Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2021, 11(2), 327-339, doi: 10.15421/2021_118

ORIGINAL ARTICLE

Zonal pathogenic community formation of gherkin hybrid cucumber under open ground conditions

S.V. Bondarenko[1], S.V. Stankevych[1], L.V. Zhukova[1], V.V. Horyainova[1], A.A. Poedinceva[1], I.A. Zhuravska[2], A.V. Kravchuk[2], L.M. Popova[3], R.M. Mamchur[4], O.V. Romanov[1], T.A. Romanova[1], O.M. Bragin[1], I.M. Hordiienko[1], O.V. Gepenko[1]

[1]V.V. Dokuchaev Kharkov National Agrarian University, v. Dokuchaevske, Kharkiv region, 62483, Ukraine
[2]Zhytomyr Agrotechnical College, 96 Pokrovska St, 10031 Zhytomyr, Ukraine
[3]Odessa State Agrarian University, 13 Panteleimonovskaya St, 65000 Odessa, Ukraine
[4]National University of Life and Environmental Sciences of Ukraine, Kyiv, 03041, Ukraine
**Corresponding author E-mail: sergejstankevich1986@gmail.com*
Received: 29.02.2021. Accepted 10.04.2021

The course of the research has been specified the regional list of Gherkin hybrid cucumber diseases. It is established that the dominant position in the pathogenic community 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). In the research area, the nature of the dynamics of the primary disease's development and spread was actively changing, particularly downy mildew – from moderate to vigorous. 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 and minimum air temperatures; the reverse dependence on the decadal maximum values of air temperatures, its relative humidity and "dew points". 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 plant's leaf apparatus.
Key words: Gherkin hybrid cucumber, *Pseudoperonospora cubensis*, dynamics, development, spread, air temperatures, relative humidity, dew points, leaf apparatus.

Introduction

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 globally (Yarovij, Kulyeshov & Batova, 2010). Having analyzed the literature sources, it was determined that diseases such as downy mildew, powdery mildew, fusarium wilt, angular bacterial spot disease, and anthracnose are constantly present in the above list cucumbers under open ground conditions (Bolotskih et al., 1987; Nalobova, 2004). 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 primary 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 (Nalobova, 1998; Maryutin et al., 2010).

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 (Yachevskij, 1929). Analysis of domestic literature has shown that the most common and harmful diseases of cucumber in the open and protected ground are downy mildew, powdery mildew, anthracnose, fusarium wilt, and angular bacterial spot disease (Kompleksna... , 2012; Bondarenko, 2013). 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 using 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 (Sergiyenko, 2003; Kompleksna... , 2012). As the main conclusion, we will note that taking into account global trends and trends in breeding theory and practice, the primary task for Ukrainian scientists today is to obtain initial material of cucumber resistance to downy mildew, including Gherkin hybrid, by working out schemes of immunological, statistical and hybrid logical analyses. This will allow selecting valuable resistant initial parental material (genotypes) for varietal and heterotic breeding, harmoniously combining a complex of valuable approbatory and economic characteristics, and effectively using it in the breeding process.

Materials and methods

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 hybrid 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 following the "Methods of field experience in vegeTable growing" (Litvinov et al. 2011), "Methods of research work in vegeTable growing and melon growing" (Bondarenko & Yakovenko, 2001), "Methods of field experience" (Dospehov, 1985), "Operational technologies of vegeTable production" (Bolotskih, 1988), "Methods of examining varieties for difference, uniformity, and resistance (DUR)" (Ohorona, 2004), "Modern technologies in vegeTable growing" (Yakovenko, 2001). Chemical assessment of fruit quality (dry matter content, sugars, nitrates) was carried out according to the "Methods of biochemical plants research" (Ermakov, 1987), the value of the "dew point" – according to the generally accepted methods. 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 some specialized recommendations and methods (Chumakov et al., 1974; Bilaj & Ellanskaya, 1982). The general system of phytosanitary monitoring of cucumber crops for detecting diseases during the growing season and describing their symptoms is given in Table 1.

Table 1. Methods and scales for diseases accounting of cucumber of Gherkin hybrid 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, located evenly along the diagonal of the 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). A scale assesses plant damage by bacteriosis: 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.
Diseases complex (astrocytosis, anthracnose)	Degree of disease development, scores	Scale for determining the degree of damage to cucumber plants by stem form of astrocytosis 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 central 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 main elements of field accounting were such parameters as the disease prevalence (P, %) and the degree of plant damage (R, % or score) (Nalobova, 2005; Yarovogo, 2006).

