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Impact of environmental degradation on the development of moniliosis: A case study of apple orchards in the Almaty region, Kazakhstan

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ABSTRACT

Monilinia fructigena Pers is a specialized fungus known for its impact on pome crops, particularly during the fruiting phase. This pathogen is responsible for causing significant damage through fruit rot, affecting fruit quality and economic outcomes for growers. The primary objective of this research was to comprehensively investigate *M. fructigena* Pers, its distribution, and its effects on various fruit crops. Additionally, the study aimed to identify other fungal species associated with fruit rot and assess varietal resistance among different fruit tree varieties. Between 2021 and 2023, isolates of fungi belonging to the *Monilinia* genus were collected from fruits, inflorescences, shoots, and fruit formations of apple trees affected by moniliosis. Identification was conducted using polymerase chain reaction with species-specific primers and sequencing of the ITS 1-5.8S rRNA-ITS 2 locus of ribosomal DNA. The prevalence and impact of *M. fructigena* Pers and other identified fungi were analyzed. *M. fructigena* Pers was found to be the dominant fungus, with a frequency of occurrence ranging from 91.6 to 100%. This fungus was responsible for damage to inflorescences, shoots (monilial burn), and fruits (fruit rot). Other fungi, such as *Fusarium proliferatum* and *Alternaria alternata*, were also identified. Quarantine species *M. fructicola* was not found in the research orchards. In addition, varietal resistance experiments revealed differing susceptibility levels among apple tree varieties, with the Maksat variety being more susceptible than Voskhod. In conclusion, *M. fructigena* posed a significant threat to fruit crops, particularly pome varieties, in the studied regions. The research shed light on its prevalence, distribution, and impact. In addition, the identification of other fungal species associated with fruit rot provided valuable insights into disease management. The variable varietal resistance underscores the challenges of breeding for fruit rot resistance and highlights the importance of continued research in this area for more effective disease control strategies.

Keywords: Fruit resistance, Fungal diseases, Horticultural practices, Rot disease, climate change.
Article type: Research Article.

INTRODUCTION

Moniliosis of pome fruits is considered a widespread disease. According to Verigo (2020), this disease causes especially great harm to orchards in Ukraine, the Russian Federation, and Kazakhstan. In the regions of the Middle Volga region, the Far East, Armenia, and some other regions, along with fruit rot, there is often a lesion of fruit formations like spurs and dards. Individual researchers (Shukhin & Kuznetsova 2019; Álvarez-García *et al.* 2023) indicated that moniliosis (caused by *Monilinia fructigena* and *Monilia cinerea*) results in wilting of inflorescences and ovaries. According to (Mang *et al.* 2022) in *M. cinerea* f. *mali* causes moniliosis in the apple tree. Besides inflorescences, ovaries, and fruits, the fungus affects young leaves. Reddish dots appear on them from a fungus lesion. The resulting spot increases rapidly and passes to the central vein of the leaf. Along the stem, the fungus reaches the base of the inflorescences and causes it to rot. Some authors (Kolytaitė *et al.* 2022) noted that the fungus *M. fructigena* is capable of infecting fruits of stone fruit crops, especially plums. Most researchers distinguish two specialized forms of this fungus: *f. mali* and *f. pruni*. *Monilinia laxa* Ehr. (*M. cinerea*) f. *pruni*

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affects various fruit crops, while *M. laxa* f. *mali* affects only the apple tree. Foreign authors describe the ascigerous stage of the fungus of the fruit rot pathogen, i.e., *M. fructigena* or *Sclerotinia fructigena* on pome and some stone fruit crops, as well as *Monilinia fructicola* on sour cherry and sweet cherry fruits. In Ukraine and the Caucasus, the fungus *Monilia linhatiana* Sacc. (*Ovularia necons* Sacc.) develops on the leaves and young shoots of quince, while the fungus *Monilia folicola* Woronich develops on pear leaves. The fruits of the apple tree in these conditions are also affected by the species *Monilia candida* Bonord. *Monilia sitophila* Sacc. is found on seeds of various tree species, including apple trees. The causative agent of moniliosis on an apple tree can be not only the fungus *M. fructigena* but also *M. cinerea*, which mainly affects stone fruit crops. Besides that, *M. fructigena* Pers ex has a broader specialization and affects the fruits of apple, pear, plum, grape, hawthorn, magnolia-vine, actinidia, and oleaster. In the European part, in Moldova, in addition to pome crops, it often affects plum fruits. In addition to rotting fruits, it causes monilial blight, i.e., rapid drying of buds, flowers, leaves, shoots, and branches. Its expression is especially interesting in spring in wet and warm weather. The incubation period of the disease (from infection to the onset of putrefaction) can be very short, only 3-5 days, while the period from infection to the appearance of sporulation is on average 8-10 days. In the southern regions of the Primorsky Territory, 2-4 days in the arid regions of Central Asia, the incubation period of the disease may increase to 7-8 days. The mycelium that has begun to develop on fruits usually spreads evenly in all directions from the site of infection, and therefore the conidial sporulation pustules are located on fruits in regular concentric circles. The most rapid development of the fungus is observed at a temperature of 24-28 °C. In conditions unfavorable for the development of rot (relatively low or, conversely, too high temperatures, very dry air, etc.), conidial sporulation on the surface of the fruit may not develop. In this case, the rot-affected fruit very quickly acquires a black (or bluish-black) color, and in some conditions, the affected fruit acquires a varnished smooth surface. Losses from apple fruit rot during cultivation and storage amount to 10-20% in Poland, Georgia, Moscow region, Kazakhstan, and 65% in Latvia. The species composition of the pathogens of rot is quite diverse. The most common types are fruit rot frog-eye rot, bitter rot, pink rot, and blue or green mold. In Turkey and South Africa, fruit rot is caused by the fungus *Alternaria alternata* (Ahmad *et al.* 2020). The researchers note that the main factor of fruit damage by *Monilinia* is mechanical damage caused by hail, followed by cracking of the fruit skin and damage to the fruits caused by *Rhagoletis cerasi* and other insects. Fruit rot is carried by brant, which can introduce infection with additional nutrition and during the oviposition period. The fruitworm is also a distributor of the disease. In apple orchards, in most cases, infection with spores occurs when insects visit them. The most common are flies of the family M. cidae and Syrphidae, as well as *Drosophila* spp. and *Hymenoptera parasitica*, Vespidae, and Apodea.

MATERIALS AND METHODS

To clarify the role of various causes of pathogen penetration, we analyzed more than 400 fruits with signs of damage by apple moth and leaf-rolling moth with signs of scab, frost necrosis, and beaten by hail. Biological preparations based on *Bacillus subtilis*, which inhibited the development of brown rot *M. fructigena*, were tested at the stationary site of the Suzdaleva farm, and before they were stored, a complex of immunomodulators was used for scientific purposes within the framework of the project.

Extrasol, concentration of the working solution: 0.4%

Phytop, concentration of the working solution: 0.001%

Agroflorin, concentration of the working solution: 0.4%

Pharmaiodine, concentration of the working solution: 0.2%

Control (without treatments)

During the research in 2021-2023, we analyzed isolates of fungi of the genus *Monilinia* obtained from moniliosis-affected fruits, inflorescences, shoots, and fruit formations of apple trees. The main object of our research was the fungus *M. fructigena* Pers. The area of distribution of the fruit rot pathogen is somewhat limited. By its specialization and ecological features, the fungus is adapted to infect mainly pome fruits, since the life cycle of the pathogen begins during the fruiting of these crops, although in our early studies, this fungus was noted on plum fruits. Currently, fruit rot caused by *M. fructigena*, tree wart caused by *Sphaeropsis malorum* Peck., bitter rot caused by *Trichothecium roseum* Zink, and Penicillium rot caused by *Penicillium expansum* are considered the most harmful types. However, most lesions are caused by moniliosis (*M. fructigena*). To identify antagonistic microbes, microorganisms were washed off the surface of the fruits, cuts were made on the fruits, and into them. After 10 days, no signs of rot or blight were found on the affected fruits. Among the antagonist microbes suitable for suppressing *Botrytis* and *Penicillium* fungi, six isolates were found on apple fruits, of which Candido sake and Candido tenuis were identified. The phytopathogens were isolated under sterile conditions from lateral roots, leaves, fruits, and stems using a microbiological method. Before placing the samples on nutrient media, they were washed in running water. The samples were sterilized using 70% ethyl alcohol, kept in solution for 1-5 min, and washed three times with sterile water. The samples were cultured on potato dextrose agar (PDA). To avoid bacterial infection, streptomycin was used. The pieces at the border of the affected and healthy tissue were cut into small pieces and placed on a PDA medium in Petri dishes at a temperature of 24-26 °C for 5-7 days under aseptic conditions. Monitoring of the growth of fungi and their isolation was carried out after 24-48 h and in the following days of growth. Then, after the growth of the mycelium of the fungus, monospore cultures were obtained on PDA and incubated at a temperature of 24-26 °C. After incubation, colonies of various shapes and colors were observed. Morphological observations were carried out based on the morphology of colonies, conidia, and other morphological features. The determination of the species composition of mycopathogens was carried out using standard methods and reference literature.

RESULTS

The results showed that insects play a significant role in the spread of pathogen spores, especially under unfavorable conditions for the pathogen. Therefore, the control of these insects is important during the growing season. As a result of polymerase chain reaction (PCR) with species-specific primers and based on the results of sequencing of ITS 1-5.8S rRNA- ITS 2 ribosomal DNA loci, *M. fructigena*, *F. proliferatum*, and *A. alternata* were identified in the population of fungi of the genus *Monilinia*. The analysis of the obtained data showed that in the general structure of species with a frequency of 91.6-100%, the fungus *M. fructigena* dominated, causing damage to inflorescences, shoots (monilial blight), and fruits (fruit rot). The occurrence of the fungus on the affected fruits and ovaries of the apple tree was 8.4% and on fruit formations 5.4%. During the research, the quarantine species *M. fructicola* was not found in our orchards. The conducted calculations allowed us to establish that the ways of infection were diverse, and their role in the pathological process and the occurrence of putrefactive diseases of various etiologies was unambiguous. As noted, the resistance of fruits to rot during storage largely depends on the growing conditions in the orchard. By the period of pre-harvest maturity of fruits, we characterized the infection pathways and vectors of fruit rot during the growing season.

Table 1. Pathways of infection, 2021-2022.

Types of damage or lesions to fruits	Number of fruits affected by moniliosis	%
Apple fruit worm	124	53.4
Leaf-rolling moth	29	12.6
Scab	7	3.0
Fruit sun scald	9	3.9
Thermal damage from spring frosts	7	3.0
Hail	27	11.6
Birds	13	5.6
Mechanical damage	7	3.0
Unknown causes of infection	9	3.9
Total viewed number of fruits affected by moniliosis	232	100

In European countries, attempts have been made to link the results of the analysis of the mineral composition of leaves and fruits with the appearance of bitter pits in apple trees and cork spotting of pears. Several agrotechnical factors, like pruning, the content of macro and microelements in fruits and leaves, fertilization, watering, and planting schemes significantly affect the condition of the tree, which in turn affects its resistance or susceptibility to certain diseases (Ansabayeva 2023). Pruning the annual growth by 1/3 and spring pruning by 1/3 did not affect the mineral composition of the leaves. More intensive spring pruning caused an increase in the potassium (K) content in the leaves by 2/3. Shoot tip nipping in June and July significantly increased the content of calcium (Ca) and magnesium (Mg) in the same season and decreased in the next one. Four-year-old and five-year-old trees exhibited an increased content of sodium (Na) and Mg while a reduced phosphorus (P) and K content compared to older trees. The Extrasol and Agroflorin preparations showed the best effect during the storage period. Their biological efficiency reached 86 and 88.2%, respectively. In unfavorable conditions, when the second half of the growing season is hot and dry, the conidial stage of the fungus on individual fruits may not form and the disease manifests itself on them without characteristic sporulation, but sclerotia forms in the form of mummified fruits or a hard wrinkled surface of the affected tissue. In this case, the surface of the fruit becomes varnished and acquires a blue/black color. Fig. 1 shows fruit sclerosis. When viewed under a microscope, spherical sclerotia are visible. In time of storage, the diseased fruits turn black and acquire a glossy surface.

Fig. 1. Fruit sclerosis.

In the Almaty region, fruit rot is one of the most common and harmful diseases during storage. The flesh of the fruit softens and turns brown but remains juicy and tastes sweet with an alcoholic aftertaste. Completely affected fruits gradually rot, and when they come in contact with healthy fruit, infect it. This year, weather conditions did not favor the development of moniliosis fruit rot. However, the high number of apple moths caused the development of the disease on the fruits.

Fig. 2. The causative agent of fruit rot entering through mechanical damage.

In laboratory conditions and sometimes in orchards, it was possible to observe the fruit bodies of the fungus apothecium, which is a potential source of infection. Therefore, the main methods of control and preventive measures should primarily be aimed at preventing the development of sclerosis. As a result of the research, three isolates of species of the genus *Fusarium* were obtained. Its species leads in the total number of obtained isolates. *M. fructigena* is easily cultivated in PDA from fruits and twigs. The affected samples were incubated in a wet chamber, and the spores formed were transplanted into the PDA.

1. Diagnostic Protocol for *M. fructigena*, the cause of Apple Brown Rot. Issued by the Subcommittee on Plant Health Diagnostic Standards (Sphds). Protocol Number Ndp 1).

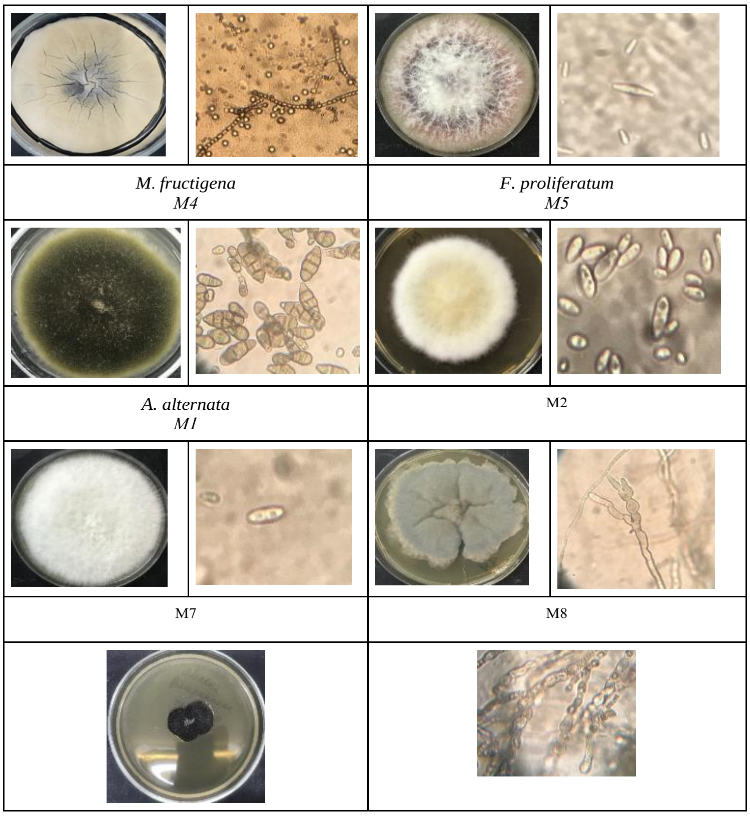

Fig. 3. The fungal organisms and their colonies on the culture media.

The results of research on the effects of diseases and rot during storage indicate that disease resistance is formed during the growing season and depends on the factors of the tree, agricultural technology, and growing conditions. We also researched the influence of the crown tier and size on the development of rot. We found that fruits affected by *California scutula* do not affect the preservation of fruits during storage, while damage by apple moths and weevils is the gateway for infection. Even minor mechanical damage can cause losses during storage of up to 30%. Numerous studies indicate that a large amount of water is needed for the normal growth and fruiting of fruit crops. S. ome researchers note that in France, despite the abundance of precipitation (800-1,000 mm) and the relatively close occurrence of groundwater, orchards are watered 5-6 and even 12 times per season, and in New Zealand, artificial irrigation is also used to obtain high and stable yields of fruits and berries. However, Some researches note that soil waterlogging affects most fruit crops worse than some lack of moisture (Kaldybaev *et al.* 2022; Yesmagulova *et al.* 2023). For fruit plants, it is not the total water supply in the soil that is important, but the amount of water available for assimilation. However, some authors note that in the Almaty region, *M. laxa* and *M. fructigena* infect both pome and stone trees. *M. laxa* differs from *M. fructicola* and *M. fructigena* in microscopic and genetic characteristics (De Miccolis Angelini *et al.* 2022). The main distinguishing features of these three species are their natural distribution, the appearance of conidial pustules, and the parts of plants affected by them. Lane (2002) notes that fruits from heavily pruned trees are more affected by fungal rot. Pruning simultaneously affects the vegetative growth and fruiting of trees. The habitus of the variety or the method of pruning the tree affects the incidence of diseases, since with the powerful development of aboveground parts of plants, as a result of soil shading, a humid microclimate is created that promotes plant infection, whereas with a well-ventilated crown, on the contrary, moisture evaporation is facilitated and thereby one of the most important conditions necessary for infection is eliminated. The tree pruning method can dramatically reduce the susceptibility of trees to various diseases not so much due to changes in the microclimate, but as a result of alterations in the dynamics of development, changes in the stage and age state as well as vitality of growing leaves and shoots, the timing and pace of flowering, in addition to maturation of seeds, fruits, etc. Abundant watering after a lack of moisture in the soil is the cause of fruit cracking. This, in turn, is the gateway for infection. On a peach, after harvesting, the following types of fungi cause rot and disease: *M. laxa*, *M. Fructigena*, and *Rhizopus* *stolonifer*. The main pathogen causing rot on apricots and peaches is *M. laxa*. By far the most well-studied is the rot caused by *P. expansum* (blue mold), which causes serious damage to apple crops worldwide.

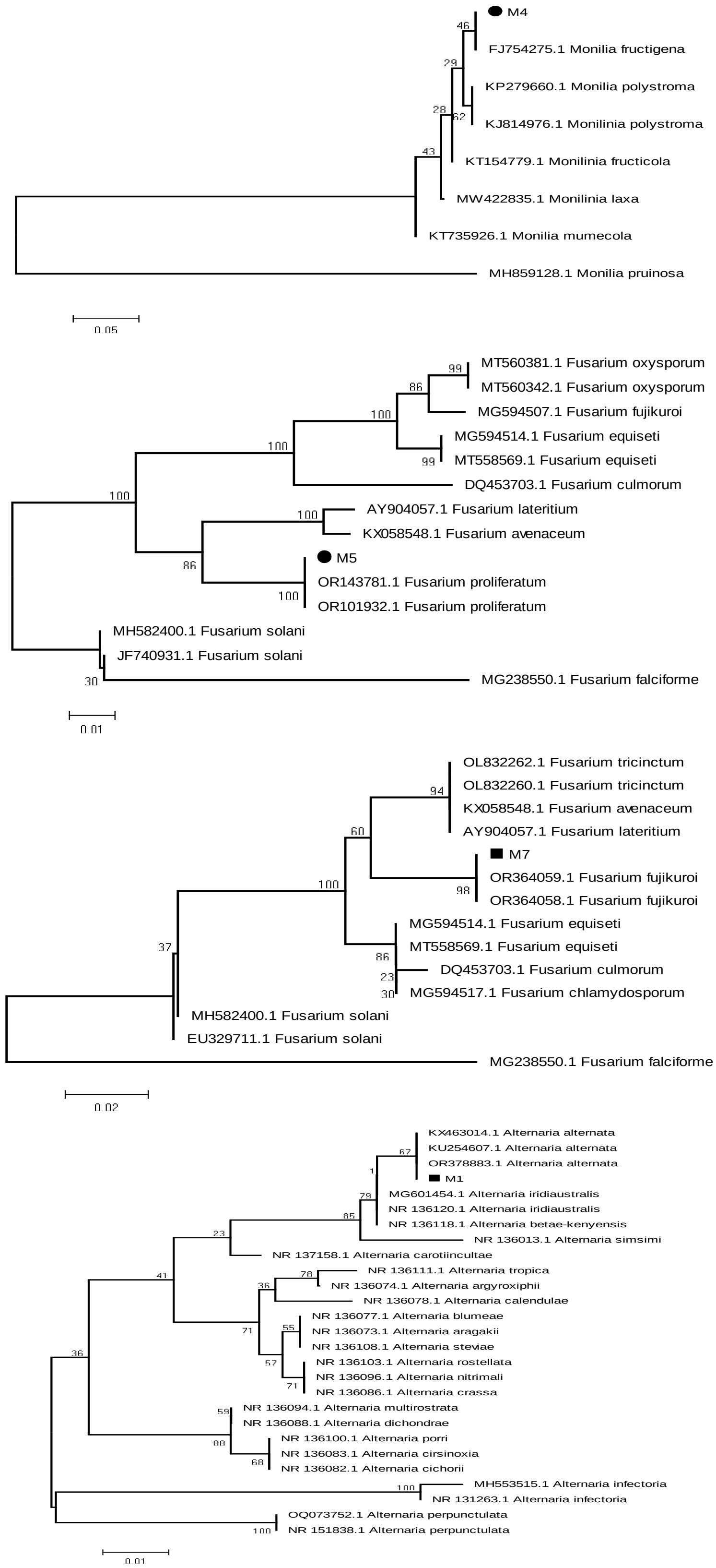

Fig. 4. The phylogenetic dendrogram of fungi in this study.

This fungus also produces the mycotoxin patulin, which is very harmful to human health and is found in apple juice Zhong *et al*. 2018). Infections caused by *P. expansum* and some other warehouse rot, such as *Botrytis cinerea* (gray rot) and *M. fructigena* (brown rot), are mainly mediated by wounds. The hyphae enter through wounds, for example, inflicted by birds and insects, or by inattentive handling of fruits during harvesting, storage, and transportation, but infection can also occur through an open flower cup. Symptoms are sometimes seen already in orchards but develop mainly during storage. The aggravation of the environmental situation in recent years caused by human-made pollution and the unwise use of fertilizers and chemical plant protection products has affected the general condition of fruit trees. According to Velásquez *et al.* (2018) the deterioration of the ecological situation is a consequence of a sharp decrease in the resistance of plants to extreme environmental factors and pathogens. One of the ways out of this difficult situation is the creation and use of apple varieties that are highly resistant or immune to various diseases in production. Fan *et al.* 2020 and Gorshkov & Tsers (2022) noted that to establish differences in the susceptibility of varieties to pathogen isolates, the infectious load should be minimal under the condition of high virulence of the pathogen and strong susceptibility of the apple tree. The assessment of the resistance of apple varieties to diseases, in particular to fruit rot, is carried out once, during harvesting. The stability of the variety is characterized by a set of indicators: the length of the incubation period and the intensity and duration of sporulation of the fungus. By the help of artificial infection, one can get an idea of the resistance or susceptibility of a particular variety. However, the rate of infection in artificial conditions does not yet give a complete picture of the rate of increase of the disease in the orchard. When breeding for disease resistance, the aggressive properties of the parasite are of the greatest importance. Since fruit rot mainly affects fruits and to a lesser extent twigs and inflorescences, the stability of varieties should be assessed based on fruit resistance.

The massive development of diseases and the increase in their harmfulness in the apple orchard is associated with a deterioration in the overall environmental situation, a violation of the stability of varieties due to the inept use of protective equipment, thickening of plantings, and the lack of appropriate measures. The development of moniliosis in stone fruits is prevented by treatment during the growing season with 1% Bordeaux mixture or copper chloride. The success of protecting orchards from diseases often depends not on the choice of a fungicide but on the correct period of use. One of the ways of introducing *M. fructigena* infection (the cracks on fruits from scab damage) is typical for the spread of fruit rot in the conditions of the North Caucasus, southern and central Ukraine, southern and southwestern Belarus, and Moldova. When affected by moniliosis, small brown spots appear on the apples first, then, they gradually grow and after about 8-10 days cover most of the fruit. The flesh darkens, softens, and becomes tasteless. Characteristic concentric circles of grayish and white pustules appear on the surface of the accumulation of spores of the fungus which causes fruit rot. Most of the diseased fruits soon fall off, then the apples remaining on the branches harden and turn black and blue. Such mummified fruits last up to 2 years, some fruits take on a blue-black color with a shiny varnished surface and a thin, easily erasable matte coating, although according to our observations, such varnished fruits are rarely found in nature and are mostly formed in laboratory conditions. In Poland, several pathogens of fruit rot were identified: *Pezicula alba*, *P. melicorties*, *B. cinerea*, *M. fructigena*, *Penicillium* spp., *Alternaria* spp., *Fusarium* spp. In Germany, the development of fungal diseases on the fruits of the Gelber Kostucher apple variety has been studied for 3 years. The isolated strains of fungi belonged mainly to the genera *Penicillium*, *Botrytis*, and *Monilia*. *Trichotecium*, *Nectria*, and *Fusarium* were isolated much less frequently. The number of obtained isolates depended on the year, in one year the *Penicillium* genus dominated, while in another *Botrytis*, etc. On stone fruit crops in the state of California, the ascigerous stage of *M. fructicola* moniliosis was found. The dependence of the formation of apothecia on mummified and stromatized fruits of peaches and nectarines on the timing of their placement was investigated. Immediately on the surface of the soil, or at a depth of 2-3 cm, a noticeable difference was found between the fruits laid in October, November, and December. Apothecia in laboratory conditions germinated at 2°C after 8 weeks and at 15°C after 2 weeks. There were no significant differences between the fruits located on the soil surface and deep underground. However, when conducting experiments in Spain to study the effect of soil solarization on the viability of *B. cinerea*, it was found that the germination of sclerotia was different on the soil surface and at different depths since the soil temperature varied depending on the depth. Despite the prevalence of the fungus in natural conditions, the fungus *B. cinerea* was not detected in our experiments. *M. laxa* is known to cause flower blight and browning of stone fruit crops. It was reported that *M. laxa* enters plum flowers through staminate filaments and sepals. The pathogen grows spores on stamens, sepals, and the cup 15 days after inoculation. The ability of *M. laxa* to survive on affected flowers leads to the spread of secondary infection during flowering. In India (Santra & Banerjee 2023) *M. laxa* causes slight browning of cells and the median lamina, causing hard dry rot. Larena *et al.* (2021) provideed information that infection with *M. laxa*, although to a small extent, occurs through the stem end when the sweet cherry is damaged. Infectious hyphae enter the fetus 18 h after inoculation. The same authors noted that positive results were obtained when the fruits of the Golden Delicious variety were infected with *M. laxa* f. sp. *mali*. In thickened, neglected plantings, the crowns close together, forming a fruit wall. In this case, the ventilation of the crowns deteriorates, the relative humidity of the air upraises, and the danger of the spread of fungal diseases will be elevated. Furthermore, the competitiveness of trees elevates, while the yield drops. The prevalence of brown rot of the plum *M. fructicola* or *M. laxa* occurs when the fruits come into contact with each other. The surface of the fruit in the experiment had microscopic cracks. After spraying with water, most fruits in bundles retained moisture for a long time, and the germination of conidia occurred after 3 hours. Individual fruits retained moisture for only 4 hours, and conidia germinated after 5 hours. After inoculation of fruits with a suspension of fungus conidia, the percentage of infected fruits was higher when they came into contact with each other compared to infection of non-contacting fruits. On the surface of contacting fruits, the species composition of fungi was more numerous than on the surface of fruits that did not have contact. As can be seen from the review, there are two main widespread forms of fungal development of the *Monilinia* Pers genus: *M. cinerea* in the form of monilial blight (browning and drying of flowers, leaves, young twigs, and annual shoots dry up after the flowers. The affected parts of the plant, including the flowers, do not fall off but remain on the tree until next year. By a strong development of the disease, they look scorched. The phase of manifestation of moniliosis in the form of fruit damage during the ripening period gives this disease its second name (gray fruit rot), manifested in the formation of small dark spots that grow rapidly throughout the fruit. The flesh of the fruit turns brown, and the surface is covered with small and sometimes gray merging pustules of the sporulation of the fungus *M. fructigena*. The affected fruits soften, become spongy, losing their taste qualities, and the sporulation of the fungus in the form of grayish-yellow pustules arranged in regular concentric circles develops on their surface. The conidia of *M. fructigena* are larger than those of *M. cinerea*. The fungus is widespread in Morocco. In South Africa, due to the dry hot weather, it does not have economic significance. In America and Australia, this pathogen is absent, although *M. cinerea* is found there. In South Africa, *Closporium clodosporiades*, *B. cinerea*, and *A. alternata* are found on plum flowers, and the fungus affects plum flowers and pistils. Until 2015, the fungus *M. fructigena* was also identified in apple orchards in Kazakhstan. Due to the appearance of a new species of *Monilnia polystroma* in European countries and the spread of the quarantine species *M. fructicola*, it became necessary to clarify the species composition of pathogens of moniliosis on the apple trees in orchards and evaluate methods of their identification. In the parasitism of many fungi, toxins that they emit and that are poisonous to plants play a huge role. In addition to toxins, fungi secrete various kinds of enzymes. Babkenov *et al.* (2023) noted that fungi have especially potent toxins and enzymes that cause rot and wilting of plants. Conversely, in response to infection of fruits with fruit rot, substances toxic to the fungus containing chlorogenic acid and its derivatives are formed in the fruits. Some researchers have identified a relationship between the resistance of varieties of pome fruit crops to monilial rot, the size of the wax layer, and the thickness of the cuticle of fruits. Some researchers attach great importance to the resistance of apple trees to fruit rot to phytoncidal characteristics of fruits. It is noted that the phytoncidal activity of fruit juice correlates with its resistance. During the storage period, the accumulation of toxic metabolites of microscopic fungi (mycotoxins) increases. The harmfulness of some pathogens is further aggravated by the fact that toxins released by the phytopathogen entering the plant very quickly combine with heavy metal ions. Thus, in the fruits of the apple tree, patulin, a mycotoxin dangerous to human health, is most often found. The level of its accumulation largely depends on the resistance of fruits to fungal rot, which in turn is determined by varietal characteristics and environmental conditions of cultivation. