INFLUENCE OF AGROCLIMATIC CONDITIONS OF THE SOUTHERN UKRAINE ON THE GENERAL PHYTOSANITARY STATE OF THE MAJOR FARM CROPS

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Abstract

The analysis of the phytosanitary state of the main agricultural crops cultivated in the southern steppe of Ukraine was carried out. The main diseases were determined and the species composition of pathogens was clarified. The extent and development of the pathogens in the field against the natural infectious background was assessed. The dominant species were identified. The contributing factors to the development and spread of diseases were analyzed.

Keywords: sunflower, soybean, pea, corn, cereals, diseases, pathogens, species composition, extent and development degree.

Introduction

Ukraine is one of the leading European countries in the cultivation and export of agricultural products. Important crops are legumes, sunflower, and corn. The leading place among the measures aimed at achieving the potential yield of agricultural crops belongs to the integrated system of protection against a number of diseases and pests. This system is based on the operative analysis of the phytosanitary condition of crops to timely implement the necessary protection measures. It is essential to annually monitor the spread and intensity of major diseases. The species composition of pathogens and their ratio is constantly changing due to different genetic resistance of varieties against pathogens, climatic conditions, and increased imports of soybean seeds, which is a real prerequisite for the import of a number of dangerous quarantine pathogens. Among the crops grown in Ukraine, sunflower, corn, and legumes are gaining importance. A characteristic feature of the agricultural development in recent years is non-compliance with the crop processing technologies, reducing the use of pesticides, and violation of agricultural culture. This leads to changes in the ecological state not only for the cultivated plants, but also for pests, and negatively affects the phytosanitary processes in agrocenoses. In addition, the phytosanitary situation is complicated in terms of the global warming, leading to mass reproduction of pests and some mycopathogens.

Sunflower is an important export crop for Ukraine, which is widely used in the food industry and other sectors of the economy. With rational cultivation technologies and favorable agro-climatic conditions, the yield of sunflower reaches 30 dt/ha. Sunflower yields are significantly affected by such negative factors as the development of diseases, pests, and weeds. At the present stage of production, the average yield of sunflower is at the level of 20-22 dt/ha. This is due to the sowing of insufficient quality seed material, non-compliance with the cultivation technologies, different genetic resistance of varieties to phytopathogens, climatic conditions, etc. [1, 2].

Soybeans rank first in the world among the legumes. It is sown in more than 40 countries on an area of 42 million hectares. In the future, Ukraine plans to sow 2 million hectares with this crop. Soybean oil is one of the major oils in the world production of vegetable oils. It is used in the food, textile, and chemical industries. Though the cake and meal are more valuable than oil. The infectious diseases that affect the vegetative plants and beans have a significant negative impact on the plants and soybean yields [1, 3].

Pea is an important legume, the grain of which is an integral part of human nutrition, as well as the feed for farm animals. From the agrotechnical perspective, the pea improves the fertility of the soil, and it is especially important in case of short supply organic and mineral fertilizers. In the range of legumes for gross grain harvest, peas occupy up to 25 %. The potential yield of the modern varieties of peas in Ukraine is 3,0-5,5 t/ha, but it is limited by the development of harmful organisms [1, 4].

Corn is an ancient bread plant that the Old World learned about relatively recently—only about 500 years ago. For Ukraine, corn is an important fodder crop as well. Due to it, the food industry and animal husbandry are provided with plant products for fresh use and processing, with the concentrated feed, silage, and green mass. The fulfillment of the potential productivity of corn is often limited by the development of infectious diseases. The diseases are detected and develop in corn not only during the growing season of plants, but also during the storage of cobs and grains. The degree of plant damage and harmfulness of the diseases depend on the biological characteristics of pathogens, hybrid composition, weather conditions, agricultural techniques, as well as the protection measures used [1, 5].

An important stage that allows to achieve the potential yield of crops is a comprehensive system of protection against diseases, pests, and weeds as well the timely implementation of the necessary measures. The timeliness of protective measures is based on rapid information on the phytosanitary condition of crops. The analysis of the phytosanitary condition allows to determine the species composition of pathogens, the prevalence and intensity of disease in the dynamics. Depending on the varietal composition of plants and agro-climatic conditions of a particular growing season, the epiphytothiological indicators of diseases change, and some of them may become very dangerous and become widespread [2, 3, 4, 5].

In Ukraine, various varieties and hybrids of **sunflower** of domestic and foreign production, different groups of maturity, different groups of resistance to herbicides are grown. Under favorable weather conditions and with a proper agricultural background, the sunflower yield can reach over 30 dt/ha. But in the absence of crop rotations and agronomic measures, with lack of funds for mineral fertilizers and chemicals for crop treatment against pests, the yields are significantly lower. An important reason for the decline in yield of sunflower in the areas of cultivation is the spreading dangerous diseases such as white (*Whetzelinia sclerotiorum (dBy) Korf. et Dumont*.) and gray *(Botrytis cinerea Fr*.) rot, downy mildew (*Plasmopara helianthi Novot. f. Helianthi Nova*), rust (*Puccinia helianthi Schw*.), verticillium (*Verticillium dahlia Kleb*.), and broomrape (*Orobanche Cumana Wallr*.). Septoria blight (*Septoria helianthi et Keel*.), alternaria blight (*Alternaria Nees*), phoma rot (*Phoma helianthi Aleks*.) as well as viral and mycoplasma diseases also occur. By 2002, a special issue in the internal and external quarantine in Ukraine was the phomopsys blight (*Phomopsis helianthi)* or dark gray stem blight which significantly impacted the sunflower [2].

In corn, one of the most harmful diseases found almost everywhere was the boil smut (*Ustilago zeae Unger*). Perhaps the most harmful is head smut (*Sorosporium reilianum McApl.f*). Sugar varieties and hybrids of corn are very susceptible to rust (*Puccinia sorghi Schw*.). The plants grown from seeds affected by cephalosporosis or blackening of vascular bundles (*Cephalosporium acremonium Cda*) do not bear fruit. The white-yellow striped spot, or sclerosporosis (*Sclerospora maydis Butler*) can cause a reduction in green mass and seeds by up to 10 %. Under the conditions of excessive moisture and elevated temperatures, especially in the late crops of corn brown spot, or helminthosporiosis (*Dlechslera turcica*) develops. The affected and infected seed remains become the sources of dry rot (*Diplodia zeae Lev*.). The fungus can stay in the remains of plants in the soil for 3-4 years. Delayed harvesting of corn causes the development of dry rot on the cobs. Very common are stem and root rot, Fusarium blight (*Fusarium gen. fungi*), charcoal rot (*Sclerotium batoticola Taub*.), white rot (*Whetzelinia sclerotinia*), and bacterial stem rot (*bacteria Pseudomonas holci*

Kendr., Erwinia carotovora pv. Carotovora Bergey et al. i Erwinia dissolvens Beorkh.). During ripening and storage, the following diseases of cobs and seeds spread: Fusarium blight (*Fusarium Lsnk*), minute leaf and grain spot (*Nigrospora oryzae Petch*), red rot (*Fusarium graminearum Schwabe*), gray mold (*Rhizopus maydis*), ear bacteriosis disease (*Bacillus merentericus*), cobs and grain mold (gray-green mold, dark mold, pink mold). In addition to these bacterial diseases, there are bacterial stem rot and heads bacteriosis, known bacterial spot (*Pseudomonas syringae pv. syringae Young et al.*), bacterial leaf mottling (*Corynebacterium michiganse pv. nedraskense Young et al.*), and bacterial wilt of maize (*Erwinia stewartii (Smith) Dye (Aplanobacter stewartii Mc.Cull.).* The latter is a quarantine object for Ukraine. Eight viral diseases of corn have been registered, most of which are common in tropical and subtropical regions. In Ukraine, only three viral diseases of corn were detected—the Siberian oats mosaic virus, the maize streak virus, and the dwarf mosaic virus (maize and sorghum redstripe virus). Among the infectious diseases of corn, the most harmful are volatile and vesicular smut, root and stem rot, and Fusarium head blight. Selection of self-pollinated lines and hybrids varieties resistant to these pathogens is the most cost-effective and environmentally safe way to combat these diseases [5, 6].

Peas and soybeans are badly damaged by pests, diseases, and weeds. In Ukraine, the potential loss of legumes from pests is about 10 million tons or 20 % of the gross grain harvest. This convincingly shows that even partial loss prevention is an important factor in increasing the productivity of legumes. The study of the phytosanitary condition of the soybean and pea crops is an extremely important task to increase their yield. To do this, it is necessary to conduct annual monitoring to identify and determine the number of major pests and diseases.