The formula determined the prevalence index of the disease:

$$P = (a / N) \cdot 100, \qquad (1)$$

where *a is the number of sick plants, pieces; N – total number of examined plants, pieces.*

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

$$R = (\Sigma(a \cdot b) / N \cdot K) \cdot 100, \qquad (2)$$

where ∑ *(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. 1) (Gannibal, Gasich & Orina, 2011; Kirichenko & Petrenkova, 2012).
When assessing the immunological potential of the breeding material of cucumber of Gherkin hybrid, 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).
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 plant's sample (score 7 – resistant sample); 1 score – from 10.1 to 35 % (score 5 – medium-resistant sample); 2 scores – from 35.1 to 50 % (score 3 – susceptible sample); 3 scores – from 50.1 to 100 %, plants completely dry up, die (score 1 – highly susceptible sample) (Fig. 1) (Nalobova, 2005; Koshnikovich, Sherbinin & Timoshenko, 2008; Chistyakova & Biryukova, 2012).

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

Experimentally obtained data were processed using statistical methods of analysis – variational, correlation, and disperse (Dospehov, 1985; Bondarenko & Yakovenko, 2001; Chistyakova & Biryukova, 2012). The economic effect of growing Gherkin hybrid 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 (Bolotskih, 1988; Bondarenko & Yakovenko, 2001).
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.

Diagnostics, prevalence, and harmfulness of the primary cucumber diseases of Gherkin hybrid

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 (Zitter et al., 1996; Babadoost et al., 2004).
Following this, during the route surveys of Gherkin hybrid cucumber crops, we studied their specific diagnostic symptoms in the dynamics of development and maximum spread on the crop. We have also established the degree (R, %) and intensity of spread (P, %) of several diseases.
Immunological characteristic of all cucumber breeding material about a disease complex was 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 pathogenic community of cucumber of Gherkin hybrid 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 hybrid 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 A, B).
Our research found out that in the future, the rapid loss of leaf mass directly affected the process of forming the setting of the fruit that was 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), the formed fruits had slight coloration, 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 a) there was active sporulation of this fungi-like organism – an abundant greyish-purple coating of sporulation was formed (Fig. 2 c, d) (Cohen, 1977).

Fig. 2. Specific diagnostic symptoms of downy mildew expression on cucumber plants are usual 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) (see section 1) (Criswell et al., 2008).
As 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 hybrid are shown in Fig. 4.
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). Simultaneously, the color of tissues that were not damaged by the pathogen did not change and remained rich green (Fig. 4 a).

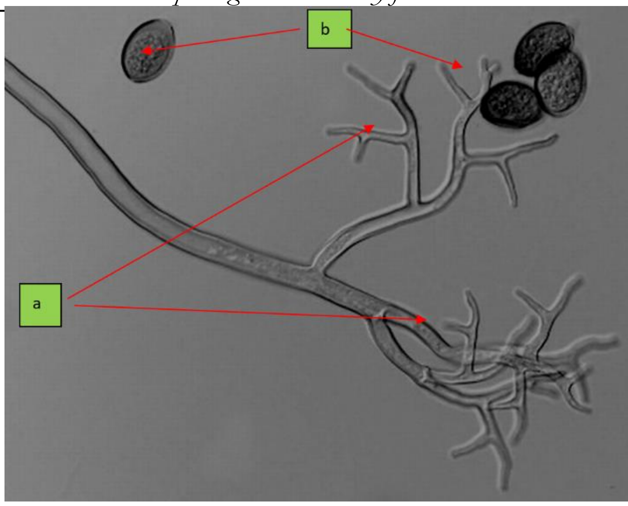

Fig. 3. Zoosporangia (a) with zoospores (dark balls – b) of the fungi-like organism *Pseudoperonospora cubensis* (wet chamber, washout, Lumam M1 microscope, UFO DS-8330 camera, 2012)

Gradually, on severely affected leaves, the spots merged and became angular due to the restriction of their size by leaf veins. The affected tissue discolored, and the leaves themselves looked like "burned". The affected tissue, limited by the veins, quickly dried out, rotted, and destroyed, making the leaf surface parchment-like and holey (Fig. 4 b).

Among other diseases of cucumber of Gherkin hybrid in the open ground, we have recorded plants with characteristic symptoms of fusarium wilt (the principal causative agent is the fungus *Fusarium oxysporum* f. sp. *cucumerinum*) (Gerlagh & Blok, 1988; Zitter, Hopkins & Thomas, 1996) (Fig. 5).

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. 5 a).

a)

b)

Fig. 4. Characteristic diagnostic symptoms of angular bacterial spot disease expression on cucumber plants of Gherkin hybrid: a – physiologically young plants; b – severe lesion by bacteriosis

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. 5 b).

