed		
Anthracnose	2,7÷7,0 5,1	6,0÷14,0 10,3	D	Affected fruits on single seed plants		
Fusarium wilt	No data available			0,0 ÷10,0 2,95	0,0÷9,8 4,9	D

Note: * D – depressive; M – moderate; S – strong (in some years – epiphytotic) [60].

Taking into account the obtained data, we specifically emphasize that determined by us tendency of gradual increase in the aggressiveness of bacteriosis in pathocomplex of open-ground cucumber bases on proved by various authors the evolutionary ability of this disease to dramatically change the nature of its development in certain weather conditions from depressive to moderate and strong [134, 135].

Based on the obtained research results, we also note that due to the global changes of weather and climatic conditions over the past decades, the nature of the dynamics of the development intensity and the prevalence of this disease in the region in recent years is sufficient reason to include it in the list of potentially dangerous.

In the future, we'll note that long-term changes in the characteristic of expression of weather and climatic conditions negatively (depressingly) affected the development and parameters of harmfulness of such cucumber diseases as powdery mildew and anthracnose in zonal agrocenoses of cucumber of open-ground (Table 2.3).

Thus, for the entire period of research, only in August 2012, characteristic lesion symptoms by anthracnose were recorded on single fruits of cucumber seed plants of Gherkin type (section 1 and table 2.3). At the same time, when conducting monitoring studies of crops [44], no specific lesion symptoms of cucumber plants of Gherkin type of open ground by such a disease as powdery mildew were recorded during the study period (Table 2.3). In addition, we have found that in recent years, the symptoms of manifistation of fusarium wilt – the main pathogen is the fungus *Fusarium oxysporum* f. sp. *cucumerinum* are annually recorded on cucumber under open ground conditions [44, 130].

Thus, according to our data, fusarium wilt in various types of its expression (fig. 2.4), for the period from 2011 to 2013, was annually found in cucumber crops of open-ground (Table 2.1). The variability of indicators of the intensity of its expression on breeding cucumber samples in the open ground varied by year at the level of 0 to 10 % ($\bar{X}$ weighted average population indicator – 2.95 %), the indicator variability of the degree of plant lesion was by years from 0 to 9.8 % ($\bar{X}$ weighted average population indicator – 4.9 %) (Table 2.3).

Thus, the results of our research clearly showed that in the region of conducting research under open ground conditions on cucumber plants in recent years, the nature of the development and intensity of the main diseases spread is actively changing, in particular downy mildew – from moderate to strong, angular bacterial spot disease, anthracnose, powdery mildew – from moderate to depressive.

However, we would like to note separately that today fusarium wilt should be added to the zonal list of potentially dangerous diseases of cucumber of Gherkin type in the open ground.

All the above arguments allow us to draw a convincing conclusion that it is downy mildew that today annually occupies a dominant position in the zonal pathocomplex of open ground cucumber of the Left-Bank Forest-Steppe of Ukraine, which served as the main argument for choosing it as the main scientific object of our research.

2.2. The influence of hydrothermal conditions on the dynamics of downy mildew development of cucumber of Gherkin type under open ground conditions

Downy mildew belongs to a group of diseases, the fungi-like pathogen of which is characterized by high reproductive capacity and is able to form several generations with conidial sporulation on cucumber plants during the growing season [108, 110].

Under favorable weather conditions, which can ensure high aggressiveness of the infection and rapid acceleration of the development of several generations of the disease causative agent, the infectious process in field agrocenoses develops by the type of epiphytotia. Under unfavorable weather and climatic conditions, the pathological process of this disease can develop relatively slowly in the research region [53, 146, 148].

According to literature data [31, 61, 115, 141, 148], the main predictors that have the ability in a certain way to influence the development dynamics (depression, moderate, strong development, epiphytotia) of this cucumber disease when growing it under open ground conditions are weather factors such as air temperature, precipitation, the presence of drop-liquid moisture, lighting, etc.

Generalization of these data confirmed that the average daily air temperature of 15–22 °C and 8–32 °C in the presence of droplet moisture – is the most susceptible to germination of zoosporangia of this pathogen [51, 129].

Under optimal conditions, the coming out of zoospores from the zoosporangia of this fungi-like phytopathogen occurs in 1-4 hours. At air temperatures of 20 ... 25 °C, under condition of droplet moisture presence on the leaf surface for more than 4 hours under the field conditions, optimal conditions are formed for re-infection and rapid spread of this disease [53, 121].

Based on the studies results of the phytosanitary state of breeding cucumber crops under open ground conditions, we have determined the peculiarities of the influence of the main climatic factors on the process formation of seasonal dynamics of downy mildew development (fig. 2.8–2.10).

Studies have determined that downy mildew has the ability to develop and spread in field crop rotation in both wet and dry decades and months. The most favorable weather for the development of this disease was with a cool temperature regime at night and warm – in the daytime.

It was this combination that provided 4–8-hour moistening of the plants leaf apparatus and was optimal for the incubation period of the noted fungi-like organism.

Thus, the first signs of disease symptoms (the third decade of June – in 2011, 2013, the first decade of July – in 2012) (Table 2.2) were usually observed against the background of high solar insolation in the daytime, but in the presence of an obligatory change in hot and cool periods (dew point) [67].

At the same time, according to our research, first of all, the appearance of the first signs of plant lesion by downy mildew was preceded by a decrease in the average daily air temperature regime indicators in the previous decade.

For example, in 2011 – from 22.6 °C (second decade of June) to 20.6 °C (third decade of this month), in 2012 – from 22.2 °C (second decade of June) to 18.9 ^{0}C (third decade of June, respectively), in 2013 – from 24.7 °C (second decade of June) to 23 ^{0}C (third decade of this month, respectively) (table 2.2, fig. 2.8–2.10).

It was this, seemingly insignificant, decrease in the temperature regime in the zone of optimum for the germination of zoospores of the downy mildew pathogen that provided optimal conditions for rapid plants re-infection and the spread of the disease in field crop rotation.

In addition, the rapid spread of downy mildew was facilitated by the presence of 4-8-hour drip moisture on the surface of the plants leaf apparatus – water condensate, which was formed due to condensation of moisture from the air (evening and morning dew).

Optimal for intensive conidial sporulation and spread of the fungi-like organism *Pseudoperenospora cubensis* during the years of research was the hydrothermal regime, which was formed in the field crop rotation in the first and second decades of July (table 2.2).

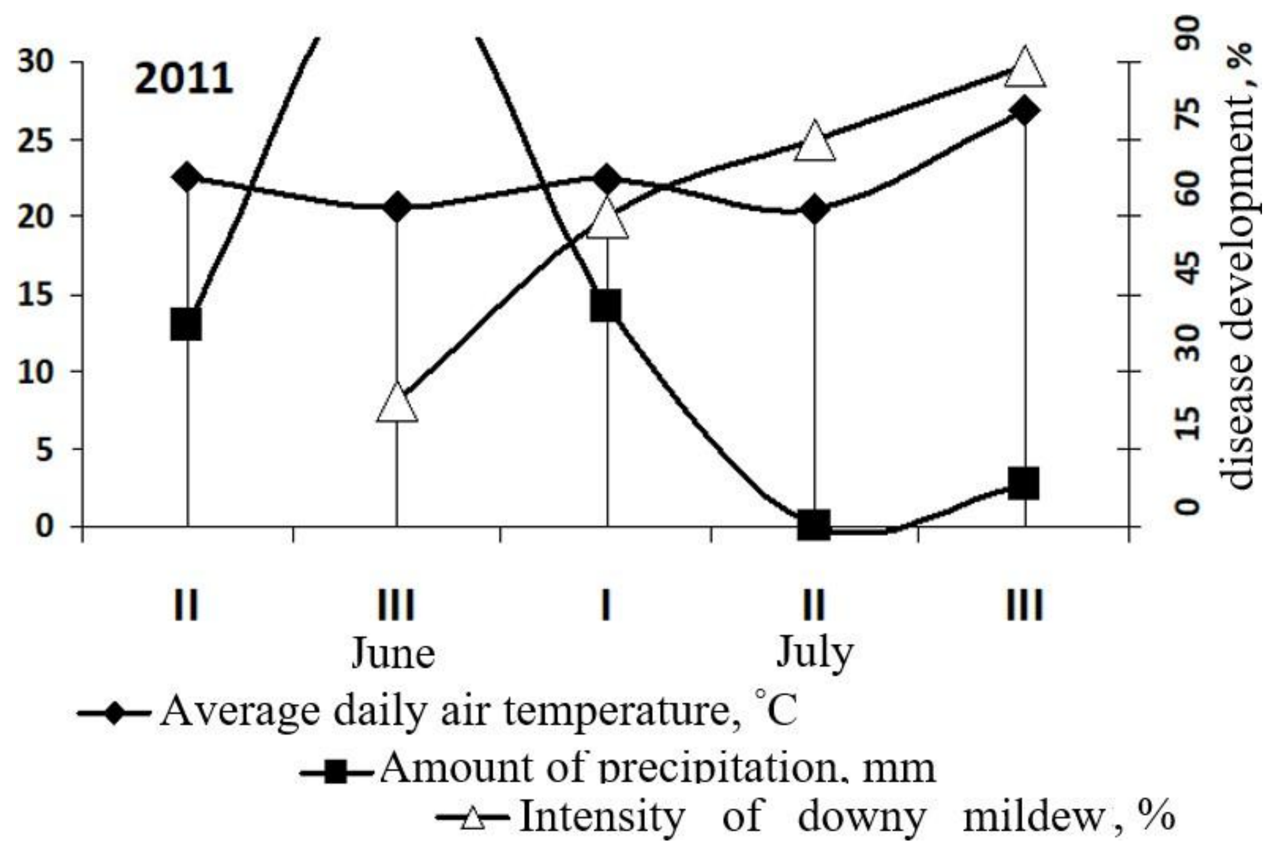


Fig. 2.8. Development of downy mildew of cucumber in the open ground depending on the weather conditions of the growing season of 2011

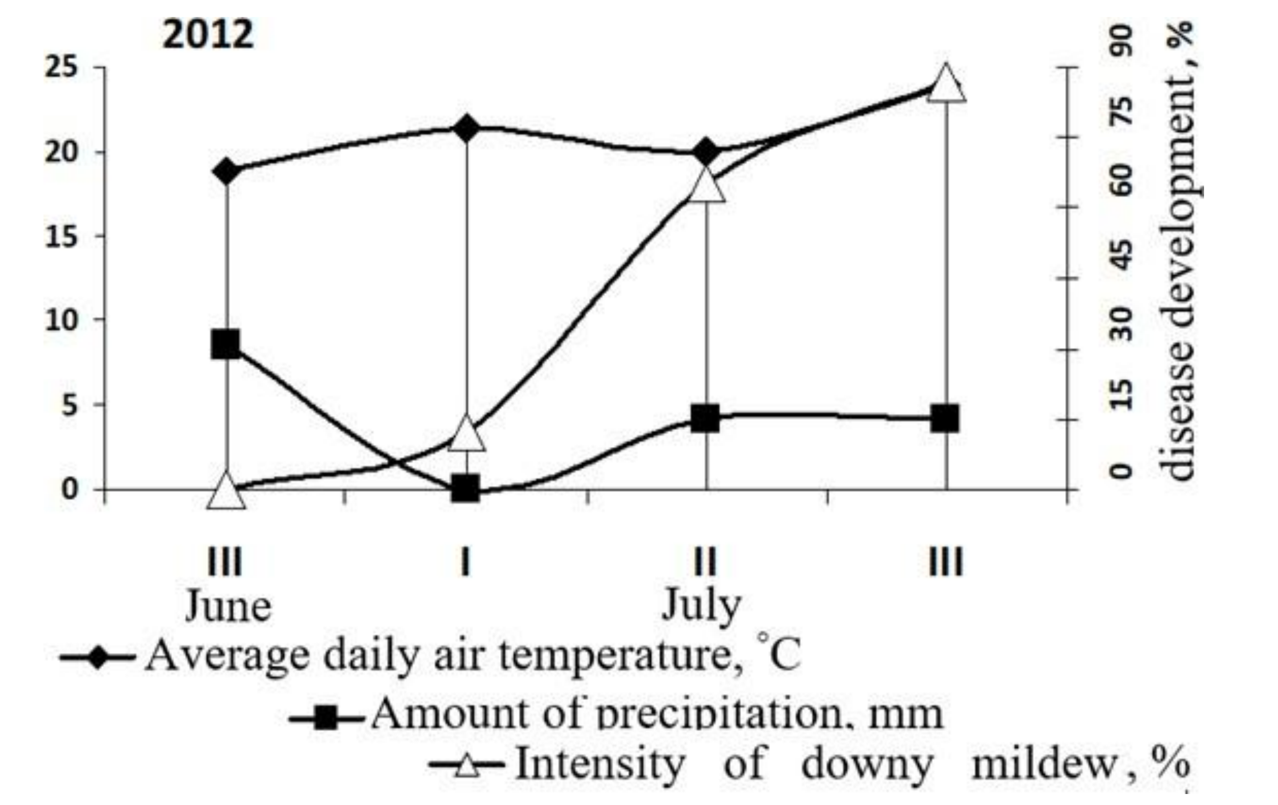


Fig. 2.9. Development of downy mildew of cucumber in the open ground depending on the weather conditions of the growing season of 2012

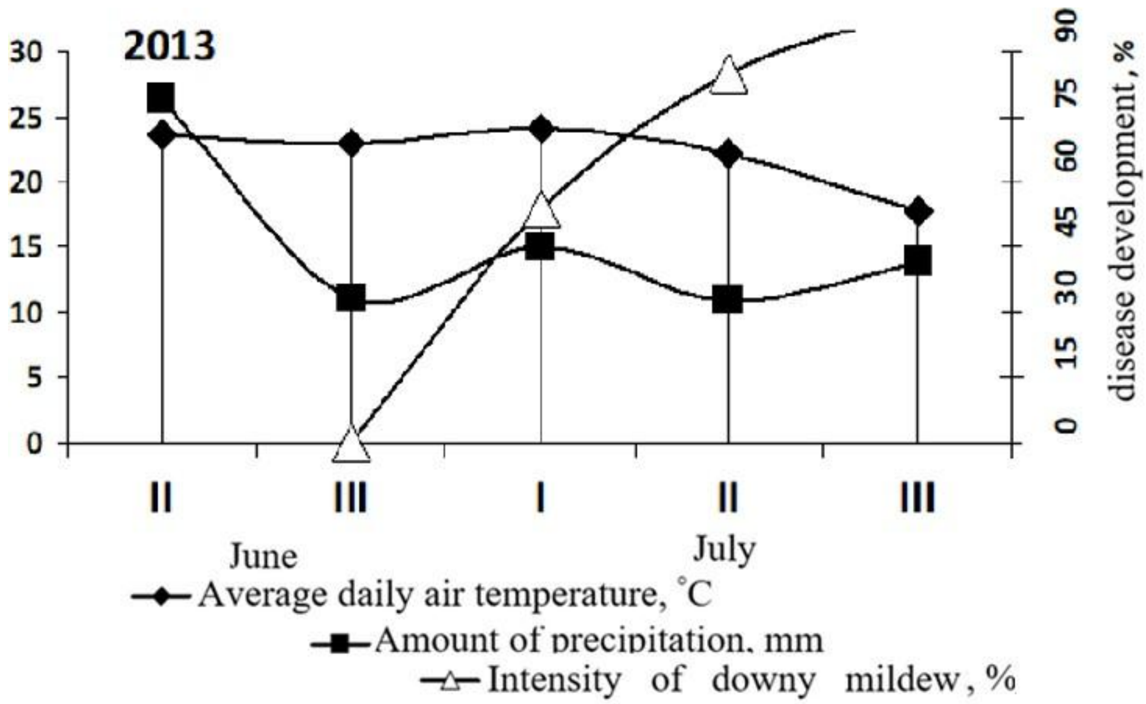


Fig. 2.10. Development of downy mildew of cucumber in the open ground depending on the weather conditions of the growing season of 2013

It was during these decades under the field conditions, in the years of research, the average daily air temperatures of 18.9–23.0 °C with a relative humidity at the level of 45–65 % provided the highest coefficients of reproduction and spread of the disease pathogen on cucumber samples of Gherkin type (Table 2.1, 2.3).

Conducted statistical analysis of data on the intensity of cucumber downy mildew spread (P, %) under the open ground conditions proved the this indicator (effective variable Y) over decades highly depends on the specificity of seasonal expression of various parameters of the air temperature regime (factorial variables X_1, X_3, X_4). Calculated by us the coefficients of determination ($D = r^2$) for all the given characteristics of pairs in addition affirm this (Table 2.4).

According to the coefficients indicators of this table, in all research years, we can clearly trace close, trustworthy correlation dependence between the decadal indicators of the development intensity (p, %) of the disease in cucumber agrocenosis (Y) and the values of decadal average daily air temperatures (X_1). This relation in all years of research was direct, close and trustworthy at 95 % level($r = 0.83 \ldots 0.94$).

The coefficient of determination (D) specially calculated for this pair by years showed that the total direct contribution of the factorial factor X_1 to the formation of seasonal dynamics of intensity of downy mildew development (effective factor Y) in cucumber agrocenoses of Gherkin type over years is from 69 to 88 % ($D \times 100$ %).

This means that the intensity of downy mildew development under the open ground conditions in the years of our research depended on 69–88 % on the direct forming effect of the average daily decadal values of air temperature on the course of the pathological process. At the same time, a residual indicator of 12–31 % indicates the participation of other, extraneous abiotic or other stressful factors in the formation of this process in field crop rotation.

We have found out that in the years of research, there was no trustworthy close interrelation between the indicators of the disease development intensity (Y) and the amount of precipitation (X_2) that fell over decades (r = - 0.54 … 0.60).

Conducted statistical analysis confirmed that the total contribution of the factorial parameter of decadal precipitation (X_2) to the overall regulation of intensity of downy mildew development (Y) in cucumber agrocenosis of Gherkin type in the years of research did not exceed values of 29–36 %.

It should be specifically noted that the obtained correlation coefficients between this pair of traits prove the fact that with an increase in the quantitative values of the parameter X_2, the increase in the values of the parameter Y annualy falls under slight but still influence.

It should be mentioned that earlier we have already stated (see sections 1 and 2) that the first characteristic visual symptoms of lesion and further spread of this disease in cucumber agrocenoses of Gherkin type (fig. 1.3) annually coincided with the end of the period of consistently warm weather both day and night.

This fact is statistically confirmed by the correlation coefficients calculated by us in the years of research between the indicators of the intensity of disease development (Y) and decadal fluctuations of the maximum (X_3) and minimum (X_4) values of the temperature regime, relative humidity (X_6), which were formed in the agrocenoses of the studying vegetable plant, starting from the end of June-July.

Thus, according to the factorial indicator (X_3), the correlation coefficients calculated by us with the indicator Y were inverse and close. It follows that with a decrease in the decadal maximum values of the variable X_3 at the end of June-July, there was a proportional increase in the effective value of the variable Y (r = - 0.88…0.98). The direct contribution of this factor to the seasonal process of forming the intensity of downy mildew development and spread was from 77 to 96 % in the years of research.

In contrast, according to the second temperature factorial indicator of decadal minimum air temperatures (X_4), over the years the decrease in its values directly and closely correlated (r = 0.83…0.99) with the growth intensity of the effective variable (Y) the rate of downy mildew spread in field crop rotation.

Table 2.4

Statistical assessment of the dependence of downy mildew development intensity (Y) on hydrothermal parameters (X*i*) of cucumber plants growing season

Hydrothermal indicators (according to the weather post of the Institute of Vegetables and Melons growing of NAAS)	X*i*	Correlation (r) and determination (D) coefficients between X*i* -Y pairs					
		2011		2012		2013	
		r	D	r	D	r	D
Decadal average daily air temperature, ^{0}C	X_1 *	0,83	0,69	0,94	0,88	0,85	0,72
Amount of precipitation per decade, mm	X_2	-0,60	0,36	-0,56	0,31	-0,54	0,29
Decadal maximum air temperature, ^{0}C	X_3 *	-0,88	0,77	-0,92	0,85	-0,98	0,96
Decadal minimum air temperature, ^{0}C	X_4 *	0,83	0,69	0,87	0,7	0,99	0,98
Decadal minimum soil surface temperature, ^{0}C	X_5	0,29	0,08	0,06	0,001	0,21	0,04
Relative air humidity, %	X_6 *	-0,88	0,77	-0,87	0,76	-0,97	0,94
Theoretically calculated “dew point”, ^{0}C [67]	X_7 *	-0,90	0,81	-0,90	0,81	-0,86	0,74
*r_{min} at the 5 percent level = 0,811 [69]							

However, any interrelation between the intensity of disease development (Y) and the variability of the values of decadal minimum soil surface temperatures (X_5) over the years of research could not be determined.

Correlation analysis of the direction and closeness of the interrelation between the factorial factor X_6 (decadal values of air humidity, %) and the effective factor Y (intensity of downy mildew development, %) determined that there was an inverse, close and trustworthy relation (r = -0.87 … 0.97) between this pair of traits in all years of research. The direct contribution of this factor to the seasonal formation of the pathological process of open ground cucumber was 76-94% by year, respectively.

At the same time, we have established a close inverse effect of decadal values of relative humidity (factor X_6) on the intensity of downy mildew prevalence (Y). The Pearson linear correlation coefficients determined by us [35] through this pair of traits over the years of research were constantly inverse, trustworthy close and were in the range of values from -0.87 to -0.97. The direct influence of this factor on the formation of the seasonal process of downy mildew course was 76-94% over the years.

The obtained data serve as a sufficient basis for the conclusion that at the end of June – July, it is a specific complex combination of maximum values of air temperature during the day (factor X_3) and reducing it to minimum values at night (factor X_4), against the background of variability in air humidity indicators (factor X_6), causes active condensation of moisture from the air with the formation of a drop-liquid coating or dew on the leaf apparatus of cucumber plants (factor X_7).

In our opinion, exactly these factors were the main unifying “starting” factors for the germination of zoospores, plant infection and further active spread of this disease on cucumber plants of Gherkin type in field crop rotation under conditions of the Left-Bank Forest-Steppe of Ukraine in the research region (Table 2.2).

The results of our research showed that under conditions of the region, such a specific temperature regime in agrocenoses usually occurred at the end of June – July, which coincided with the critical ontogenesis phase of Gherkin type cucumber of open ground – the period of mass plants fruiting.

So, in the first decade of July 2011 (the beginning of the disease mass spread in crop rotation), the maximum decadal air temperature was 30 °C with a relative humidity of 65 % per decade. The calculated dew point was 22.7 °C [67], while the minimum air temperature in this decade ranged from 15 °C (fig. 2.11, Table 2.2, Table 2.5).

This confirms that with a decrease in the maximum air temperatures at night to 22.7 °C, an active process of moisture condensation from the air (HB,%) to the surface of the plants leaf apparatus begins. This process of moisture condensation on the leaf apparatus continues until the air temperature factor reaches the minimum value (15 °C). At the same time, it was found out that the higher the air humidity indicator was, the higher and closer the "dew point" is to the maximum temperature factor [67].

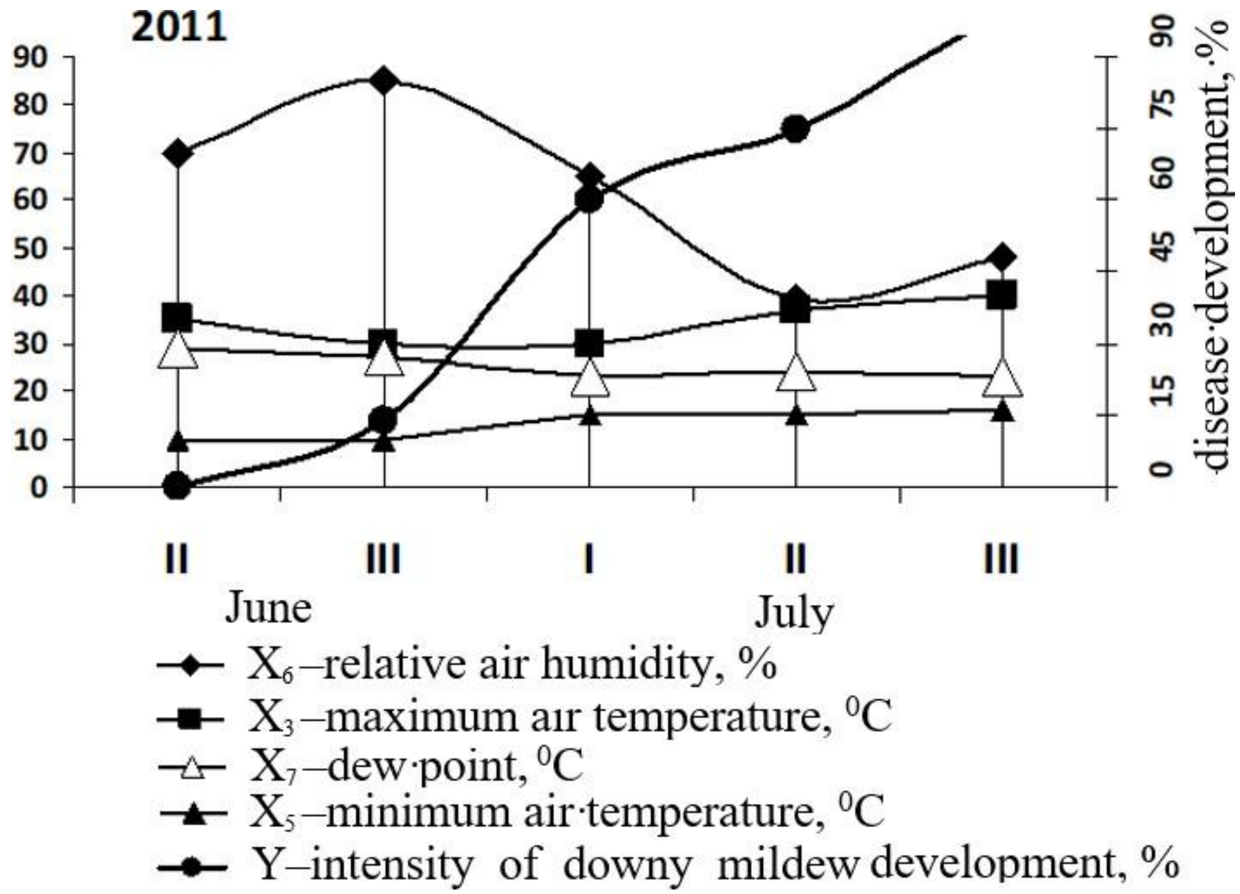


Fig. 2.11. Graphic representation of factorial factors contribution to the formation process of the intensity of downy mildew development and spread in cucumber agrocenosis in 2011

In our case, the greater the absolute difference between the factorial factors X_7 (calculated dew point, °C) and X_5 (value of the minimum decadal air temperature, °C), against the background of decadal values of the air humidity indicator (X_6), the longer the time period of the presence of drop-liquid moisture (dew) on the surface of the leaf apparatus was. This is what served as the main integral regulating factor for infection and spread of the studying phytopathogenic organism (Y) in field agrocenosis in all years of research.

The mass spread of downy mildew in the field crop rotation in 2012 occurred in the second decade of July. The maximum air temperature in this decade was 37 ^{0}C, the relative air humidity was 45 %. The calculated dew point was 24 ^{0}C [67]. At the same time, the average decadal value of the minimum air temperature was within 9 ^{0}C (fig. 2.12, Table 2.2, 2.5).

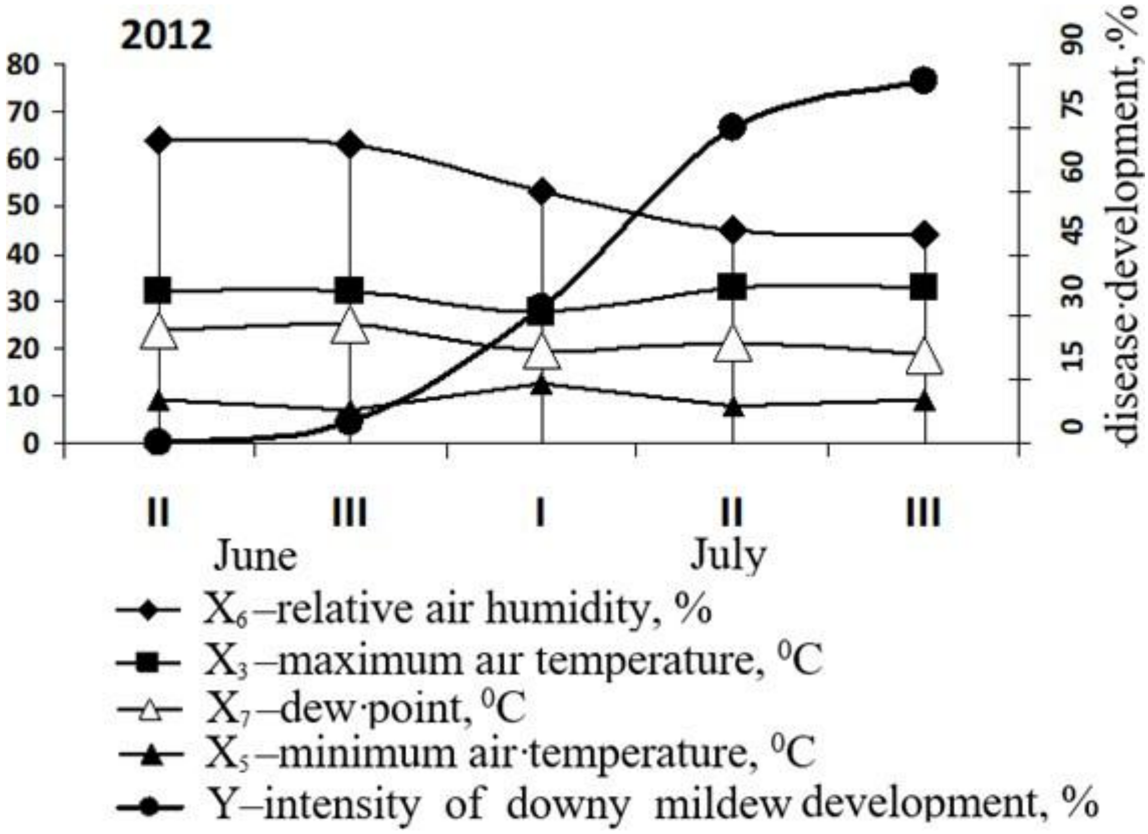


Fig. 2.12. Graphic representation of factorial factors contribution to the formation process of the intensity of downy mildew development and spread in cucumber agrocenosis in 2012

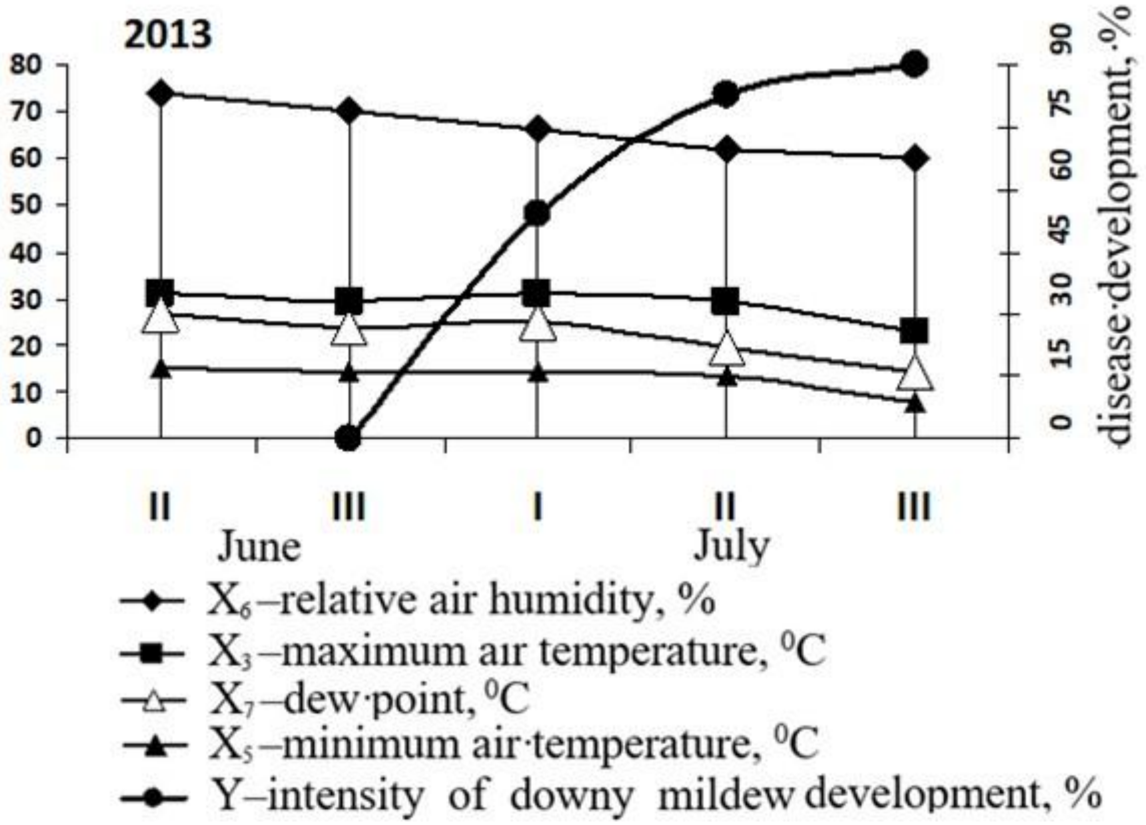


Fig. 2.13. Graphic representation of factorial factors contribution to the formation process of the intensity of downy mildew development and spread in cucumber agrocenosis in 2013

Table 2.5

Decadal characteristics of the hydrothermal regime that was formed in the field crop rotation of open ground cucumber from the beginning of fixing the first lesion symptoms to the mass spread of downy mildew

Years / Decades	Hydrothermal indicator																	
	Decadal average daily air temperature, ^0C			Amount of precipitation per decade, mm			Decadal maximum air temperature, ^0C			Decadal minimum air temperature, ^0C			Relative air humidity, %			Theoretically Calculated "dew point", ^0C [67]		
	X_1			X_2			X_3			X_5			X_6			X_7		
	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013	2011	2012	2013
June II decade	22,6	22,2	24,7	12,5	0,0	26,8	35,0	36,0	35,0	10,0	10,0	17,0	70,0	64,0	74,0	28,7	27,1	29,7
June III decade	20,6	18,9	23,0	71,5	8,5	13,5	30,0	36,0	33,0	10,0	8,0	16,0	85,0	63,0	70,0	27,2	27,8	26,8
July I decade	22,4	21,4	24,2	15,5	0,0	15,9	30,0	31,0	35,0	15,0	13,5	16,0	65,0	53,0	66,0	22,7	22,3	27,7
July II decade	26,4	20,0	22,2	0,0	3,5	13,3	37,0	37,0	33,0	13,5	9,0	15,0	39,0	45,0	62,0	24,1	24,1	21,7
July III decade	26,9	23,9	17,7	1,5	2,2	16,1	40,0	37,0	26,0	15,5	10,0	9,0	48,0	44,0	60,0	23,4	20,7	15,6

In 2013, mass development and re-infection of cucumber plants in the field crop rotation occurred in the first decade of July. The maximum decadal air temperature was 35 ^{0}C, relative air humidity – 66 %. The calculated dew point is 28 ^{0}C [67]. The decadal values of the minimum air temperature in this span of time had an average value of 16 ^{0}C. (fig. 2.13, see table 2.2). These results are confirmed by the analysis of the classical phytopathological literature in this area of research [38, 87, 107-109, 119, 139].

So, obtained by us the experimental data reasonably confirm that when during the growing season of open ground cucumber in the phase of plants mass fruiting (critical phase of ontogenesis), a specific temperature regime is established with a sharp fluctuation of maximum and minimum air temperatures, moisture from the air actively condenses on the surface of the leaf apparatus in the form of a water layer (dew), which creates ideal conditions for the zoospores germination of the downy mildew causative agent, namely rapid infection and re-infection of plants.

3. IMMUNOLOGICAL CHARACTERISTIC OF THE BREEDING MATERIAL OF CUCUMBER OF GHERKIN TYPE BY RESISTANCE TO DOWNY MILDEW

It is generally known that the success of breeding of Gherkin type cucumbers for disease resistance is largely determined by the presence of resistant initial material of both collection and breeding origin in crossbreeding schemes [20, 29, 42].

For this purpose, it is primarily recommended to work with the most polymorphic plant populations for purposeful multiple selection of genotypes with better combinative combinations of genes and gene complexes of various economic traits, including resistance traits to the main diseases [25, 83, 89, 123].

Thus, V.L. Nalobova in her monograph “Cucumber breeding for diseases resistance” [60] notes one of the main conclusions that taking into account the formation peculiarities of the structure of natural populations of certain phytopathogens types in cucumber agrocenoses, breeding for the resistance of this vegetable crop to downy mildew should be carried out on a protracted (polygenic, race-nonspecific, horizontal) type. At the same time, the author emphasizes that this type of sustainability will allow scientists to conduct 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 [7, 26, 110].

So, at present, a comprehensive assessment of breeding (in a broad aspect) 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 a resistant initial material of Gherkin type cucumber is extremely relevant and priority for domestic agricultural science [81, 92].

3.1. Immunological characteristics of cucumber breeding material by the resistance to downy mildew

When conducting research in this area, we used recommendations on how to work more effectively with a complex of small or minor genes (polygenic blocks) of cucumber resistance to downy mildew in order to concentrate them as much as possible in the genotypes newly created by a breeder [39, 40].

In addition, it should be separately noted that today only a close tandem “immunologist-breeder” is able to most effectively study the breeding material for a complex of basic, valuable and economic characteristics of a variety or hybrid for the future user, conduct multiple mass selections and obtain valuable initial material. It is under this scheme that breeders are guaranteed the fastest (in two-four years) effect of increasing the concentration of a complex of small resistance genes (polygenes) and other traits in the selected cucumber plant populations [39, 89].

By such a scheme of the breeding process of creating a new resistant initial material, it is recommended to necessarily involve local aboriginal varieties and hybrids that were created against the background of constant annual crops lesion in cross-breeding. It also allows you to effectively optimize the effectiveness of cucumber breeding process for protracted genetic resistance to downy mildew [74, 126, 145].

Along with this, experimental studies have earlier determined the presence of a very close (r = 0.97) correlation relation between the lesion degree (R, %) of cucumber plants by downy mildew in the cotyledon leaf phase during artificial infection (*classical, but resource-intensive method*) with this indicator, but under conditions of a natural infectious background [60, 62].

In addition, it is emphasized that the differentiation of cucumber samples by resistance to downy mildew should be carried out only under conditions of gradually increasing tension of the natural infectious background, due to the fact that all artificially created cucumber samples known today have not genetically acquired the ability to withstand the high infectious load of this disease for a long time yet [57, 62, 98].

Cucumber breeding material received a basic assessment of the level of protracted genetic resistance to downy mildew by years at the end of the first decade of the mass fruiting plants phase. It was during this period of ontogenesis that the lesion degree of the collection sample Nizhynsky local (Ukraine) of susceptibility standard to downy mildew exceeded the values of 50–70 % over the years of research (resistance score1 by the REV scale) (Table 3.1–3.3).

At the same time, the lesion degree by downy mildew of collection samples – resistance standards Dzherelo (Ukraine), Phoenix 640 (Russia), Ajax F_1 (Netherlands), during this period did not exceed the mark of 20–34 % over the years (resistance scores 7, 5).

For the purpose of puporseful rejection from the breeding process of susceptible and highly susceptible forms to downy mildew, all the breeding material of Gherkin type cucumber of the collection, hybrid (breeding) nursery gardens, as well as linear and initial material nursery gardens was involved in immunological screening (Table 3.1–3.3).

Table 3.1

Reaction of *Cucumis sativus* L. genotypes to the intensity of downy mildew lesion under open ground conditions, 2011

Scales of assessment		number	Original name of the sample
of resistance	of lesion degree		
score	%	pieces	
9	0	0	there is no
7	0,1–10	20	**F1 Ajax – standard, Dzherelo – standard, Phoenix 640 – standard,** F_3I_2 (F_1 Patriarh x F_3I_2 D96a№2-96), F_1 (F_3I_3 Fansipak x F_4I_1 Solovey), F_3I_2 (F_1 Ivolga x F_3I_3 D96a№2-95), F_4I_2 Semkross, F_4I_2 Semkross, F_4I_1 Semkross, F_4I_2 Krak, F_5 (F_2 Regina x F_1 Mazaj), F_5 (F_2 Regina x F_1 Mazaj), F_5I_1 (F_2 Regina x F_1 Mazaj), F_5I_2 (F_1 Maliia x Geim), F_5I_1 Hermes Skernevytsky, F_5I_3 (F_1 Romans x F_3I_3 D96a№2-95), F_6I_1 Zasoliuvalny, F_6I_1 Zasoliuvalny, F_1 (Nizhynsky local x Era), F_1 (Nizhynsky 12 x Nosivsky).
5	10,1–35	44	F_1 Samorodok, F_3I_1 Nastoyashchij polkovnik, F_7I_4 Kozyrnaia karta, F_4I_3 Danila, F_4I_3Muravej, F_5I_2Amur, F_5I_2 Yemelia, F_6I_3 Gepard, F_6I_4 Polina, F_6I_3 Podmoskovnye vechera, F_1I_1Gerkin, F_3I_2 (F_1 Buyan x F_3I_3 D96a№2-96), F_5I_2 (F_1 Aurach x F_3I_3 D96a№2-95), F_5I_3 (F_1 Fortuna x F_3I_3 D96a№2-95), F_1 (F_3I_2 Fansipak x F_3I_1 line P-1), F_1 (F_5I_1 Donia x line 23162 D96a№2-95), F_1 (Gerkin x bush cucumber), F_3I_1 (F_1 Ivolga x F_3 D96a№2-95), F_3I_1 (F_1 Ivolga x F_3 D96a№2-95), F_3I_1 Yulian, F_4I_2 (F_1 Mastak x F_3I_3 D96a№2-95), F_4I_1 Prestige, F_4I_2 Krak, F_4 Pervyj klass, F_4 Tsygan, F_4I_2 Tsygan, F_4 (F_1 Finist x Phoenix), F_4 (F_1 Phoenix x Finist), F_3I_3 Odocheck, F_5 (F_2 Regina xMazaj), F_5I_2 Potomak, F_5I_2 (F_1 Maliia x Geim), F_5I_2 (F_1 Maliia x Geim), F_5I_3 Syn polka, F_5I_3 Syn polka, F_6I_2 Zasoliuvalny, F_1 Etap, F_2I_1 (Geim x Nizhynsky 12), F_2I_1 (Dzherelo x Nizhynsky 12), F_2 (Era x Geim), F_2 (Era x Geim), F_2I_1 (Era x Nizhynsky 12), F_1 (Geim x Nizhynsky local), F_1 (Nosivsky x Nizhynsky Local).

Table 3.1 (continuation)

Scales of assessment		number	Original name of the sample
of resistance	of lesion degree		
score	%	pieces	
3	35,1–50	42	F_4Izyd, F_6I_9Chistyie prudy, F_3I_2 Denek, F_4I_1 (F_1 Denek x F_3I_3 D96a№2-95), F_1 (F_4I_1 line P-1 x F_3I_3 D96a№2-95), F_1 (F_8I_3 Donia x F_1I_1 Dzherelo), F_1 (F_8I_3 Donia x F_5I_1 Solovey), F_1 (F_5I_3 Ametyst x F_4I_1 Solovey), F_1 (Gerkin x bush cucumber), F_1 (Gerkin x bush cucumber), F_1 (Gerkin x bush cucumber), F_1 (Gerkin x bush cucumber), F_1I_1 Melnitsa, F_1I_1 Melnitsa, F_2I_2 Bush cucumber, F_3 (F_1 Sultan x F_3I_3 D96a№2-95), F_4I_3 Krak, F_4 Pervyj klass, F_4I_2 Tsygan, F_4I_1 Tsygan F_4 (F_1 Romans x F_3I_3 D96a№2-95), F_4 (F_1 Romans x F_3I_3 D96a№2-95), F_4I_1 (F_1 Romans x F_3I_3 D96a№2-95), F_3I_3 Odochek, F_6I_3 (F_1 Masha x Geim), F_1 Etap, F_2I_1 (Nizhynsky 12 x 2316D96a№2-3), F_2I_1 (Geim x Nizhynsky 12), F_2I_1 (Dzherelo x Nizhynsky local), F_2 (Era x Geim), F_2 (Staya x Nizhynsky 12), F_1 (Geim x Nizhynsky local), F_1 (Geim x Era), F_1 (Era x Nizhynsky local), F_1 (Nizhynsky local x Era), F_1 (Nosivsky x Geim), F_1 (Nosivsky x F_3I_3 D96a№2-96), F_1 (Nosivsky x Nizhynsky 12), F_1 (Nizhynsky x line 2316D96a№2-3), F_1 (Nizhynsky local x Etap), F_1 (Nizhynsky 12 x line 2316D96a№2-3), Melkij, Unknown hybrid, Unknown hybrid.
1	50,1–100	46	**Nizhynsky local – standart,** F_4I_2 Odogs, F_4I_1 Zhelud, F_4I_1 Regina plus, F_5I_1 Kuznechik, F_5I_3 Syn polka, F_3 (Amur x Geim), F_4I_2 (F_1 Mar'ina roshcha x F_3I_3 D96a№2-95), F_1 (Gerkin x bush cucumber), F_2 Hrustyashchij, F_1 Gomes, F_2 Gomes, F_2I_1 Bush cucumber, F_2I_1 Bush cucumber, F_2I_2 Bush cucumber, F_2I_2 Bush cucumber, F_2I_2 Bush cucumber, F_1I_1 Bush cucumber from Russia, F_1 Bush cucumber from Russia F_3I_2 Finist, F_3I_1 Finist, F_3I_1 Finist, F_3 Tomast, F_1 Filippok, F_2 Filippok, F_2I_1 Filippok, F_3I_1 Filippok, F_3I_2 Filippok, F_3 Filippok, F_3 Yulian, F_3 Yulian,

Table 3.1 (continuation)

Scales of assessment		number	Original name of the sample
of resistance	of lesion degree		
score	%	pieces	
1	50,1–100		F_3 Yulian, F_3 (F_1 Sultan x F_3I_3 D96a№2-95), F_5I_1 Tsezar, F_6I_2 Tsezar, F_2 (Dzherelo x Nizhynsky local), F_2I_1 (Dzherelo x Nizhynsky 12), F_2 (Staya x Nizhynsky 12), F_1 (Era x Nizhynsky local), F_1 (Era x Nizhynsky local), F_1 (Era x Nizhynsky local), F_1 (Era x Dzherelo), F_1 (Nosivsky x F_1I_1 Dzherelo), F_1 (Nizhynsky 12 x F_1I_1 Dzherelo), Unknown hybrid, F_8I_5 Kozyrnaya karta, F_1 (Buyan F_1 x Bush cucumber).

Thus, an immunological characteristic of the reaction level of protracted genetic resistance to downy mildew in the open ground at the end of the first decade of the mass fruiting phase was obtained in 2011 by 152 cucumber breeding samples, in 2012 – 110 samples, in 2013 – 69 breeding samples. So, in total, for the entire period of research under conditions of a natural infectious background, we determined the level of resistance to downy mildew of 331 breeding samples.

As noted above, the lesion degree (R) of cucumber samples by downy mildew under open ground conditions as of early-mid – July ranged in the general totality at the level of 2.5 to 75 %, and the intensity of the disease spread (P) – from 24 to 100 % (Table 3.3).

Thus, as of the end of the first or second decade of July, we did not find very highly resistant breeding samples of Gherkin type cucumber (score 9 of the immunological scale) to downy mildew under open ground conditions during the years of research (Table 3.4).

Field resistance at the level of 7 scores to this disease in 2011 was found in 20 cucumber samples (13 %) from the general totality (collection, hybrid material, multiple self-pollination – lines of different generations), namely: F1 Ajax (standard), Dzherelo (Standard), Phoenix 640 (standard), F_3I_2 (F_1 Patriarh x F_3I_2 D96a№2-96), F_1 (F_3I_3 Fansipak x F_4I_1 Solovey), F_3I_2 (F_1 Ivolga x F_3 D96a№2-95), F_4I_3 Semkross, F_4I_2 Semkross, F_4I_1 Semkross, F_4I_2 Krak, F_5 (F_2 Regina x F_1 Mazaj), F_5 (F_2 Regina x F_1 Mazaj), F_5I_1 (F_2 Regina x F_1 Mazaj), F_5I_2 (F_1 Maliia X Geim), F_5I_1 Hermes Skernevytsky, F_5I_3 (F_1 Romans x F_3I_3 D96a№2-95), F_6I_1 Zasoliuvalny, F_6I_1 Zasoliuvalny, F_1 (Nizhynsky Local x Era) and F_1 (Nizhynsky 12 x Nosivsky) (Table 3.1).

Table 3.2

Reaction of *Cucumis sativus* L. genotypes to the intensity of downy mildew lesion under open ground conditions, 2012

Scales of assessment		number	Original name of the sample
of resistance	of lesion degree		
score	%	pieces	
9	0	0	There is no
7	0,1–10	28	**F1 Ajax – standard, Dzherelo – standard, Phoenix 640 – standard,** F_7I_5 Chistyie prudy, F_8I_2 Begio 1802, F_9I_2 Fansipak, F_4I_2 Nastoyashchij polkovnik, F_5I_3 Odys, F_6I_3 Amur, F_5I_2 Mirabell, F_5I_3 (F_1 Mar'ina roshcha x F_3I_3 D96a№2-95), F_3I_3 (F_1 Fortuna x F_3I_3 D96a№2-95), F_7I_4 Podmoskovnye vechera, F_1 Zhelud, F_5I_2 (F_1 Denek x F_3I_3 D96a№2-95), F_5 Izyd, F_3I_1 Pavlik, F_5I_3 Krak, F_4I_1 Semkross, F_4I_3 Danila, F_4I_3 (F_1 Ivolga x F_3I_3 D96a№2-95), F_2 Rufus, F_6I_4 Syn polka, F_7I_2 Emelya, F_7I_2 Emelya, F_5I_1 (F_1 Denek x F_3I_3 D96a№2-95), F_3I_1 Pavlik, F_5I_4 Krak
5	10,1–35	68	F_1 Samorodok, F_5I_2 Zhelud, F_5I_1 Romans, F_7I_2 Polina, F_5I_2 Mirabell, F_5I_2 Mirabell, F_6I_1 (F_1 bee pollinating cucumber x F_3I_3 D96a№2-95), F_8I_5 Kozyrnaya karta, F_4I_1 (F_1 Saltan x F_3I_3 D96a№2-95), F_6I_2 Tsezar, F_2I_1 Rufus, F_2 Rufus, F_2 Tytus, F_2I_1 Gector, F_2 Gerkin, F_2 Gerkin, F_2I_1 Gerkin, F_4I_1 Nastoyashchij polkovnik, F_5I_3 Odys, F_5I_2 Odys, F_5I_3 Regina plus, F_5I_1 Regina plus, F_7I_4 Chistyie prudy, F_7I_3 Chistyie prudy, F_7I_3 Chistyie prudy, F_7I_2 Емеля, F_7I_2 Emelya, F_7I_6 Polina, F_7I_4 Podmoskovnye vechera, F_7I_4 Podmoskovnye vechera, F_5I_1 (F_1 Denek x F_3I_3 D96a№2-95), F_5I_1 (F_1 Denek x F_3I_3 D96a№2-95), F_5I_1 Pervyj klass, F_5 Pervyj klass, F_5 Pervyj klass, F_5I_2 (F_1 Romans x F_3I_3 D96a№2-95), F_6I_5 (F_1 Romans x F_3I_3 D96a№2-95), F_6I_4 (F_1 Romans x F_3I_3 D96a№2-95), F_5I_3 Semkross, F_5I_2 Semkross, F_3I_2 Pavlik, F_3I_1 Hrustyashchij, F_3I_1 Hrustyashchij, F_3I_1 Hrustyashchij.

Table 3.2 (continuation)

Scales of assessment		number	Original name of the sample
of resistance	of lesion degree		
scores	%	pieces	
9	0	0	
5	10,1–35		F_3I_2 Bush cucumber, F_4I_2 (F_1 Ivolga x F_3I_3 D96a№2-95), F_4I_3 Finist, F_4I_2 Finist, F_4I_2 Yulian, F_4I_1 (F_1 Saltan x F_3I_3 D96a№2-95), F_4I_1 (F_1 Saltan x F_3I_3 D96a№2-95), F_4I_1 (F_1 Saltan x F_3I_3 D96a№2-95), F_4I_2 Mestnyj, F_4I_2 Mestnyj, F_4I_1 Mestnyj, F_4I_1 (F_1 Mastan x F_3I_3 D96a№2-95), F_5 (F_1 Finist x Phoenix), F_5I_2 Yanus, F_5I_2 Yanus, F_6 (F_2 Regina x F_1 Mazaj), F_4I_1 Potomak, F_4I_1 Potomak, F_6I_3 (F_1 Masha x Geim), F_6I_2 Tsezar, F_7I_4 (F_1 Masha x Geim), F_7I_4 (F_1 Masha x Geim), F_7I_3 (F_1 Masha x Geim), F_7I_2 Zasolochnyj, F_7I_2 Zasolochnyj.
3	35,1–50	13	F_9I_7 Ajax, F_2I_1 Gector, F_5I_2 Mazaj, F_5I_1 Regina plus, F_7I_5 Polina, F_8I_6 Kozyrnaya karta, F_3I_1 Pavlik, F_6I_2 Tsezar, F_3I_2 Bush cucumber, F_3I_2 Bush cucumber, F_3 Tomast, F_5 (F_1 Finist x Phoenix), F_5I_1 Yanus.
1	50,1–100	1	**Nizhynsky local – standard**

Table 3.3

Reaction of *Cucumis sativus* L. genotypes to the intensity of downy mildew lesion under open ground conditions, 2013

Scales of assessment		Number	Original name of the sample
of resistance	of lesion degree		
score	%	pieces	
9	0	0	There is no
7	0,1–10	15	**Phoenix 640 – standard, Dzherelo – standard,** F_5I_2 (F_1 Bee pollinating cucumber x F_3I_3 96a№2-95), F_6I_3 (F_1 Denek x F_3I_3 96a№2-95), F_4I_1 (F_1 Saltan x F_3I_3 96a№2-95), F_3I_2 Pavlik, F_6I_5 Krak, F_6I_3 Semkross, F_5I_4 (F_1 Ivolga x F_3I_3 96a№2-95), F_7I_2 Tsezar, F_3I_3 Patriarh, F_1 (F_8I_4 Kozyrnaya karta x Dzherelo), F_6I_2 (F_1 Bee pollinating cucumber x F_3I_3 96a№2-95), F_1{F_6I_3 (F1 Fortuna x F3I3 96a№2-95)} x Dzherelo, Geim.

Table 3.3 (continuation)

Scales of assessment		number	Original name of the sample
of resistance	of lesion degree		
score	%	pieces	
9	0	0	
5	10,1–35	27	**F1 Ajax – standard,** F_9I_6 Bejio 1802, $F_{10}I_6$ Fansipak, F_2I_1 Rufus, F_3I_2 Gektar, F_6I_3 Odys, F_6I_2 Mirabella, F_6I_4 (F_1 Mar'ina roshcha x F_3I_3 96a№2-95), F_8I_4 Patriarh, F_9I_5 Kozyrnaya karta, F_6 Izyd, F_5I_3 Danila, F_7I_3 Potomak, F_1 (F_5I_3 Odys x Dzherelo), F_1 {F_6I_2 (F_1 Bee pollinating cucumber x F_3I_3 96a№2-95)} x Dzherelo, F_1 (F5I4 Krak x Dzherelo), F_5I_4 Krak, F_1 (F_6I_3 Potomak x Dzherelo), F_1 {F_6I_3 (F_1 Fortuna x F_3I_3 96a№2-95) x Geim}, F_1 (F_5I_4 Krak x Geim), F_4I_3 (F_1 Ivolga x Geim x F_3I_3 96a№2-95), F_1 {F_5I_1 (F_1 Romans x 57787 x F_3I_3 96a№2-95) x Phoenix 640}, F_1 (F_5I_4 Krak x Phoenix 640), F_1 {F_4I_3 (F_1 Ivolga x F_3I_3 96a№2-95) x Phoenix 640}, F_1 (F_6I_2 Tsezar x Phoenix 640), F_6I_3 Potomak, F_1 {F_6I_3 (F_1 Masha x Geim) x Phoenix 640}, F_1 (F_5I_2 Zhelud x F_8I_2 Bejio 1802).
3	35,1–50	20	F_5I_3 Zhelud, F_6I_2 (F_1 Romans x F_3I_3 Д-96№2-95), F_8I_6 Ajax, F_5I_5 Polina, F_3I_2 Tytus, F_5I_2 Mirabella, F_6I_3 (F_1 Fortuna x F_3I_3 96a№2-95), F_8I_5 Patriarh, F_7I_3 (F_1 Masha x Geim), F_5I_3 Odys, F_6I_3 Potomak, F_1 {F_6I_3 (F_1 Masha x Geim) x Dzherelo, F_6I_3 (F_1 Masha x Geim),
3	35,1–50		F_1 (F_5I_2 Zhelud x Phoenix 640), F_1 {F_6I_3 (F_1 Fortuna x F_3I_3 96a№2-95) x Phoenix 640}, F_8I_2 Bejio 1802, F_5I_5 Bejio 1802, F_9I_5 Fansipak, F_1 (F_7I_5 Ajax x F_9I_5 Fansipak), F_7I_5 Ajax.
1	50,1–100	7	**Nizhynsky local – standard,** F_8I_7 Kozyrnaya karta, F_1 (F_5 Izyd x Phoenix), F_5 Izyd, F_5I_2 Zhelud, F_6I_2 Tsezar, F_1 (F_6I_3 Potomak x Phoenix 640).

Table 3.4

Distribution of the general totality of breeding material of Gherkin type cucumber by the level of resistance to downy mildew (natural infectious background, end of the first decade of mass fruiting)

Year	Unit of measurement	Immunological group			In total
		Resistant	Medium-resistant	Susceptible	
	scores	7	5	3–1	
	%	0,1–10	10,1–35	35,1–100	
2011	pieces	20	44	88	152
	%	13	29	58	100
2012	pieces	28	68	14	110
	%	25	62	13	100
2013	pieces	15	27	27	69
	%	22	39	39	100
In total	pieces	**63**	**139**	**129**	**331**
	%	**19**	**42**	**39**	**100**
Correlation		**1**	**2**	**2**	**5**

An average resistance at the level of 5 scores of the immunological assessment scale was found in 44 samples (29 %) of the general totality, respectively.

88 samples or 58% of all breeding material that was studied in 2011 belonged to the “susceptible” group (scores 3-1) (fig. 3.1, Table 3.1, 3.4).

According to our research, in 2012, out of the entire general totality (110 samples) of Gherkin type cucumber under open ground conditions, 28 samples (or 25%) were classified as resistant (score 7).

This group includes breeding material, namely:

collection samples –Ajax F_1, Dzherelo, Phoenix 640 (standards);

breeding – F_7I_5 Chistye prudy, F_8I_2 Begio 1802, F_9I_2 Fansipak, F_4I_2 Nastoyashchij polkovnik, F_5I_3 Odys, F_6I_3 Amur, F_5I_2 Mirabell, F_5I_3 (F_1 Mar'ina roshcha x F_3I_3 D96a№2-95), F_3I_3 (F_1 Fortuna x F_3I_3 D96a№2-95), F_7I_4 Podmoskovnye vechera, F_7I_3 Patriarh, F_5I_2 (F_1 Denek x F_3I_3 D96a№2-95), F_5 Izyd, F_3I_1 Pavlik, F_3I_2 Pavlik, F_5I_3 Krak, F_5I_4 Krak, F_4I_1 Semkross, F_4I_3 Danila, F_4I_3 (F_1 Ivolga x F_3I_3 D96a№2-95), F_2 Rufus, F_6I_4 Syn polka, F_7I_2 Emelya, F_7I_2 Emelya, F_5I_1 (F_1 Denek x F_3I_3 D96a№2-95) (Table 3.2).

According to the studies results of 2012, 68 samples (62 %) were assigned to the “medium resistance” group (score 5 of the immunological scale), and 14 samples (13 %) were assigned to the susceptible group (scores 3-1 of the scale) (fig. 3.1, Table 3.2, 3.4).

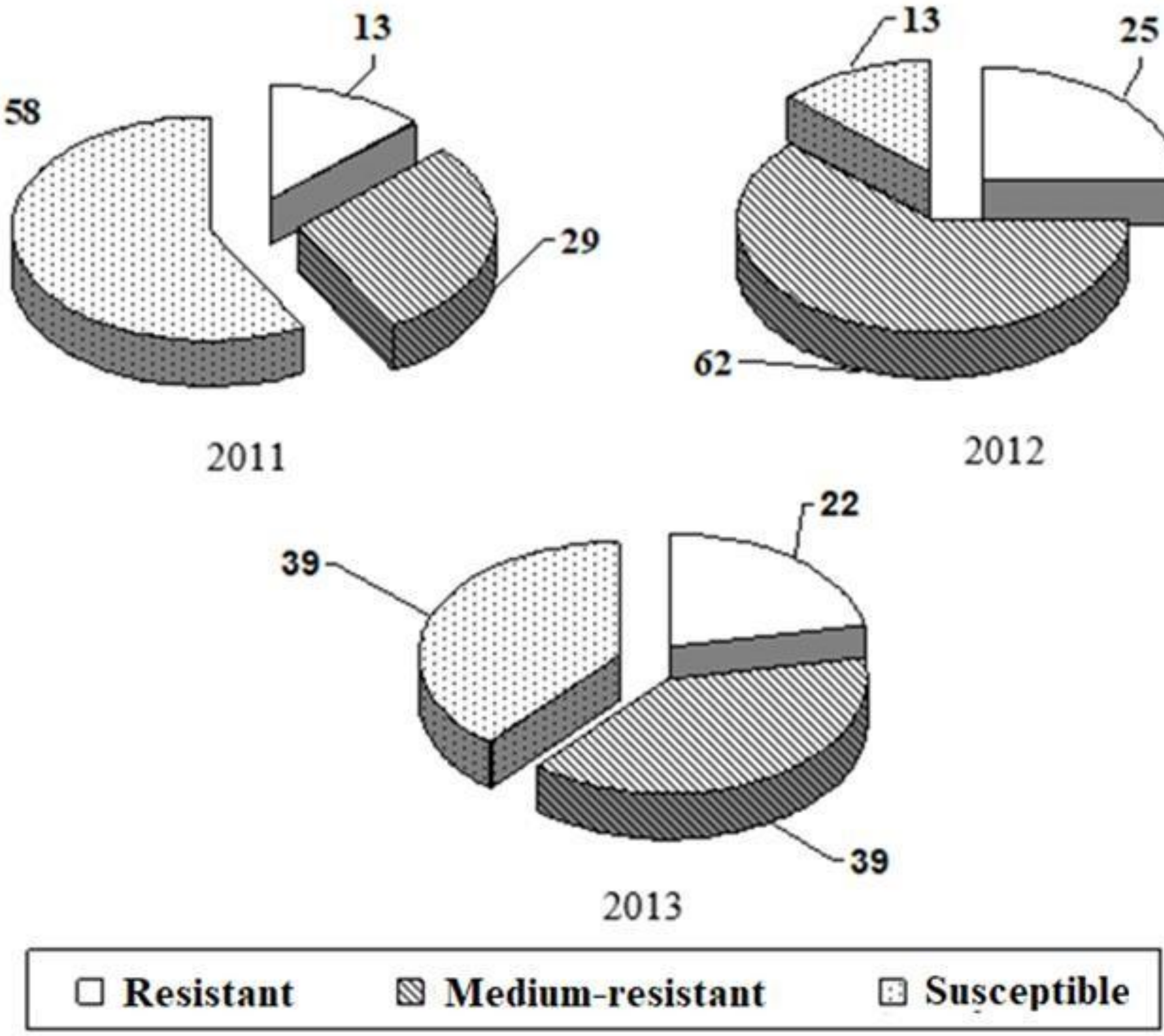


Fig. 3.1. Distribution of cucumber breeding material according to the expression of field resistance to downy mildew under conditions of a natural infectious background, %

A sampling of 17 samples (10.6 %) from the analyzed general totality (69 samples) showed high resistance (score 7 of the immunological scale) in 2013 (Table 3.4).

This group includes collection and breeding samples of Gherkin type cucumber, namely: Phoenix 640, Dzherelo, Geim, F_5I_2 (F_1 Bee pollinating cucumber x F_3I_3 96a№2-95), F_6I_3 (F_1 Denek x F_3I_3 96a№2-95), F_4I_1 (F_1 Saltan x F_3I_3 96a№2-95), F_3I_2 Pavlik, F_6I_5 Krak, F_6I_3 Semkross, F_5I_4 (F_1 Ivolga x F_3I_3 96a№2-95), F_7I_2 Tsezar, F_3I_3 Patriarh, F_1 (F_8I_4 Kozyrnaya karta x Dzherelo), F_6I_2 (F_1 Bee pollinating cucumber x F_3I_3 96a№2-95), F_1{F_6I_3 (F_1 Fortuna x F_3I_3 96a№2-95)} x Dzherelo (Table 3.3).

In 2013 27 samples (39 %) from the entire analyzed totality were included in the group of medium-resistant samples (score 5 of the immunological scale).

27 genotypes (39 %) of all breeding material studied this year were assigned to the susceptible group (scores 3-1) (fig. 3.1, Table 3.3, 3.4).

Thus, according to the generalizing results of the three-year immunological assessment, we will note that a sampling of 63 samples that, under the conditions of a natural infectious background, showed high resistance (score 7) to downy mildew over the years was used annually at most actively by breeders for selection both for resistance and for a complex of other characteristics (fig. 3.2).

Samples (139 pieces or 42 %), which showed medium resistance (score 5 of the immunological scale), were the most polymorphic and by their composition were a mixture of high-, medium- and low-resistance genotypes in different proportions.

It was among the samples of this group that tandem selection of the best forms was carried out annually, which harmoniously combined in their genotypes the trait of protracted resistance to downy mildew with a complex of other important economic characteristics [20, 25].

In our opinion, it is this group of samples that acts as the flexible adaptive buffer (the middle zone of σ-sigma curve of the normal distribution of the resistance trait) [35], which most effectively controls the natural evolutionary processes of shaping and regulates the aggressiveness of the *Pseudoperonospora cubensis* population in agrophytocenoses.

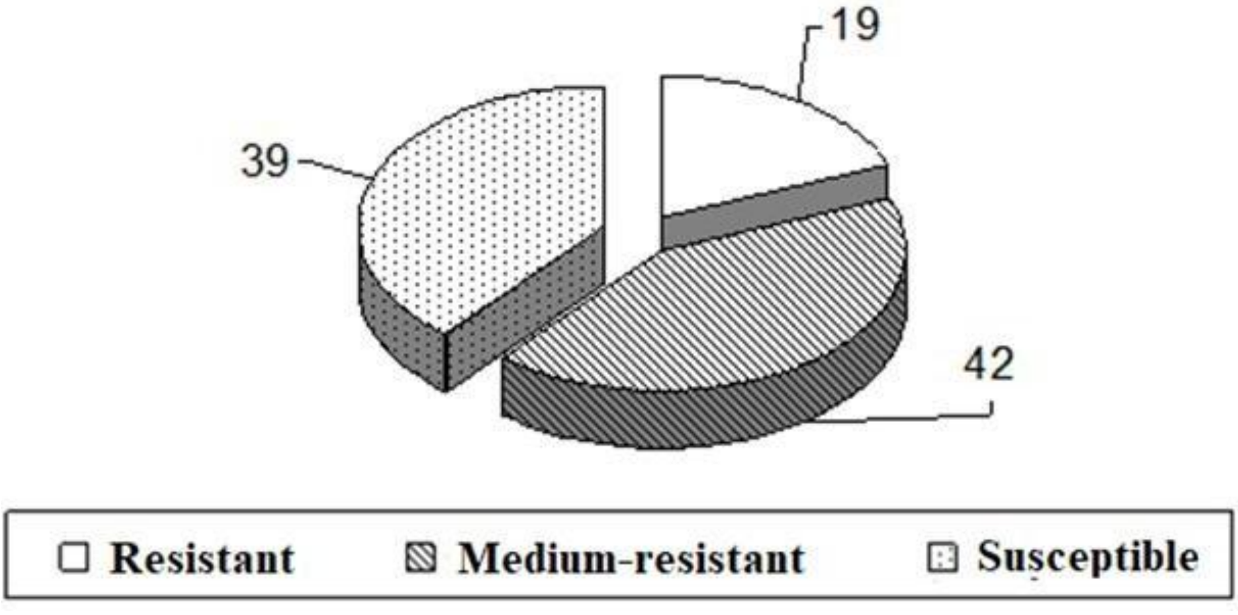


Fig. 3.2. Generalizing distribution of breeding material of Gherkin type cucumber according to the expression of samples resistance to downy mildew (natural infectious background 2011–2013, %)

The whole last selective totality of the studied breeding material, represented by 129 samples (39.0 %), is classified as susceptible to downy mildew by the type of immunological reaction(scores 3, 1) (Table 3.4, fig. 3.2).

According to scientists' recommendations, samples with such a low expression of resistance trait to downy mildew were annually withdrawn from the breeding process [40, 45, 57].

Thus, based on the obtained summary immunological characteristics among the available breeding material, we determined the intensity of selection of downy mildew-resistant forms (genotypes) of Gherkin type cucumber under conditions of a natural infectious background [68, 74] (fig. 3.3).

Complete information on the degree (R) and intensity of downy mildew lesion (P) of cucumber breeding material studied in 2011-2013 was provided annually, in the form of an information database, to scientists of the laboratory of pumpkin plant breeding of the Institute of Vegetables and Melons growing of NAAS.

So, from the above experimental material, we can draw the following generalizing conclusions.

According to the level of resistance to the most common disease in the region – downy mildew, a phytoimmunological characteristic of 331 breeding samples of Gherkin type cucumber was obtained, which was used annually in breeding studies in the form of a database.

NATURAL INFECTIOUS BACKGROUND Studying, selection and rejection of breeding material (collection, selection - hybrid, linear, initial) of cucumber of Gherkin type by the susceptibility trait to downy mildew. Conducting *tandem* selection of resistant forms with their simultaneous assessment by a complex of other valuable features [74, 139]
2011 According to susceptibility and other traits, up to **60 %** of the breeding material was rejected (Table 3.1, 3.4)
2012 According to susceptibility and other traits, up to **40** % of the breeding material was rejected (Table 3.2, 3.4)
2013 According to susceptibility and other traits, up to **25** % of the breeding material was rejected (Table 3.3, 3.4)

Fig. 3.3. Scheme of assessment and stepwise selection of the initial material of Gherkin type cucumber by the resistance trait to downy mildew

It was found out that a sampling of 63 breeding samples (19 %) is of practical interest for breeding programs by the resistance trait to downy mildew, the lesion degree of which by the causative agent of this disease at the end of the first decade of mass fruiting (critical phase of ontogenesis) did not exceed 10% (resistance score 7 of the REV immunological scale).

For a group of 139 samples (42 %) that showed medium resistance (score 5 of the REV scale) under conditions of a natural infectious background, it is recommended to conduct an annual tandem selection of forms that are most harmoniously able to combine the trait of resistance to downy mildew with a complex of other valuable traits in their genotypes.

3.2. Variability of the initial breeding material of cucumber by the resistance to downy mildew and complex of main traits

Scientists have determined that the breeding of cucumbers for disease resistance should be carried out stepwise, that is, 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 [37, 60].

World experience proves that 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 [62].

Based on the above, the purpose of this block of research was to determine the level of variability (stability) of the main traits of cucumber of Gherkin type in obtaining new initial forms that can meet different consumers' needs and tastes of the created final breeding innovative product – 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 conducting examination of varieties for difference, uniformity and resistance (DUR)" [70], chemical assessment of fruit quality (dry matter content, sugars, nitrates) was carried out according to the "Methods of biochemical plants research" [55].

The main object for this research area was the initial breeding (linear) material of Gherkin type cucumber of nursery gardens of preliminary and competitive variety testing. In the future, all obtained experimental data on a complex of basic economic characteristics

(5 pieces) and a number of 22 approbatory traits were processed by the method of variational analysis [35].

As a result of studying the variability of the five main economic traits in 27 initial cucumber samples (lesion degree, intensity of disease spread, total crop capacity, crop capacity for the first decade of fruiting, duration of the mass fruiting period), the following statistical characteristics were obtained: variation coefficient (Cv), limits of trait expression ($LV = \nu_{min} \div \nu_{max}$) and the average value of the norm range of the genotype reaction ($\bar{X}_{Am} = (\nu_{max} + \nu_{min}) / 2$).

According to the studies results of the initial breeding material (innovative product), the lesion degree of samples (27 numbers) by downy mildew ranged from 2.5 to 79.2 % over the years.

At the same time, the whole experimental material of cucumber according to the range of reaction expression of the resistance trait to downy mildew is divided into two nominal subgroups: resistant (scores 7, 5) and susceptible (scores 3, 1 of the immunological scale) by the type 50÷50, or resistance is present ÷ absent. The results of such a comparative assessment of the 5 main economic characteristics variability both for the entire general totality of samples and for the corresponding immunological subgroups arranged according to the expression of the downy mildew resistance reaction are shown in Table 3.5.

Table 3.5.

Results of assessing the variability of a complex of basic economic characteristics in different by resistance expression subgroups of Gherkin type cucumber, %

Traits	General totality of samples (27 pieces)		Subgroups			
			resistant (scores 7, 5)		susceptible (scores 3, 1)	
	CV	LV	LV	$\bar{X}_{Am}$	LV	$\bar{X}_{Am}$
Downy mildew, the degree of development, %	49	2,5 ÷ 79,2	2,5 ÷ 34,1	18,3	44,0 ÷ 79,2	61,6
Downy mildew, the intensity of spread, %	29	10,0 ÷100,0	10,0 ÷ 64,4	37,2	50,0 ÷ 100,0	75,0
Total crop capacity, t/ha	39	3,8 ÷44,6	20,0 ÷ 44,6	32,3	3,8 ÷ 11,9	7,85
Crop capacity for the first decade of fruiting, t/ha	48	2,6 ÷ 12,4	7,8 ÷ 12,4	10,1	2,6 ÷ 6,0	4,3
Period of mass fruiting, days	29	10,0 ÷ 45,0	34,0 ÷ 45,0	39,5	10,0 ÷ 25,0	2,3

Note: $\bar{X}_{Am}$ is the average value of the reaction norm range of the trait.

From the obtained results, it can be seen that according to these main economic traits, all the initial material was not genetically aligned. Thus, the variation coefficients (CV, %) of all the above main economic traits in the initial forms and standards were very high and ranged from 29 to 49 %.

Comparison of the average values of the reaction norm range ($\overline{X}_{Am}$) of these traits in 2 selective totalities grouped by the trait presence or absence of resistance to downy mildew allowed us to find out the following fact.

In the group of susceptible samples (genotypes), an average of reaction norm range ($\overline{X}_{Am}$) of such an indicator as the degree of the disease development exceeded this indicator in the resistant group by more than 3.4 times, by the trait of the intensity of the disease spread – by more than 2 times.

So, in samples (genotypes) of resistant and susceptible groups, the difference between the average values of the reaction norm range of such traits as total crop capacity was 4 times greater, the crop capacity for the first decade of fruiting – 2.4 times, by the trait of the mass fruiting period – 1.7 times, respectively.

Accordingly, the variability range of cucumber samples of the susceptible group according to such traits as development degree and intensity of downy mildew spread was the largest, by the indicator of total crop capacity, the absolute value of this trait for the first decade of fruiting, and the duration of the mass fruiting period – the smallest.

This allows us to conclude that the samples of different resistance groups differ in the following way – the general reaction norm of such main economic traits as total crop capacity, crop capacity for the first decade of fruiting, the duration of the mass fruiting period for each group is constant, and the phenotypic difference in the extreme values of these trait between groups becomes most noticeable as indicators such as development degree and the intensity of downy mildew spread grow.

For breeding practice, this proves the possibility of successful selection of initial forms – sources of high resistance and crop capacity among the breeding material at the final stages of its creation.

In the future, we present summary by years more detailed immunological characteristic of the initial breeding material, divided according to the resistance expression under field conditions into 4 immunological groups (scores 7-1 of the immunological scale) (Table 3.6).

Stably high field resistance over the years of research (the degree of the disease development – up to 10%, score 7 of the immunological scale) was found by 14 initial cucumber breeding lines with the numbers of the Institute’s catalogue №№ 57713, 57770, 57729, 57703, 57396, 57803, 57851, 1240, 57707, 57826, 57756, 57711, 57797 and 57774.

Table 3.6

Immunological characteristics of the initial material of Gherkin type cucumber, natural infectious background (2011-2013)

General totality of samples (27 pieces), their numbers of the selection catalogue of the Institute of Vegetables and Melons growing of NAAS	Accounting date – end of the first decade of mass fruiting		
	degree of disease development, %		resistance, scores
	LV	Am	
№№ 57713, 57770, 57729, 57703, 57396, 57803, 57851, 1240, 57707, 57826, 57756, 57711, 57797, 57774	2,5 ÷ 10,0	7,5	7
№№ 57759, 1806, 57767, 1797, 57862, 57836	12,5 – 31,1	18,6	5
Phoenix 640, Ajax $F_{1,}$ Dzherelo (standards of resistance)	8,5 ÷ 34,1	25,6	7 - 5
Nizhynsky local (standard of susceptibility), susceptible hybrid populations from collection samples Pavlik, Fansipak, Krak	44,0 ÷ 79,2	35,2	3 - 1

Stable average resistance to downy mildew (the degree of the disease development – up to 35%, score 5 of the immunological scale) was shown by 6 lines selected for resistance and a complex of other valuable traits (catalogue №№ 57759, 1806, 57767, 1797, 57862 and 57836).

As a standard of susceptibility, we used Nizhynsky local variety. To increase the representativeness of the analyzed sampling by traits variability, a group of nonresistant forms – selections of different generations of hybrid populations of 3 collection samples was additionally involved in the initial material.

At the same time, the whole contrasting sampling (initial material, standards) by the level of reaction expression of the resistance to downy mildew was analyzed by us according to a complex of 24 standard approbatory (morphological, biochemical) traits and indicators of the sample's resistance to downy mildew – lesion degree (X_{23}) and the intensity of disease spread (X_{24}) [55, 70, 97]:

in a leaf, these traits were: its length (X_1), blade size (X_2), blistering (X_4), wavy edges (X_5), length (X_6) and width of the upper lobe (X_7);

in a plant– sex-expression (X_8), the number of female flowers per first node (X_9), lesion degree (X_{23}), the intensity of disease spread (X_{24});

in a fruit – its shape (X_{10}), intensity of green colouring (X_3), length (X_{11}), diameter (X_{12}), presence of pubescence (X_{13}), stripes (X_{14}), spots (X_{15}), fruit stalk length (X_{16}), bitterness (X_{17}), weight (X_{18}), number of fruits on the plant (X_{19}) during the period of maximum disease development on a susceptible standard (Nizhynsky local), dry matter content (X_{20}), monosaccharides (X_{21}) and nitrates (X_{22}) (Table 3.8).

According to literature data, it has been established that the initial material with short cylindrical fruits of dark green color, with a hard skin and fruits pubescence of black colour has the greatest value for breeding to create short-fruited короткоплідних early rpening varieties and hybrids of cucumber of Gherkin type [62]. Such samples are the most popular for various types of processing (canning, pickling), because even after heat treatment or fermentation, they have an attractive commercial shape and quality for consumption.

According to the research results, it was found out that all the selected initial breeding material of cucumber of Gherkin type (27 samples) had 24 main necessary in breeding and production valuable approbatory, economic traits and parameters of resistance to downy mildew an average (Cv = 10–20 %) and high ($Cv \geq 20$ %) variability level. No trait showed high stability (low variability, *Cv* up to 10 %) within the analyzed totality (Table 3.7).

The average variation (*Cv* = 10–20 %) was typical for the width of the upper leaf lobe (X_7), fruit shape (X_{10}), fruit length (X_{11}), fruit weight (X_{18}), dry matter content in a fruit (X_{20}), monosaccharides content in a fruit (X_{21}).

The following main traits varied strongly (*Cv* ≥ 20 %) within the studied initial breeding material:

in a leaf – its length (X_1), blade size (X_2), blistering (X_4), and wavy edges (X_5);

in a plant – sex-expression (X_8), the number of female flowers per first node (X_9), indicators of resistance to downy mildew – lesion degree (X_{23}), the intensity of disease spread (X_{24});

in the fruit – its diameter (X_{12}), presence of pubescence (X_{13}), stripes (X_{14}), spots (X_{15}), fruit stalk length (X_{16}), bitterness at the base (X_{17}), the amount on the plant (X_{19}) on the date of maximum disease development on the susceptible standard (Nizhynsky local), nitrate content (X_{22}).

So, the calculated statistical characteristics affirmed a wide genetic polymorphism of the initial breeding material of this vegetable crop in a complex of basic characteristics. Today, this allows mobile and efficiently solve most of the demands that consumers of the final product (variety or hybrid) make for breeders in the near future.

Table 3.7

Characteristics of variability of a basic traits complex (X_1–X_{24}) in the initial material of Gherkin type cucumber, generalized for 2011-2012.

Plant organ, trait (X_i), value of its variation coefficient (Cv), %		
insignificant, up to 10	average, 10–20	significant, more than 20
--	*Leaf* - X_7; *Fruit* – X_{10}, X_{11}, X_{18}, X_{20}, X_{21}	*Leaf* – X_1, X_2, X_4, X_5; *Plant in general* – X_8, X_9; *Fruit* – X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{19}, X_{22}; *Indicators of resistance to downy mildew* – X_{23}, X_{24}

Along with this, the analysis results of the newly created initial material of Gherkin type cucumber according to the most important characteristics for practical breeding and production showed the following distribution of valuable initial forms identified for resistance to downy mildew (Table 3.8).

Consequently, the degree of downy mildew lesion (X_{23}) in 60% of the initial material selected for this trait at the end of the first fruiting decade was low, which corresponded to score 7 of the immunological scale of accounting, and in 36 % – average (score 5 of this scale).

72 % of the genotypes identified for resistance had the average size of the leaves blades (X_2), strong intensity of fruits green colour (X_3) – 32 %, moderate leaves blistering (goffering) (X_4) – 64 %, moderate waviness of the leaves edges (X_5) – 72 %, small (up to 12 cm) length of the upper leaves lobe (X_6) – 96 %, the average width (16-20 cm) of the upper leaves lobe (X_7) – 56 % of the sample, respectively.

Among the studied initial material, 16% of the selected resistant initial forms had a predominantly female flowering type (X_8). At the same time, 16 % of cucumber genotypes selected for resistance to downy mildew had the number of female flowers on the first node (X_9) more than 3 pieces.

Table 3.8

Results of assessing the variability level of cucumber initial material by the level of resistance and a main traits complex

Trait	The number of samples, %			
	Trait gradation [55, 70, 97]			
Leaf length (X_1)	from 5,3 to 11,5 cm			
Leaf blade size (X_2)	Small	Medium	Big	
	24	72	4	
Intensity of fruit green colouring (X_3)	Weak	Moderate	Strong	
	20	48	32	
Leaf blistering (X_4)	Weak	Moderate	Strong	
	20	64	16	
Waviness of leaf edges (X_5)	Absent	Weak	Moderate	Strong
	4	16	72	8
The length of the upper lobe (X_6)	Small (up to 12 cm)	Medium (12–15 cm)		
	96	4		
The width of the upper lobe (X_7)	Small (up to 15 cm)	Medium (16–20 cm)	Big (more than 20 cm)	
	44	52	4	
Plant: sex-expression (X_8)	♂ and ♀ flowers equally	♀ flowers predominate		
	84	16		
The number of female flowers per node (X_9)	From 1 to 3 pieces	Over 3 pieces		
	84	16		
Fruit shape (X_{10})	Spindle-shaped	Cylindrical		
	36	64		
Fruit length (X_{11})	Short (6–10 cm)	Medium (11–20 cm)		
	44	56		
Fruit diameter (X_{12})	Medium (2,1–3,5 cm)	Big (more than 3,6 cm)		
	84	16		
Black or white fruit pubescence (X_{13})	Absent	Insignificant	Moderate	
	48	40	12	
Presence of stripes on a fruit (X_{14})	Absent	Present		
	12	88		
Spots on a fruit (X_{15})	Absent	Present		
	36	64		

Table 3.8 (continuation)

Fruit stalk length (X_{16})	Small (up to 2 cm)		Medium (2,1–5,0 cm)
	60		40
Fruit: bitterness at the base (X_{17})	Absent		Present
	96		4
Fruit weight (X_{18})	65–100 g		
Additional number of fruits per plant (X_{19}) at the end of the mass fruiting phase – compared to the susceptible standard – Nizhynsky local	3–9 pieces		
Dry matter content in a fruit (X_{20})	3,91–5,8 %		
Monosaccharides content in a fruit (X_{21})	1,32–2,17 %		
Nitrates content in a fruit (X_{22})	69–224 mg/kg		
Lesion degree (X_{23}) of the sample by downy mildew, score of the immunological scale	Low (7)	Average (5)	High (3–1)
	60	36	4
Lesion of the sample (X_{24}) by downy mildew, score	Low (0–1)	Average (2)	High (3–4)
	8	52	40

By the shape trait (X_{10}), sampling of 64 % of resistant initial forms had a fruit of the cylindrical shape, its short (6–10 cm) length (X_{11}) – 44 %, and an average (2.1 to 3.5 cm) diameter (X_{12}) – 84 % of the selected genotypes.

In 40 % of the initial forms selected for resistance, black pubescence in fruits (X_{13}) was insignificant. The presence of stripes on the fruit (X_{14}) was absent in 12% of the selected initial material, spots on a fruit (X_{15}) – in 36 %.

Fruits in 60 % of the genotypes selected for resistance to downy mildew had small (up to 2 cm) fruit stalk length (X_{16}) and bitterness at the base of the fruit (X_{17}) was absent in 96% of the newly created initial forms.

The given characteristics of the level of variability made it possible to select for breeding programs (primarily taking into account the traits of resistance to downy mildew) the initial breeding material of different quality according to the complex of main approbatory and economic characteristics to attract it to the process of creating modern domestic competitive varieties and hybrids of gherkin cucumber.

Thus, according to the results of our research at the final stage of the breeding process, we, together with breeders, selected a promising initial form (bee–pollinated line of Gherkin type cucumber *P 57/745–11*) of Gherkin type cucumber, which, against the background of a high expression of a number of important economic characteristics, has high resistance to downy mildew under conditions of a natural infectious background.

Bee-pollinated line of cucumber of Gherkin type *P 57/745–11*. The line is early ripening (before the first harvest – 42 days). The total yield under boharic growing conditions is 20.4 t/ha, commercial – 18.3 t/ha, for the first fruiting decade – 8.9 t/ha. Marketability – 84 %. The line is resistant to downy mildew (score 7 of the REV scale) and medium-resistant to bacteriosis (score 5). The tasting evaluation of fresh fruits is 4.8 scores. Plants are mainly of the female flowering type. The fruit is up to 9 cm long of a cylindrical shape. The pubescence is complex, black in colour. The average weight of commercial fruit is 60 g.

As a valuable sample of the gene pool and a promising initial parent component for creating future heterotic hybrids, in 2013 this line was transferred for registration to the National Center for Plant Genetic Resources of Ukraine (V.Ya. Yuriev Institute of crop production of NAAS). Now it has received the registration number of the national catalogue UL3700411.

The created line is a valuable maternal form, and is involved in the process of heterotic breeding in order to create new domestic hybrids of cucumber of Gherkin type for open ground.

Thus, the obtained experimental data proved that the selected initial material by a complex of basic traits fully meets the modern demands made by the market for short-fruited varieties and hybrids of Gherkin type cucumber under the conditions of their cultivation in the open ground of the Left-Bank Forest-Steppe of Ukraine.

3.3 Peculiarities of resistance traits inheritance of cucumber plant to downy mildew under conditions of natural infectious background

Under 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 which harmoniously combine in their genotypes resistance to diseases with the maximum possible combination of a complex of useful traits with the genetic ability to transmit the specified complex of traits to hybrids when crossing with the maximum possible heterotic effect [29].

Studies of N.I. Medviedieva, V.F. Pivovarov, E.G. Dobrutska and N.M. Balashova [*cited* by 60] 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 fact, under conditions of the Left-Bank Forest-Steppe of Ukraine, we have analyzed the results of 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 out 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 that were 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 (Table 3.9).

The degree of dominance (*Hp*) of the resistance trait to downy mildew in Gherkin type cucumber F_1 hybrids was determined by the formula:

$$Hp = \frac{F_1 - MF}{HF - MF}, \qquad (3.1)$$

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 [40, 89].

Values of *Hp*: from -∞ to -1 is negative overdominance of a trait (–OD); from -1 to -0.5 – negative dominance (–D); from -0.5 to 0.5 – intermediate dominance (ID), from 0.5 to 1 – positive dominance (D), from 1 to + ∞ – positive overdominance, or heterosis (OD). At *Hp* = ±1– complete dominance of better (+) or worse (-) expression of trait value [89].

Analysis results of downy mildew development in F_1 hybrids and parental forms in our experiments have proved that in the initial forms obtained by crossing contrasting to this disease initial forms in the obtained F_1 hybrids, resistance depended on the combination of parental components. Thus, in hybrid populations № 1-6, it had an intermediate character (*Hp* = from -0.5 to 0.5), and in combinations № 7, 8 – positive (*Hp* = from 0.5 to 1).

As can be seen from the analysis of hybrid combinations № 1, 2, when crossing the medium-resistant to downy mildew maternal form (score 5 of the immunological scale) with the susceptible (score 3) and highly susceptible (score 1) parental form, the obtained F_1 hybrids inherited the resistance (susceptibility) of the parenal component.

Table 3.9

Characteristics of the dominance of downy mildew resistance trait in Gherkin type cucumber F_1 hybrids under natural infectious conditions (open ground, 2013)

№	Hybrid combination F_1 (♀ x ♂), catalogue number of the Institute of Vegetables and Melons growing of NAAS	Degree (R) of diseases development, percentage / immunological scale						Average indicator of initial forms, MF	Indicator of the best parental form, HF	Degree of dominance of the resistance trait , *HP*
		F_1		♀		♂				
		%	score	%	score	%	score	%	%	
1	58258	39,0	3	21,1	5	45,0	3	33,0	21,1	-0,50
2	57982	49,0	3	13,7	5	75,0	1	44,4	13,7	-0,15
3	58076	34,5	5	62,5	1	13,7	5	38,1	13,7	0,15
4	58012	10,0	7	7,5	7	13,7	5	10,6	7,5	0,20
5	58156	15,0	5	25,0	5	10,0	7	17,5	10,0	0,33
6	57987	27,5	5	55,0	1	15,6	5	35,3	15,6	0,40
7	58040	42,5	3	62,5	1	37,5	3	50,0	37,5	0,6
8	58150	15,0	5	25,0	5	13,7	5	19,4	13,7	0,76

When a highly susceptible (score 1) maternal form was involved in crossing with a medium-resistant (score 5) parental component (combinations №3, 6), the obtained hybrids inherited the resistance of the paternal form (score 5).

In hybrid combinations № 4 and 5, which were obtained by crossing resistant (score 7) and medium-resistant (score 5) to downy mildew parental initial forms, the obtained F_1 hybrids inherited resistance to this disease of the maternal form.

When both non-resistant to downy mildew (scores 3 and 1) parental forms were involved in crossing (combination № 7) or both forms with the same level of average resistance (score 5 of the immunological scale) (combination № 8), the obtained hybrids had a positive dominance of resistance level of the parent component.

From the given experimental material, it is clearly recognized that it is the initial parental (male) form against the background of different in resistance of the maternal one that is the main carrier and transmitter of the resistance trait to downy mildew to the hybrid generation F_1 with an intermediate and positive character of its dominance.

When selecting the initial material, considering the previously established specificity of the relationship in the pathosystem “pathogen – plant – environment” and determined nature of trait inheritance of protracted cucumber resistance to downy mildew as resistance sources (donors), we recommend using parental components with high (score 7) and average expression (score 5) of resistance to this disease.

3.4. Correlation dependences between the complex of main traits and resistance of cucumber of Gherkin type to downy mildew

It is known that 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. At the same time, the tightness and direction of relationships between traits in this structure is fully responsible for the degree of 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 traits that are most strongly related to each other. This allows scientists to more effectively control the effectiveness of the breeding process, especially at its final stages [45].

The importance of the structure of these relationships in the adaptive breeding of vegetable crops, including cucumbers, is very important, because they allow the breeder to indirectly judge the direction and tightness of the influence of one selective (working) trait on others [60].

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 very weak; 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 [149].

We believe that just this gradation calibration of the correlation assessing scale for the tightness of determining relationships between breeding traits, in contrast to the standard scale proposed by B.O. Dospekhov [35], "...which is recommended for analyzing the results of field research, of mainly technological direction", that most optimally levels the uncontrolled influence of abiotic and biotic stressors and, accordingly, more impartially reveals the peculiarities of the genetic framework of relationships between plant traits it is in genetic and breeding research.

Thus, of particular interest to us was the studying of the tightness and direction of relationships between the block of main approbatory and economic traits of Gherkin type cucumber, at which the breeders research work aims, with the trait parameters of resistance to downy mildew. The main interest for indirect selection were pairs with relationship tightness at a level not lower than strong and very strong (correlation coefficient from 0.60 to 1.0) [45, 69, 149].

Based on the conducted correlation analysis results, we have established the directions and tightness of relationships of the main economic traits complex of the initial material (27 samples) of Gherkin type cucumber with their resistance parameters to downy mildew under the field conditions.

Thanks to correlation analysis, we have identified a genetic block (framework) from economic traits pairs, the relationship of which with resistance parameters turned out different in direction, but reliably strong and very strong ($p = 0.60 \div 1.0$, $r_{critical} = 0.48$, $\alpha = 0.01$ [69]) (Table 3.10).

So, in the analyzed totality of initial material, the following pairs revealed a direct strong influence on each other – the degree of downy mildew development, % (trait№1) – fruiting period, days (№7); downy mildew prevalence, % (№2) – fruiting period, days (№7); the degree of downy mildew development, % (№1) – total cropping capacity, t/ha (№4);

downy mildew prevalence, % (№2) – total cropping capacity, t/ha (№4); the degree of downy mildew development, % (№1) – commercial cropping capacity, t/ha (№5); downy mildew prevalence, % (№2) – commercial cropping capacity, t/ha (№5); degree of downy mildew development, % (№ 1) – the number of fruits on the plant at the end of the first decade of mass fruiting, pieces (№ 27), a total of 4 economic traits.

Table 3.10

Correlation relationships between the complex of main traits and resistance parameters to downy mildew of Gherkin type cucumber, 2011-2013

Relationship characteristics	Pairs of traits, № ÷ №, (correlation coefficients *, r/determination, D)
REVERSE	
strong (r = 0,6–0,79)	1 ÷7 (-0,65/0,42); 2÷7 (-0,61/0,37); 1 ÷4 (-0,72/0,52); 2 ÷4 (-0,74/0,55); 1 ÷5 (-0,69/0,47); 2 ÷5 (-0,75/0,56) 1÷27 (-0,62/0,38)
DIRECT	
strong (r = 0,6–0,79)	1 ÷28 (0,67/0,45), 2 ÷28 (0,64/0,40)
very strong (r = 0,8–1,0)	1 ÷2 (0,88/0,77)

The results of the conducted correlation analysis allowed us to identify a group of traits and form a correlation pleiad in which the indicators of the sample's resistance to downy mildew Y_i (in our case – № 1 and № 2) are connected and negatively affect the processes of values forming of variable X_i (traits №№ 4, 5, 7, 27) (fig. 3.3).

The obtained data prove that severe lesion of plants by downy mildew (lesion score 3-4) led to a significant loss of moisture by plant tissues and, accordingly, an increase in the dry matter content in fruits.

The calculated coefficients of determination for these traits pairs, which are shown in Table 3.10, statistically prove that the direct contribution of the studying biological stress factors to the overall formation process in cucumber of this biochemical trait is from 41 to 45 %.

So, according to this block of studies, it was found out that an increase in the main parameters of downy mildew harmfulness under the field conditions directly affects the decrease in such indicators of cucumber as total cropping capacity (by 52–55 %), commercial cropping capacity (by 47–56 %), the duration of the fruiting period (by 37–42%), the number of fruits on the plant at the end of the first decade of mass fruiting (by 38 %), change the biochemical composition of fruits in the direction of increasing their dry matter content by 41–45 %.

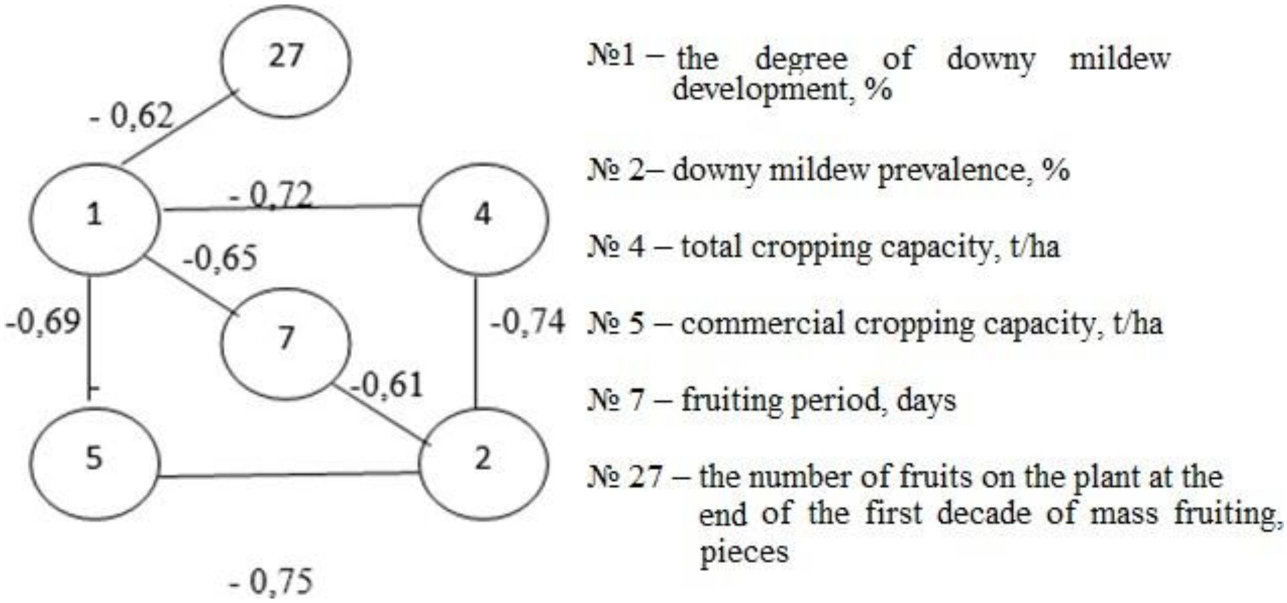


Fig. 3.3. Correlation pleiad of *reversal* relationship between resistance parameters to downy mildew (Y_i) and a complex of other traits (X_i) in Gherkin type cucumber, 2013.

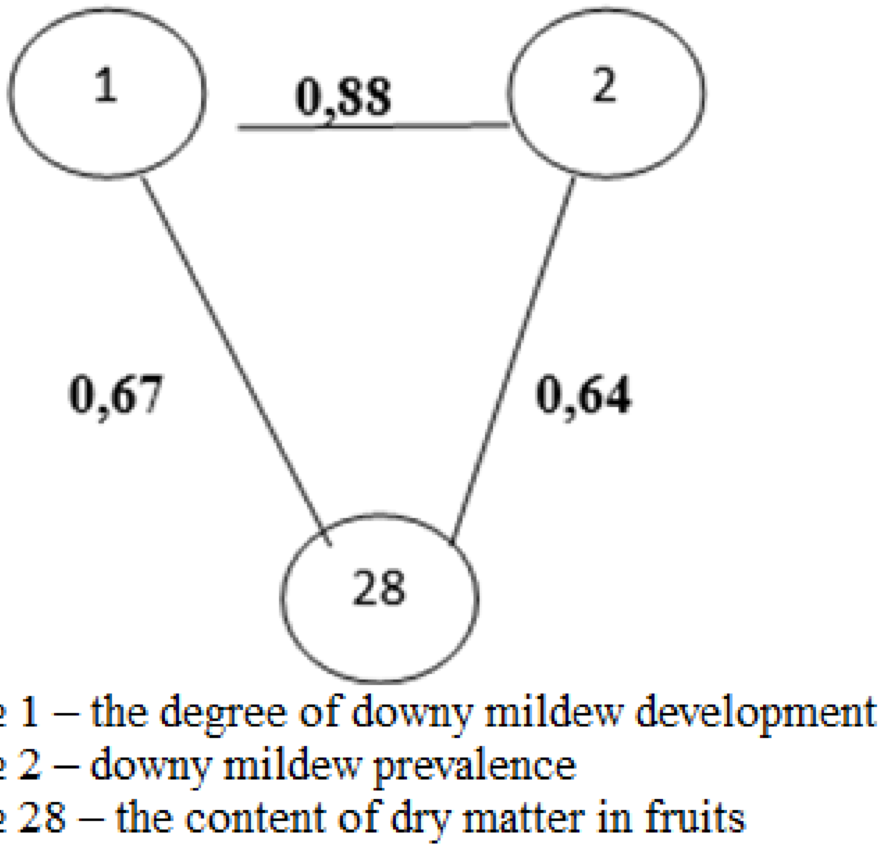


Fig. 3.4. Correlation pleiad of *direct* relationship between resistance parameters to downy mildew (Y_i) and the content of dry matter in cucumber fruits of Gherkin type (X_{28}), 2013.

In contrast, the following traits pairs revealed a direct strong influence on each other: the degree of downy mildew development, % (trait № 1) – the content of dry matter in fruits, % (№ 28); downy mildew prevalence, % (№ 2) – the content of dry matter in fruits, % (№ 28), which is very important for breeders and producers of processed products (fig. 3.4).

We have established that such economic characteristics as the duration from the beginning of the mass germination phase to the beginning of the first fruit harvest, days (№ 8), leaf blade length, cm (№ 9), leaf blade size, cm (№ 10); intensity of fruits green colouring, scores (№ 11); leaf blistering, scores (№ 12); waviness of leaf edges, scores (№ 13), the length of the upper leaf lobe, cm (№ 14); the length of the lower lobe, cm (№ 15); sex-expression in the plant (№ 16), the number of female flowers on the plant, pieces (№ 17), the shape of the fruit, scores (№ 18), fruit length, cm (№ 19), the diameter of the fruit, cm (№ 20), the intensity of pubescence (№ 21), the presence of stripes (№ 22) and spots on the fruit (№ 23), the length of the fruit stalk (№ 24), the presence or absence of bitterness (№ 25), weight, g (№ 26), the content of monosaccharides, % (№ 29), remnants of nitrates (№ 30) didn't show strong and very strong correlation relationship with the indicators of downy mildew resistance and are inert to changes in the parameters of downy mildew resistance.

This means that the breeder can work with this group of traits individually, without caution that artificial change of their characteristics during the breeding process for resistance to downy mildew can negatively affect the final result of the breeding process.

4. ECONOMIC SIGNIFICANCE OF RESISTANCE TRAIT TO DOWNY MILDEW IN AN INCREASE IN CUCUMBER CROPPING CAPACITY

As it was found out earlier, the process of forming the basic components of cucumber cropping capacity parameters 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.

The stably moderate, and according to our data in recent years – moderately strong nature of this disease development in the research region requires constant application of versatile measures of protection. 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 (see Section 1).

But, 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 it was noted earlier (see Sections 1-4), 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 [21, 45].

In this connection, the introduction into industrial production of varieties and hybrids of Gherkin type cucumber that are resistant to the most common under growing conditions diseases is of very important economic significance for obtaining stably high and, at the same time, high-quality commercial yields of this vegetable crop [42].

So, we have calculated the economic effect of growing Gherkin type cucumber samples under the field conditions with different characteristics of downy mildew resistance. The control when conducting economic calculations was Nizhynsky local cucumber variety – susceptibility standard (score 1 of the immunological scale) (table 4.1).

Experimental breeding samples when conducting the comparative analysis in order 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 4.1).

The total cropping capacity of the susceptible variety Nizhynsky local (control variant) was 7.2 t/ha in the selection crop, attracted to the economic evaluation of breeding samples of the nursery garden of competitive variety testing, depending on the level of their downy mildew resistance – from 11.9 (line F_3I_1 Pavlyk) to 28.6 t/ha (Ajax F_1 hybrid) (boharic conditions). At the same time, the amount of yield additionally obtained due to the present resistance to downy mildew, compared with the susceptible control, ranged from 4.7 to 21.4 t/ha for these breeding samples (Table 4.1).

It should be separately noted, that this indicator for the original line P 57/745-11 and the resistance standard (variety Dzherelo) was almost at the same level (within the average error) – 13.2 against 14.2 t/ha (Table 4.1).

In the future, economic analysis showed that an increase in the value of the field resistance expression in samples of the susceptible group by one gradation of 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 get additional products from the field in the amount of 8695 UAH/ha.

With a further score increase in resistance in breeding samples of Gherkin type cucumber, the cost of additionally obtained products 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 actually increased to 2.9–4.5 times (line P 57/745-11 – Ajax F1 hybrid).

An important generalizing indicator of economic efficiency from the introduction into breeding practice and production of the developed immunological measure of Gherkin type cucumber, in the narrow sense of this concept (line, variety, hybrid, etc.), is the profitability indicator (P, %).

It is calculated by dividing the total value of the obtained products of the line, variety, hybrid (profit) by the total production costs when its growing (cost price).

Table 4.1

Economic effect of growing Gherkin type cucumber samples different in downy mildew resistance, 2012

№	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, score	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 additionally obtained products, including at expense of resistance, UAH/ha	CP 5= CP 3 x CP 4	8695	18870	26270	39590	24420
7	Total costs of growing and harvesting a susceptible standard Nizhynsky local (control), UAH/ha	CP 6	14701 [65, 85]				
8	Costs for growing and harvesting additional yield of breeding samples of different resistance groups, UAH/ha	CP 7	523	2134	3496	5196	2939

Table 4.1 (continuation)

9	Additional net profit, including at expense of resistance, UAH/ha	CP 8= CP 5 – CP 7	8172	16736	22774	34394	21481
10	Growth of net profit values between different in resistance samples, times	CP 9	1	2,05	2,78	4,2	2,62

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

So, the overall profitability level, when growing in production variety testing, of different in resistance groups breeding samples (P, %) of Gherkin type cucumber was calculated using the following formula [54, 85]:

$$P = \frac{C-CP}{CP} \bullet 100, \qquad (4.1)$$

where *C – the total cost of sold products, UAH/ha,*

CP – cost price of sold products, UAH/ha

Based on the calculated data, we have found out the profitability level of growing breeding material of Gherkin type cucumber of different quality in terms of field resistance to downy mildew under production conditions from collection and nurseries gardens of competitive (production) variety testing (Table 4.2).

Thus, based on the obtained results of the economic effect evaluation, it was found out 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 for protecting crops from this disease, is unprofitable (-9,4 % – 44,6 %) [44].

Growing samples of the medium-resistant group (score 5) without applying a system of protection measures against diseases, on the example of F_5I_3 Odys line, which is resistant in this parameter, shows an average level of profitability of 91.2 %.

Consequently, the cultivation of cucumber samples resistant to the downy mildew pathogen under production conditions makes it possible in the region of research conducting to obtain profitability at the level of 113.9–165.9 % without using intensive technologies to protect this crop (Table 4.2).

Table 4.2

Profitability (P, %) of growing Gherkin type cucumber samples different in downy mildew resistance, 2012

№	Indicators	Initial breeding sample (variety, line, hybrid)					
		Nizhynsky local	Line F_3I_1 Pavlyk	Line F_5I_3 Odys	Line P 57/745-11	Dzherelo	Ajax F_1
		standart				standart	
1	Resistance, score	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

Note* **–** the calculation was made according to a typical techno-logical map of growing cucumbers under open ground conditions [54, 85].

Thus, the economic analysis convincingly proved that under conditions of obligatory fulfilment 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 most important is the trait of sample resistant as a key factor in rise in cropping capacity and increasing the economic effect of this vegetable crop production.

CONCLUSIONS

In the course of research, we have theoretically generalized and practically solved an important scientific task on determining the peculiarities of downy mildew development, the harmfulness of the disease and relationships with Gherkin type cucumber by forming a database, which allowed us to select and introduce into the process of varietal and heterotic breeding valuable for resistance to downy mildew and other traits complex of the initial material (parental forms), which has an important scientific and practical significance in the field of agricultural science.

1. It has been specified the regional list of Gherkin type cucumber diseases. It is established that the dominant position in the pathocomplex of this vegetable crop when growing under open ground conditions is occupied by the population of oomycetes representative (fungi-like organisms) – downy mildew or powdery mildew (*Pseudoperonospora cubensis*).

2. It is found out that for the period from 1995 to 2013 in the region of research, the nature of the dynamics of the main diseases development and spread was actively changing, in particular, downy mildew – from moderate to strong, angular bacterial spot disease, anthracnose, powdery mildew – from moderate to depressive, and the list itself includes fusarium wilt.

3. Calculated correlation coefficients between the intensity of downy mildew spread and the main abiotic stress factors of June – July proved the direct dependence of this indicator on the decadal values of average daily (r = 0.83…0.94) and minimum (r = 0.832…0.99) air temperatures; the reverse dependence on the decadal maximum values of air temperatures (r = - 0.88...-0.98), its relative humidity (r = -0.87...-0.97) and “dew points” (r = -0.86…-0.90).

4. It is established that optimal for infection and re-infection of plants under conditions of the Left-Bank Forest-Steppe of Ukraine is a specific temperature regime of the first-second decades of July –with a sharp fluctuation of maximum and minimum temperatures, which maximally activates the process of moisture condensation from the air and forms the duration of preservation of drop-liquid moisture on the plants leaf apparatus.

5. It was obtained an immunological characteristic of 331 breeding samples (collection, hybrid, linear, initial material) of Gherkin type

cucumber of Ukrainian and World breeding according to the level of downy mildew resistance under natural infectious background.

6. It was selected groups of 63 samples (or 19 %) of cucumber–promising sources of genetic resistance to downy mildew, the lesion degree of which under the field conditions at the end of the first decade of mass plants fruiting did not exceed the value of 10 % (score 7 of the immunological scale).

7. It was identified a group of 139 samples (42 %), which revealed suitability for purposeful tandem selection of promising sources in order to harmoniously combine high downy mildew resistance in their genotypes in a complex with other valuable for selection and production traits.

8. It was found that in samples of the resistant group, in comparison with the susceptible group, the difference between the average values of the reaction norm range for such parameters as total cropping capacity is 4 times greater, cropping capacity for the first decade of fruiting is 2.4 times, and the duration of the mass fruiting period is 2.3 times.

9. It was determined that the initial breeding (linear) material of cucumber of Gherkin type selected for resistance had an average (Cv = 10-20 %) and high (Cv ≥ 20 %) range of variability in 24 main valuable approbatory and economic traits, which are in demand in production, which allows mobile solutions to the main demands that consumers of the final product –variety or hybrid – make to breeders.

10. It was found out that it is the initial parental (male) form against the background of different resistance of the maternal one that is the main carrier and transmitter of the trait resistance to downy mildew to the hybrid generation F_1 with an intermediate and positive character of its dominance.

11. It was determined that a rise in the main parameters of downy mildew harmfulness under the field conditions directly affects the decrease in such indicators of cucumber as total cropping capacity (by 52–55 %), commercial cropping capacity (by 47–56 %), the duration of the fruiting period (by 37–42 %), the number of fruits on the plant at the end of the first decade of mass fruiting (by 38 %), changes the biochemical composition of fruits in the direction of rising in their dry matter content by 41–45 %.

12. With the help of correlation analysis among the 30 main economic and approbatory traits it was identified a group of inert (21 pieces), with which the breeder can work individually, without caution that an artificial change in their characteristics in the breeding process for

downy mildew resistance can negatively affect the final result of the breeding process for other traits.

13. It was found out that the share of additional net profit in the medium-resistant group of samples (score 5), in comparison with the susceptible group (scores 1-3), increases by 2 times, in the resistant group (score 7) – increases by 2.6–4.2 times.

14. It was found out that the growing cucumber samples of Gherkin type susceptible to downy mildew of the immunological group (scores 1–3) under production conditions without additional use of a comprehensive system of crops 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 %).

SUGGESTIONS FOR PRACTICAL BREEDING AND PRODUCTION

Breeding institutions and producers are offered:

1) use an informative database of immunological characteristics of resistance to downy mildew of domestic breeding material of Gherkin type cucumber (331 samples);

2) involve in the process of heterotic breeding selected initial material (63 samples) with high genetic value on the basis of resistance to downy mildew and the combination of a complex of other valuable traits in the selected genotypes (original Gherkin type cucumber line P 57/745-11);

3) use in research of phytopathological and immunological directions procedure of variational and correlation analysis (method of pleiades) in order to obtain valuable additional information about the specific participation of the biological stress factor (downy mildew) in the formation process of various valuable economic traits;

4) when selecting the initial material and determined nature of inheritance of the cucumber resistance trait to downy mildew as a source (donors) of resistance it is recommended to use parental components with high (score 7) and average (score 5) indicators of its expression;

5) to farms of the agro-industrial complex of Ukraine: use the system of phytosanitary monitoring of cucumber crops under open ground conditions (scientific and practical recommendations).

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Scientific edition

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Вперше для сучасних вітчизняних селекційних і технологічних програм сформована інформаційна база даних (акт впровадження) щодо визначення імунологічних характеристик колекційного, селекційного та вихідного матеріалу огірка корнішонного типу вітчизняної та світової селекції. Кореляційним аналізом серед 30 основних господарських та апробаційних ознак визначено групу інертних, з якими селекціонер може працювати індивідуально, без перестороги, що штучна зміна їх характеристик у процесі селекції на стійкість до пероноспорозу може негативно вплинути на кінцевий результат селекційного процесу по інших ознаках. Отримана оригінальна селекційна лінія огірка корнішонного типу із високою тривалою генетичною цінністю за стійкістю до пероноспорозу і комплексом господарських ознак. З'ясовано, що вирощування у виробничих умовах зразків огірка корнішонного типу сприйнятливої до пероноспорозу імунологічної групи (бали 1–3) без додаткового застосування комплексної системи захисту посівів від хвороб є збитковим або низько рентабельними; середньостійкої (бал 5) – середньо рентабельним; стійкої (бал 7) – рентабельним. У ході досліджень теоретично узагальнено і практично вирішено важливе наукове завдання з визначення особливостей розвитку пероноспорозу, шкідливості хвороби та зв'язків з огірком корнішонного типу шляхом формування бази даних, що дозволило відібрати та впровадити у процес сортової і гетерозисної селекції цінний за стійкістю до пероноспорозу та комплексом інших ознак вихідний матеріал (батьківські форми), що має важливе наукове та практичне значення у галузі сільськогосподарської науки. Для фахівців захисту рослин, селекції, наукових співробітників, викладачів, аспірантів і студентів біологічних і сільськогосподарських спеціальностей вищих навчальних закладів і для всіх тих кого цікавить підвищення кількості та якості врожаю огірка корнішонного типу.

DOWNY MILDEW OF CUCUMBER OF GHERKIN TYPE AND IMMUNOLOGICAL POTENTIAL OF BREEDING MATERIAL

Monograph

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