The pathogenic microflora of soybeans of the Southern Steppe of Ukraine consists mainly of the pathogens of fungal diseases, as climatic conditions, high temperature, and minimum humidity contribute to their mass spread and development. The most dangerous and common soybean disease is Fusarium blight (Fusarium oxysporum). Every year, soybean crops are increasingly affected by this disease. This is facilitated by non-compliance with crop rotation, abiotic factors, in particular early sowing in poorly aerated soil, which leads to the accumulation of soil infection and seedling death rate of up to 40 %. Since 2002, new soybean diseases have been diagnosed in the Odessa region—ash rot (*Macrophomina phaseolina (Tassi.) Goid.*) and phomopsis blight (*Diaporthe phaseolorum (Cke. et Ell) Sacc. Var. Sojae Wehm.)*. In 2002–2004, ash rot occurred only on single plants, but in the subsequent years it spread, especially during drought years, causing a crop failure of up to 20–35 %. Quite common in crops culture is anthracnose (*Colletotrichum dematium (Pers. ex Fr.) Grov var. Truncatum (Schw.) Arx*), ascochita leaf blight (*Ascochyta phaseolorum Sacc.*), false mildew (*Peronospora manshurica (Naum.) Syd.*), Septoria blight (*Septoria glycines T. Hemm.*), and verticillium (*Verticillum dahliae Kleb.*). Less common bacterial diseases of soybeans include angular (*Pseudomonas glycinea* Coerper) and pustule chocolate spot (*Xanthomonas phaseoli* var. *sojense* (Hedges) Starr et Burkh), and the viral diseases such as rugose (*Soja virus 1* Smith.) and yellow mosaic (*Phaseolus virus 2* Smith.) [4, 5, 7].

Fungal diseases of peas are very diverse. The most common of these are Fusarium blight. Fusarium blight of seeds, shoots, and young plants (*Fusarium gibbosum Appel et Wr.*). Fusarium blight of leaves (*Fusarium ssp.*). Fusarium blight of root system (*Fusarium ssp.*). Fusarium-related wilting of plants (*Fusarium oxysporum (Schl.) Snyd. et Hans.*). Fusarium blight of beans and seeds (caused byt *Fusarium* ssp.). Anthracnose (caused by *Colletotrichum dematium (Pers. et Fr.) Grov.* Truncatum (Spcw.) Arx.). Ascochytosis (caused by *Ascochyta phaseolorum Sacc. of Sphaeropsidales order*), the false powdery mildew or downy mildew (*Peronospora manshurica (Naum.) Syd. of Peronosporales order. Septoria* blight, or rusty spot (caused by *Septoria glycines T.*Hemm), verticillium (caused by *Verticillum dahliae* Kleb.). The bacterial diseases of peas are chocolate angular spot (caused by bacterium *Pseudomonas glycinea Coerper*), pustular spot (caused by *Xanthomonas phaseoli*, var. sojense (Hedges) Starr et Burkh.) [4, 5, 7].

Methodology

Aim. To analyze the phytosanitary condition of the main crops grown in the Southern Steppe of Ukraine. Determine the species composition of the pathogens, the degree of their spread and development, the dominant species, and the factors that contribute to the spread of diseases.

Materials and methods. The analysis of phytosanitary condition of soybeans and sunflowers was carried out during 2012-2019 in the field conditions of the experimental base of the Breeding and Genetic Institute, National Center for Seed Science and Variety Research of NAAS (SGI—NC NA) "Dachna" (Bilyaiv rayon, Odessa oblast). Analysis of the phytosanitary status of corn and peas for 2018-2019 was conducted in farms of Odessa oblast; the laboratory study was conducted by the Department of entomology and plant pathology of Plant Breeding and Genetics Institute and by the Department of Protection, Genetics, and Plant breeding of Agro-biotechnology Faculty of OSAU.

Agroclimatic conditions of the southern steppe of Ukraine are quite favorable for the growth and development and seed production of sunflower, soybean, pea, and corn. The experimental plots were located on a typical plain relief on the southern and ordinary chernozems. The climate is mostly warm and arid. The average annual temperature ranged from 4 to 7.7 °C. The frost-free period lasts from 170 to 210 days. The annual precipitation is 350–460 mm. The natural conditions are favorable for the development and spread of major diseases of crops, especially fungi. For the development of diseases, of great importance were the meteorological conditions during the growing season. The growing seasons (April to August) of the years of observations in the southern steppe of Ukraine were characterized by sharp temperature drops, lack of precipitation in spring, and high temperatures in summer.

The material of the study were 23 varieties and hybrids of sunflower, 35 variety samples of soy of foreign and domestic breeding from the collection of Plant Breeding and Genetics Institute, National Center of Seed Breeding of NAAS, 2 hybrids of peas, and 2 hybrids of corn from the working farms in area. The resistance of samples to the disease was evaluated on the natural infectious background. For the accumulation of soil infection, the constant crops in the fields with plant residues were used. The affection of plant disease was determined visually by conventional techniques of field experiments. During the phytopathological assessment the external visual observation with a microscope and the biological analysis were used. The visual examination revealed spots and pathological changes in organs and tissues without fungi sporification. The analysis of affected tissues was performed using anatomical method with sections of necrotic tissue and study under a binocular microscope (x2, x4) and a monocular microscope (x20, x40). This material was selected for further study using a biological method, which allowed to detect internal infection in the plant material and isolate it as a pure culture. The affected tissue was incubated for 3–8 days on a nutrient base in a moist chamber. The sunflower disease agents were determined by the spores detected. Based on the obtained results, the prevalence and intensity of sunflower disease were calculated according to the generally accepted methods [6, 7, 8, 9, 10].

Since each crop is affected by many diseases, many of which have similar symptoms, in order to avoid the recurrence of common features of similar diseases, they were considered by type of lesion [8, 9, 10, 11].

The results of research

While analyzing the degree of damage to sunflower, corn, soybean, and pea by pathogens, it should be borne in mind that the research took place in typical soils in the climatic conditions of the southern Ukraine, namely—Odessa region, characterized by deep groundwater and hot, dry summers. Among the diagnosed pathogens, fungi predominate, because even a certain minimum of moisture in the soil contributes to their active development and accumulation in the soil. The species composition of pathogens is constantly changing, which is due to a number of reasons, such as the genetic resistance of the variety to pathogens, the agro-climatic conditions of cultivation, and the pest damage. The main indicators of phytosanitary condition of sunflower, corn, soybeans, and peas are shown in Figures 1–4.

I. PHYTOSANITARY STATE OF SUNFLOWER UNDER THE CONDITIONS OF THE SOUTH OF UKRAINE

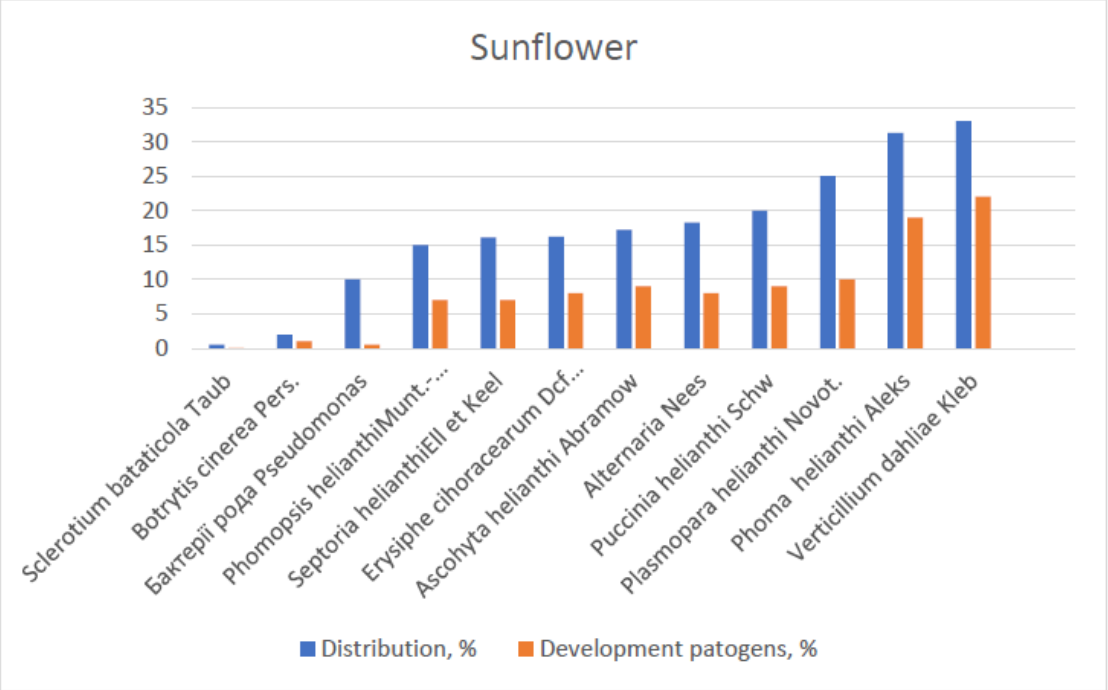

Fig. 1. Distribution and Development of Sunflower Diseases, %

As a result of the analysis of the phytosanitary state of the sunflower agrocenoses, the species composition of sunflower pathogens under the conditions of the Black Sea Steppe of Ukraine has been established. Eleven pathogens, mainly of fungal origin, have been diagnosed. During the growing season, leaf spot, phoma rot, phomopsys blight, alternaria blight, ascochita blight, and septoria blight was detected; in adult plants in the flowering and filling phase—gray rot, powdery and false mildew, and rust were detected. The development of tracheomycosis—verticillium wilt—was observed everywhere with some bacterial wilt. In the sunflower agrocenoses, the most common were the representatives of mycoflora:

Phoma helianthi Aleks, *Verticillium dahliae Kleb*. At the average level, the saprophytic microflora: *Ascohyta helianthi Abramow, Alternaria Nees, Septoria helianthiEll et Keel*. In few instances—*Erysiphe cihoracearum Dcf helian, Plasmopara helianthi Novot, Puccinia helianthi Schw, Phomopsis helianthi Munt.-Cwet.* Bacteria of the genus *Pseudomonas* and the basket form of *Botrytis cinerea Pers* were diagnosed in single cases.

I. PHYTOSANITARY STATE OF SOYBEAN UNDER THE CONDITIONS OF SOUTH OF UKRAINE

The analysis of phytosanitary state of soybeans under the conditions of the south of Ukraine is given in Figure 2.

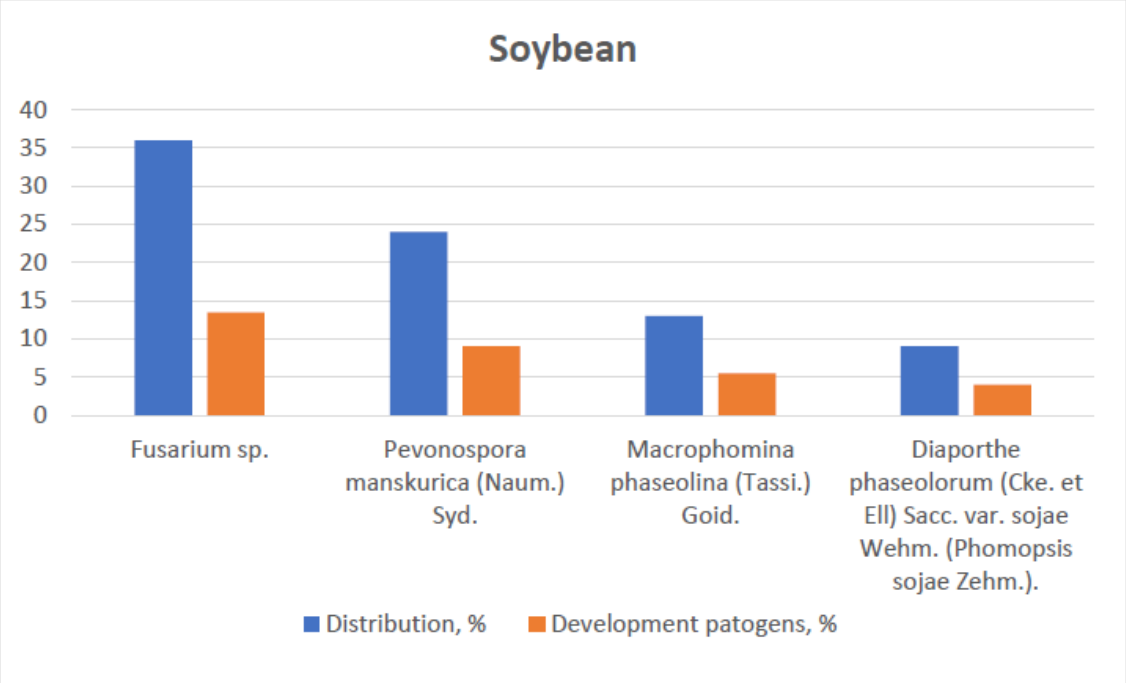

Fig. 2. Prevalence and Development of Soybean Diseases, %

While analyzing the phytosanitary state of the soybean varieties in the southern steppe of Ukraine, we determined the species composition of pathogens of their diseases. 4 main pathogens, mostly of fungal origin were diagnosed. The most common disease was Fusarium blight in young crops, the least developed was phomopsis blight. Fusarium blight of seedlings and root rot (caused by *Fusarium sp.*) were found on the sprouts with the average spread of the disease of 36.0 % at the development of 13.5 %, the maximum reached 68.8 % of the spread. False powdery mildew was diagnosed on plants in the flowering phase (peronosporosis caused by *Peronospora manskurica (Naum.)*), which affected 24.0 % of plants with the development of 9.0 %. In the ripening phase of beans, ash rot (caused by *Macrophomina phaseolina (Tassi.)*

Goid) was determined at the level of 13.0 % with prevalence with a development of 5.5 %. On the formed beans, phomopsis (stem and bean burns) (caused by *Diaporthe phaseolorum (Cke. et Ell) Sacc. var. sojae Wehm. (conidial stage Phomopsis sojae Zehm.)* was determined, which affected 9.0 % of plants with the development of 4.0 %.

III. PHYTOSANITARY STATE OF CORN UNDER THE CONDITIONS OF THE SOUTH OF UKRAINE

The analysis of phytosanitary state of corn under the conditions of the south of Ukraine is given in.

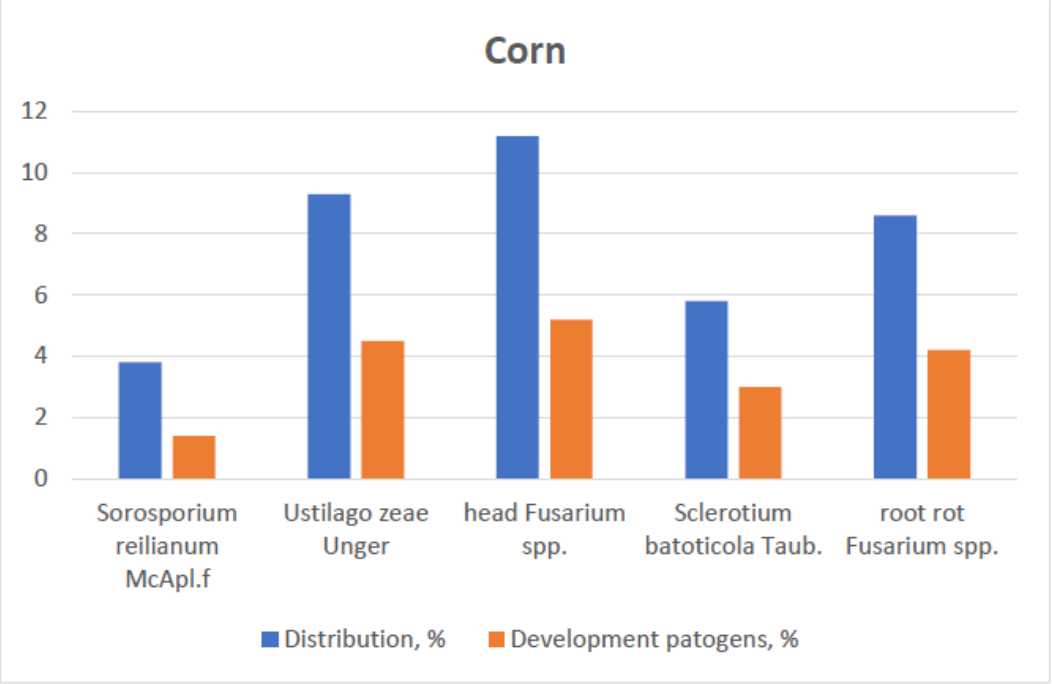

Fig. 3. Prevalence and Development of Corn Diseases, %

The main diseases identified in corn were volatile and vesicular smut on heads, which turned them into a black mass of teliospores. Their prevalence was 3.8–6.9 % of volatile smut and 9.3–10.2 % of vesicular smut. Fusarium head blight was detected in 11.2–12.6 % of cases. Stem rot (charcoal rot) was observed in 5.8– 8.1 % of plants, root rot (fusarium rot) in 8.6–13.8 % of plants. In the table, it is clear that "Kremen 200SV" hybrid is more susceptible to all common diseases than "Odeskiy 346MV" hybrid.

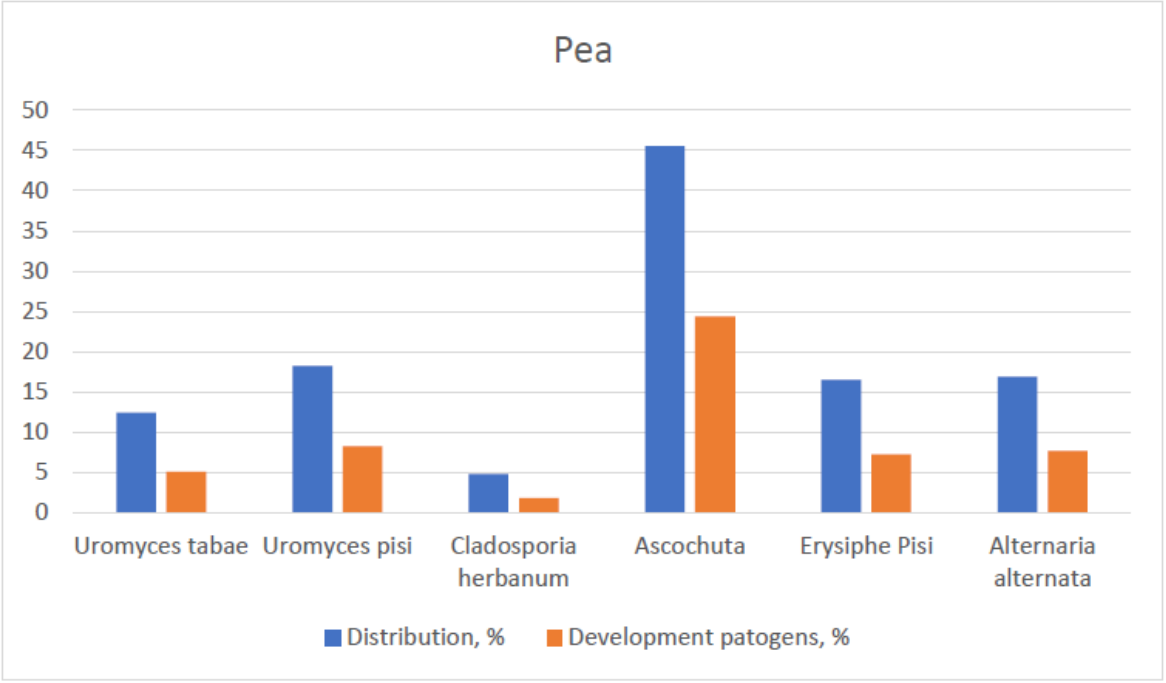

Fig. 4. Prevalence and Development of Pea Diseases, %

Summarizing the research data of 2018–2019, we can identify the trends in the spread and development of diseases. Comparing the varieties "Intensivny 92" and "Pelushka", we can conclude that there are no differences in the species composition of the diseases: 6 pathogens were identified, mainly of fungal origin. On both varieties during the study, massively development of ascochitosis (45.5–55.4 %) was observed with the extent of 24.4–28.65 %.

At the average level of prevalence was the pea rust (18.2–21.2 %) with the development of 8.25–9.9 %. Powdery mildew had a distribution of 16.5–21.55 % with the development of 7.25–9.6 %. Alternaria was observed in 16,9–18,9 % of samples with the development of 7,7–7,95 %. Legume rust was observed in 12.4–11.35 % of samples with the development of 5.05–4.8 %.

The lowest development was in olive mold (4.8 %) with the development of 1.8–1.95 %.

Comparing the varieties with each other, we observe a tendency to higher development of diseases in the variety "Pelushka" than in the variety "Intensivny 92". Comparing the prevalence of ascochitosis in the varieties, we observe a lower rate in the variety "Intensivny 92" (45.5 %) than in the variety "Pelushka" (55.4 %). The development, respectively, was 24.4 % in "Intensivny 92" and 28.7 % in "Pelushka".

Conclusions

The pathogenic microflora of the southern steppe of Ukraine consists mainly of the pathogens of fungal diseases, as climatic conditions, high temperature, and minimum humidity contribute to their mass spread and development. The most common in the **sunflower agrocenoses** were phoma rot (*Phoma helianthi Aleks*), verticillium (Verticillium dahliae Kleb), ascochita blight (*Ascohyta helianthi Abramow*), alternaria blight (*Alternaria Nees*), Septoria blight (*Septoria helianthi et Keel.*), also there were mildew (*Erysiphe cihoracearum Dcf helian*), false mildew (Plasmopara helianthi Novot), rust (*Puccinia helianthi Schw*), and

phomopsis blight (*Phomopsis helianthi Munt.-Cwet*). Bacteria of the genus Pseudomonas and the basket form of Botrytis cinerea Pers were diagnosed in single cases.

In the soybean agrocenoses, there were diagnosed 4 pathogens, mainly of fungal origin: fusarium germination and root rot (*Fusarium* sp.), downy dew (*Pevonospora manskurica* (Naum.)), ash rot (*Macrophomina phaseolina* (Tassi.) Goid), phomopsys (burns of stems and beans) (*Diaporthe phaseolorum (Cke. et Ell) Sacc. var. sojae Wehm. (conidial stage Rhomopsis sojae Zehm.*).

In the corn agrocenoses, there were identified five pathogens, mainly of fungal etiology such as: fusarium head blight (fungi of the genus *Fusarium*), boil smut (*Ustilago zeae Unger*), root rot (fungi of the genus *Fusarium*), stem rot (*Sclerotium batoticola Taub.*), and volatile smut (*Sorosporium reilianum McApl.).*

In the pea agrocenoses, there were identified ascochita leaf blight (*Ascochyta phaseolorum Sacc.*), pea rust (*Uromyces pisi*), powdery mildew (*Erysiphe pisi*), alternaria blight (*Alternaria alternata*), bean rust (*Uromyces fabae*), and olive mold (*Cladosporia herbanum).*

References

1. Kutsenko O. M., Dmitryshak M. Ya., Lyashenko V. V., The Most Common Agricultural Crops of Ukraine. Cereal Grains, Legumes. Tuber Crops: Study Guide [Найпоширеніші сільськогосподарські культури України. Зернові колосові, бобові. Бульбоплоди: Навчальний посібник] (in Ukrainian) — Poltava: FOP Govorov S. V., 2015. — 80 pp. with figures

2. Balan H. O., Prevalence and Species Composition of Sunflower Diseases Pathogens [Розповсюдженість та видовий склад збудників хвороб соняшнику] (in Ukrainian) / H. O. Balan // Collected papers of Institute of Oilseed Crops, UAAS. — Zaporizhya, 2001. — Vol. 6. — pp. 131–137.

3. Tsykov V. S., Corn: Technology, Hybryds, Seeds [Кукуруза: технология, гибриды, семена] (in Ukrainian. — Dnipropetrovsk, Zorya, 2003. —-296 pp.

4. Pospelova G. D., Species Composition of Phytopathogenic flora of Soybean Seeds [Видовий склад фітопатогенної флори насіння сої] (in Ukrainian) / G. D. Pospelova, Bulletin of the PSAA, 2015. — № 1–2. — Pp. 44–48.

5. Polozhenets V. M., Popova L. V., Pathogenesis of Plant Diseases: Studu Guide [Патогенез хвороб рослин: Навчальний посібник] (in Ukrainian). — Zhytomyr: Ruta Publ., 2015 — 216 pp.

6. Balan H. O., Tkachyk S. O., Orlenko O. N., Bushulyan O. V., Analysis of Phytosanitary State of Crops of Different Varieties of Soybean under the Conditions of the Southern Steppe of Ukraine [Аналіз фітосанітарного стану посівів різних сортів сої в умовах Південного степу України] (in Ukrainian) / Balan H. O. // Variety Study and Protection of Plant Variety Rights: Scientific and Practical Journal [Сортовивчення та охорона прав на сорти рослин: науково-практичний журнал]. — Kyiv, 2018. — Vol. 14(3). — Pp. 295–301.

7. Petrenkova V. P., Chernyaeva I. M., Markova T. J. et al. Seed Infection of Field Crops [Насіннєва інфекція польових культур] (in Ukrainian). — Kharkiv: Magda LTD, 2004. — 54 pp.

8. Dospakhov V. A., Methodology of Field Tests [Методика полевого опыта] (in Russian) / Dospekhov V. A. // M.: Kolos, 1979. — 415 pp.

9. Bilay V. i., Methods of Experimental Mycology [Методы экспериментальной микологии] (in Ruaaian) / Bilay V. I. — Kiev, Naukova Dumka, 1982. — 487 pp.

10. Methods of Identification of Phytopatogenic Fungi (Method. Instr. for Scient. Work) [Методы идентификации фитопатогенных грибов (Метод. указ. для науч-исслед. роботы студентов)] (in Russian) — Moscow, 1984. — Pp. 12–13, 17–31.
11. Methods of Phytopathological Study of Artificially Infected Plants [Методика проведення фітопатологічних досліджень за штучного зараження рослин] (in Ukrainian) / ed. by Tkachyk S. O.: TOV Nilan-LTD, 2014. — 76 pp.