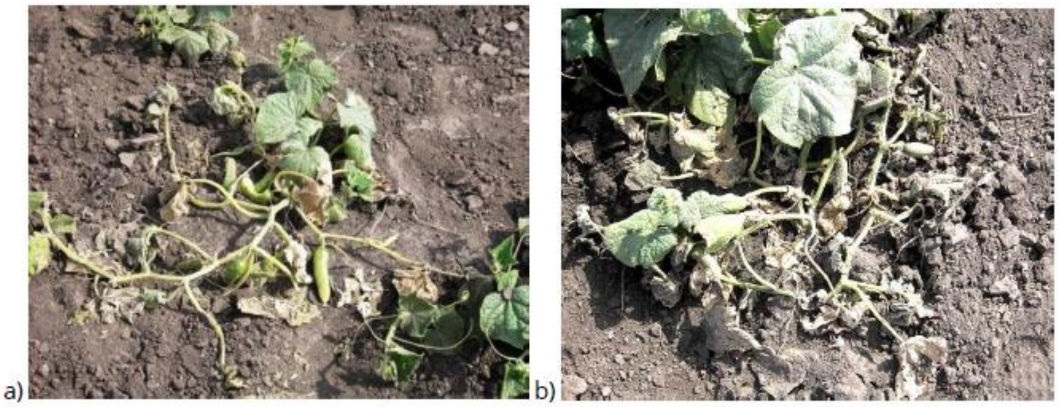

Fig. 5. Specific diagnostic symptoms of fusarium wilt expression on cucumber plants: a – most of the plant has wilted, b – the plant is underdeveloped, dwarf, the internodes are short, the leaves and fruits are small, drying out

When analyzing the specific seasonal combination of weather and climatic factors, it was found that the leading indicators of harmfulness – the intensity of spread (P, %) and the degree of the lesion (R, %) of cucumber samples of Gherkin type by a diseases complex, in particular downy mildew, under open ground conditions directly depended on two essential components: firstly, it depends on the peculiarities of the combination of the meteorological factors 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); secondly, it depends on the level of reaction expression of field (protracted) resistance to downy mildew of the studying cucumber breeding material (Fig. 6).

As can be seen from the indicators given in Table 2, the variability of the intensity value of development or prevalence (P, %) of downy mildew is different by the resistance of the breeding material of Gherkin hybrid 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 (mean of weighted average population indicator **=** 63 %) on breeding crops of cucumber of Gherkin hybrid 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 (Bondarenko, 2012; Bondarenko, 2013). As a comparative analysis showed, calculated by us the weighted average population intensity indicator (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).

Table 2. The intensity of development or prevalence (P,%) of the primary diseases, open ground cucumber – the end of the first decade of fruiting, %

Year	Downy mildew LV $\nu_{min} \div \nu_{max}$*	Angular bacterial spot disease LV $\nu_{min} \div \nu_{max}$	Fusarium wilt 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.

Thus, according to our research, it was established that the individual share of the contribution to the overall process of zonal pathogenic community formation of open ground cucumber of Gherkin hybrid (the frequency of occurrence of a biological object (Genta, Farnsworthb & Johnson, 2011)) 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. 7, Table 2).

In the future, we determined that between such valuable economic characteristics of cucumber of Gherkin hybrid 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).

We suggested that 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 (Chernenko et al., 2014). 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. 6 and section 3).

Fig. 6. The immunological reaction of a control breeding sample susceptible to downy mildew (Nizhynsky local variety, the last on the right, 2011)

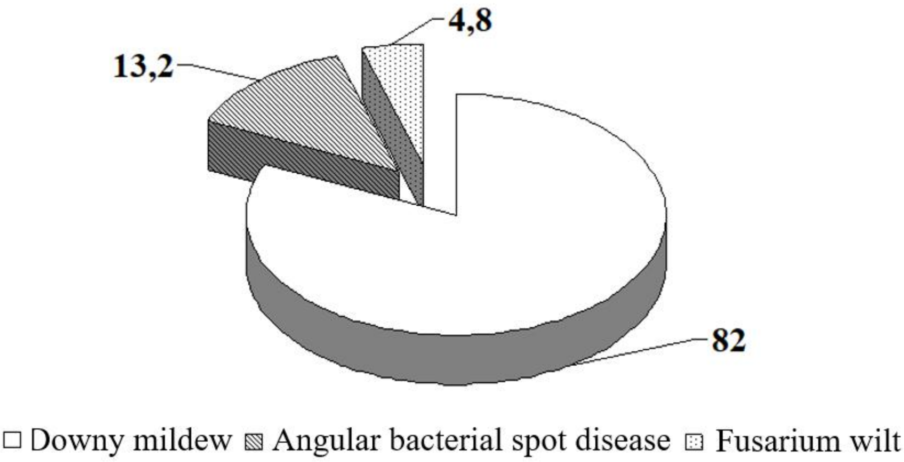

Fig. 7. Zonal pathogenic community of open ground cucumber of Gherkin hybrid, the individual share of the main diseases contribution, summarized for 2011-2013, %

Table 3. Characteristics of the development of the primary 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, the regime did not meet the traditional values of the long-term climate norm for the zone of conducting research.

The first visual lesion signs of cucumber samples of Gherkin hybrid 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 3).

Also, 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 3, Fig. 8).

Fig. 8. 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 pathogenic community of cucumber of Gherkin hybrid 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 the lesion (R, %) of breeding crops of Gherkin hybrid cucumber were usually recorded by us in the first decade of July.

This period 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 origins (Table 3). These facts once again confirmed the presence of an annual complicated natural infectious background of downy mildew in the research region (essential breeding and genetic center of Ukraine), indicating high representativeness of the conducted assessments of cucumber breeding material the protracted resistance trait. In the future, to confirm the above conclusion about the constant dominance of such disease of Gherkin hybrid 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 (Yarovij, G.I., Kulyeshov & Batova, 2010).

Comparing long-term changes in the list of cucumber diseases, the nature of their dynamics, variability of fundamental indicators of harmfulness in the open ground with the obtained experimental data are summarized in Table 4.

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 x weighted average population indicator – 27.8 %), the value of lesion degree of plants (R,%) – at the level of 2.2–27.4 % (x weighted average population indicator – 14.5 %) (Table 4). 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 two 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 %. This indicator's weighted average population value (weighted average population indicator) increased 2.5 times – from 14.5 to 35.6 % (Table 2, 4).

All this gives us reason to say that during the period from 1995 to 2013 in the research region, 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 epiphytotic) (Table 4). 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 two times (9.8 vs. 22.1 %), the average value of lesion degree of plants (R) in crops in recent years had been gradually increasing – from 11.1 to 17.4 % (more than 1.5 times) (Table 2, 4). Taking into account the obtained data, we specifically emphasize that determined by us tendency of gradual increase in the aggressiveness of bacteriosis in the pathogenic community 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 robust (Kritzman & Zutra, 1983; Kagiwata, 1991).

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 will note that long-term changes in the characteristic of the expression of weather and climatic conditions negatively (depressingly) affected the development and parameters of the harmfulness of such cucumber diseases like powdery mildew and anthracnose in zonal agrocenoses of cucumber of open-ground (Table 4).

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 hybrid (section 1 and Table 4). At the same time, when conducting monitoring studies of crops (Kompleksna..., 2012), no specific lesion symptoms of cucumber plants of Gherkin hybrid of the open ground by such a disease as powdery mildew were recorded during the study period (Table 4). Also, we have found that in recent years, the symptoms of manifestation of fusarium wilt – the primary pathogen is the fungus *Fusarium oxysporum* f. sp. *cucumerinum* are annually recorded on cucumber under open ground conditions (Gerlagh & Blok, 1988; Kompleksna..., 2012).

Table 4. 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. (Yarovij, G.I., Kulyeshov & Batova, 2010)			2011–2013 pp.		
	LV $\nu_{min} \div \nu_{max}$ / $\bar{x}$ weighted average population indicator		The nature of the disease development *	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) (Gerlagh & Blok, 1988).

Thus, according to our data, fusarium wilt in various types of its expression (fig. 5), for the period from 2011 to 2013, was annually found in cucumber crops of open-ground (Table 2). 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 % (x weighted average population indicator – 2.95 %), the indicator variability of the degree of plant lesion was by years from 0 to 9.8 % (x weighted average population indicator – 4.9 %) (Table 4). 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 primary 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's fusarium wilt should be added to the zonal list of potentially dangerous diseases of cucumber of Gherkin hybrid 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 pathogenic community of open ground cucumber of the Left-Bank Forest-Steppe of Ukraine, which served as the main argument for choosing it as the primary scientific objectives of our research.

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

Downy mildew belongs to a group of diseases, the fungi-like pathogen characterized by high reproductive capacity and can form several generations with conidial sporulation on cucumber plants during the growing season (Badr & Mohamed, 1999; Arauz et al., 2010). 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 epiphytoty. Under unfavorable weather and climatic conditions, the pathological process of this disease can develop relatively slowly in the research region (Morishita et al., 2003). According to literature data (Palti & Cohen, 1980), the main predictors that have the ability in a certain way to influence the development dynamics (depression, moderate, strong development, epiphytoty) 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. 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 (Granke & Hausbeck, 1995). 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 the 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 (Criswell et al., 2008). Based on the study 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. 9).

Studies have determined that downy mildew can 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 relaxed temperature regime at night and warm – in the daytime. This combination provided 4–8-hour moistening of the plant 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 3) 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).

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 3, Fig. 9). 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. The rapid spread of downy mildew was facilitated by the presence of 4-8-hour drip moisture on the surface of the plant's 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 3).

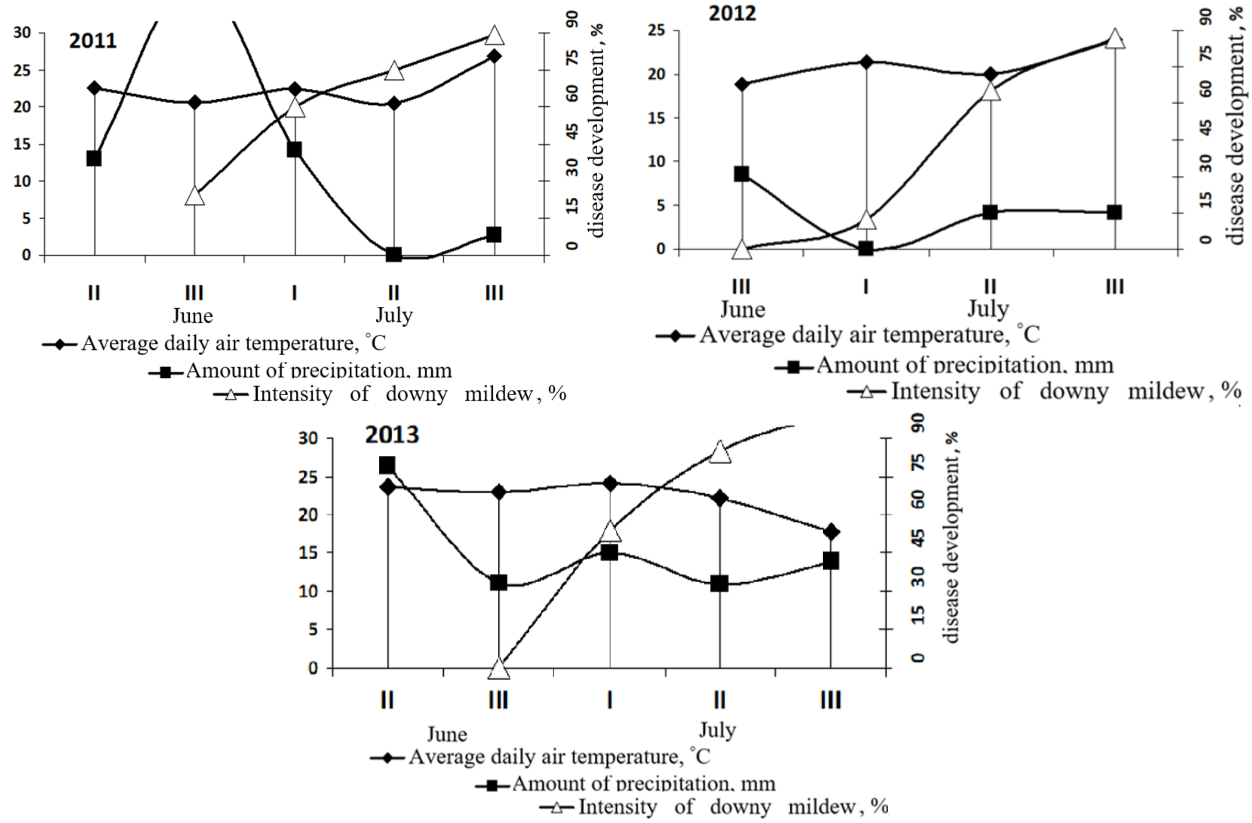

Fig. 9. Development of downy mildew of cucumber in the open ground depending on the weather conditions of the growing season of 2011–2013

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 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 hybrid (Tables 2, 4). Conducted statistical analysis of data on the intensity of cucumber downy mildew spread (P, %) under the open ground conditions proved 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 also affirm this (Table 5). According to the coefficients indicators of this Table, in all research years, we can 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 the 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 … 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 the intensity of downy mildew development (effective factor Y) in cucumber agrocenoses of Gherkin hybrid over the years is from 69 to 88 % (D × 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. Simultaneously, 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 the intensity of downy mildew development (Y) in cucumber agrocenosis of Gherkin hybrid in the years of research did not exceed values of 29–36 %.

It should be noted explicitly that the obtained correlation coefficients between this pair of traits prove that with an increase in the quantitative values of the parameter X2, the increase in the parameter Y annually falls under slight but still influence. It should be mentioned that earlier we have already started (see sections 1 and 2) that the first characteristic visual symptoms of the lesion and further spread of this disease in cucumber agrocenoses of Gherkin hybrid (Fig. 1) 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 growing intensity of the influential variable (Y) the rate of downy mildew spread in field crop rotation.

Table 5. 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, °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, °C	X_3*	-0,88	0,77	-0,92	0,85	-0,98	0,96
Decadal minimum air temperature, °C	X_4*	0,83	0,69	0,87	0,7	0,99	0,98
Decadal minimum soil surface temperature, °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", °C	X_7*	-0,90	0,81	-0,90	0,81	-0,86	0,74

*r_{min} at the 5 percent level = 0.811 (Osnovnye..., 1974)

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 (Dospehov, 1985) 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 of dew on the leaf apparatus of cucumber plants (factor X_7) (see Appendix B).

In our opinion, precisely 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 hybrid in field crop rotation under conditions of the Left-Bank Forest-Steppe of Ukraine in the research region (Table 3). 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 hybrid 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, while the minimum air temperature in this decade ranged from 15 °C (Fig. 10, Table 3, 6).

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 plant's 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. In our case, the more significant 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 period of the presence of drop-liquid moisture (dew) on the surface of the leaf apparatus was. This 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 °C, the relative air humidity was 45 %. The calculated dew point was 24 °C. Simultaneously, the average decadal value of the minimum air temperature was within 9 °C (Fig. 10, Table 3, 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 °C, relative air humidity – 66 %.

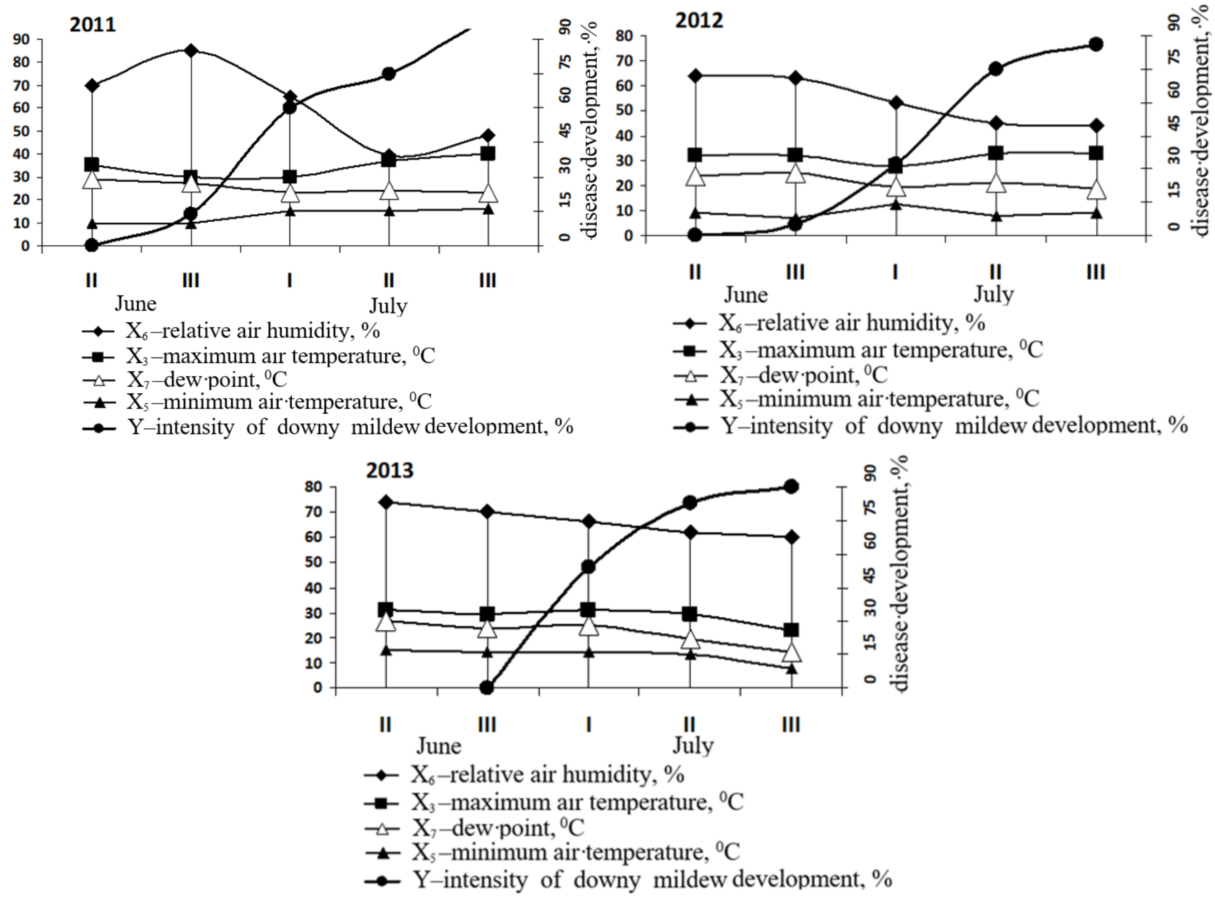

Fig. 10. Graphic representation of factorial factors contribute to the formation process of the intensity of downy mildew development and spread in cucumber agrocenosis in 2011–2013

Table 6. 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, ˚C X1			Amount of precipitation per decade, mm X2			Decadal maximum air temperature, ˚C X3			Decadal minimum air temperature, °C X5			Relative air humidity, % X6			Theoretically Calculated' "dew point", °C (http://planetcalc.ru/248/) X7		
	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

The calculated dew point is 28 °C. The decadal values of the minimum air temperature in this period had an average value of 16 °C. (Fig. 10, see Table 3). These results are confirmed by analyzing the classical phytopathological literature in this area of research (Cohen, 1977; Babadoost, Weinzieri & Masiunas, 2004). 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.

Conclusions

We specified the regional list of Gherkin hybrid cucumber diseases. It is established that the dominant position in the pathogenic community 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*). From 1995 to 2013, we found out that in the region of research, the nature of the dynamics of the main diseases development and spread was actively changing, particularly downy mildew – from moderate to strong. We 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 plant's leaf apparatus.

References

Arauz, L.F. et al. (2010). Quantitative models for germination and infection of Pseudoperonospora cubensis in response to temperature and duration of leaf wetness. Phytopathology, 100, 959–967.

Babadoost, M., Weinzieri, R.A. & Masiunas, J.B. (2004). Identifying and Managing Cucurbit Pests. The University of Illinois, 4–23.

Badr, L.A.A. & Mohamed, F.G. (1999). Inheritance and nature of resistance to Downy mildew disease in Cucumber (Cucumis sativus L.). Fac. of Agric. Moshtohor, Zagazig University (Benha Branch, Egypt.), 22.

Bondarenko, G.L. & Yakovenko, K.I. (2001). Metodika doslidnoyi spravi v ovochivnictvi i bashtannictvi. Harkiv: Osnova, 369 (in Ukrainian)

Bondarenko, S.V. (2011). Ogirok: suchasnij fitosanitarnij stan ta metodi zahistu vid hvorob. Visnik HNAU im. V.V. Dokuchayeva. Ser."Tehnichni, silskogospodarski, ekonomichni nauki", 6(1), 32–42 (in Ukrainian)

Bondarenko, S.V. (2012). Urazhenist ogirka nespravzhnoyu boroshnistoyu rosoyu (Pseudoperonospora cubensis Rostow): zb. nauk. prac mizh nar. nauk.-prakt. konf. ["Ovochivnictvo Ukrayini. Naukove zabezpechennya i rezervi zbilshennya virobnictva tovarnoyi produkciyi ta nasinnya"], Merefa, 2012 r. NAAN, IOB. Harkiv, Pleyada, 12–14 (in Ukrainian)

Bondarenko, S.V. (2013). Rezultaty ocenki ustojchivosti k peronosporozu linejnogo materiala ogurca kornishonnogo tipa: zb. tez nauk. prac mizhnar. nauk.-prakt. konf. ["Selekciya i tehnologichni innovaciyi v ovochivnictvi, rezervi zbilshennya virobnictva produkciyi ta nasinnya"], Merefa, 2013 r. NAAN, IOB. Harkiv, Pleyada, 17–18 (in Russian)

Bondarenko, S.V., Stankevych, S.V., Matsyura, A.V., Zhukova, L.V., Zabrodina, I.V., Rysenko, M.M., Golovan, L.V., Romanov, O.V., Romanova, T.A., Novosad, K.B., Klymenko, I.V. (2021). Major cucumber diseases and the crop immunity. Ukrainian Journal of Ecology, 11 (1), 46-54.

Chernenko, V.L. et al. (2013). Osobennosti vzaimosvyazi osnovnyh kachestvenyh i kolichestvennyh priznakov s vredonosnostyu peronosporoza u ogurca kornishonnogo tipa. Visnik HNAU im. V.V. Dokuchayeva. Ser. "Fitopatologiya ta entomologiy"», 10, 179–185 (in Russian)

Chernenko, V.L., Sergienko, O.V. & Bondarenko S.V. (2014). Zavisimost hozyajstvenno – cennyh priznakov ogurca kornishonnogo tipa ot ustojchivosti k peronosporozu. Zashita i karantin rastenij, 10, 44–45 (in Russian)

Chistyakova, L.A. & Biryukova, N.K. (2012). Ocenka selekcionnyh linij ogurca na ustojchivost k peronosporozu i muchnistoj rose. Gavrish, №1, 38–41 (in Russian)

Criswell, A.D. et al. (2008). Use of sporulation and other leaf and vine traits for evaluation of resistance to downy mildew in Cucumber. Cucurbitaceae. 2008, Proceedings of the IXth EUCARPIA meeting on genetics and breeding of Cucurbitaceae (Pitrat M, ed), INRA, Avignon (France), May 21-24th, 2008, 433–439.

Gannibal, F.B., Gasich, E.L. & Orina, A.S. (2011). Ocenka ustojchivosti selekcionnogo materiala krestocvetnyh i paslyonovyh kultur k alternariozam. Metodicheskoe posobie. Sankt-Peterburg, GNU VIZR Rosselhozakademii, 50 (in Russian)

Genta, D.H., Farnsworthb, J.L. & Johnson, D.A. (2011). Spatial analysis and incidence-density relationships for downy mildew on hop. *Plant Pathology*, 10, 26–37.

Gerlagh, M. & Blok, W.J. (1988). *Fusarium oxysporum* f.sp. *cucurbitacearum* n.f. embracing all formae speciales of *F. oxysporum* attacking cucurbitaceous crops. *Netherlands Journal of Plant Pathology,* 94 (1), 17–31.

Kirichenko, V.V. & Petrenkova, V.P. (2012). Osnovi selekciyi polovih kultur na stijkist do shkidlivih organizmiv: navchalnij posibnik; NAAN. Harkiv, In-t roslinnictva im. V.Ya. Yur'yeva, 320 (in Ukrainian)

Kompleksna sistema zahodiv zahistu ogirka vid shkidnikiv, hvorob i bur'yaniv (naukovo-praktichni rekomendaciyi) (2012). Harkiv, Pleyada, 24 (in Ukrainian)

Koshnikovich, V.I., Sherbinin, A.G. & Timoshenko, N.N. (2008). Peronosporoz ogurca. Novosibirsk, ZAO Novosibirskij poligrafkombinat (in Russian)

Litvinov, S.S. et al. (2011). Metodika polevogo opyta v ovoshevodstve. Moscow, Rosselhozakademiya, GNU VNIIO, 636 (in Russian)

Morishita, M. Et al. (2003). Review Powdery Mildew Resistance in Cucumber. JARQ, 37(1), 7–14

Nalobova, V.L. (2003). Immunologicheskaya harakteristika kollekcionnogo ta selekcionnogo materiala ogurca. Izvestiya Nacionalnoj akademii nauk Belarusi, 1, 42–44 (in Russian)

Nalobova, V.L. (2004). Vidovoj sostav i osobennosti ekologii gribov – vozbuditelej boleznej ogurca. Vesci Nacyyanalnaj Akademii navuk Belarusi. Seryya biyalagichnyh navuk, 2, 30–34 (in Russian)

Nalobova, V.L. (2005). Selekciya ogurca na ustojchivost k boleznyam. Minsk: Belprint, 200 (in Russian)

Ohorona prav na sorti roslin (2004). Metodika provedeniya ekspertizi sortiv na vidmitnist, odnoridnist i stabilnist (VOS). Kiyiv, Alefa, 56–66 (in Ukrainian)

Palti, J. & Cohen, Y. (1980). Downy mildew of Cucurbits (Pseudoperonospora Cubensis): the Fungus and its hosts, distribution, epidemiology and control. Phytoparasitica, 8(2), 109–147.

Sich, Z.D. & Medvedyeva, G.O. (2011). Korelyacijni zv'yazki mizh kilkisnimi oznakami gibridiv ogirka. Available from: http://archive.nbuv.gov.ua/portal/chem_biol/nvnau_ agro/2011/11szd.pdf (in Ukrainian)

Yachevskij, A.A. (1929). Spravochnik fitopatologicheskih nablyudenij, Leningrad, 133–139 (in Russian)

Yakovenko, K.I. (2001). Suchasni tehnologiyi v ovochivnictvi. Harkiv: IOB UAAN, 128 (in Ukrainian)

Yarovij, G.I., Kulyeshov, A.V. & Batova O.M. (2010). Shlyahi udoskonalennya meteopatologichnogo metodu prognozuvannya hvorob roslin. Visnik HNAU. Seriya "Fitopatologiya ta entomologiya", 1, 115–120 (in Ukrainian)

Yarovogo, G.I. (2006). Dovidnik z pitan zahistu ovochevih i bashtannih roslin vid shkidnikiv, hvorob ta bur'yaniv. Harkiv, Pleyada, 58–62 (in Ukrainian)

Zitter, T.A., Hopkins, D.L. & Thomas C.E. (1996). Compendium of Cucurbit Diseases, University of Illinois APS Press, 66, 25–27.

Citation:

Bondarenko, S.V., Stankevych, S.V., Zhukova, L.V., Horyainova, V.V., Poedinceva, A.A., Zhuravska, I.A., Kravchuk, A.V., Popova, L.M., Mamchur, R.M., Romanov, O.V., Romanova, T.A., Bragin, O.M., Hordiienko, I.M., Gepenko, O.V. (2021). Zonal pathogenic community formation of gherkin hybrid cucumber under open ground conditions. *Ukrainian Journal of Ecology, 11* (2), 327-339.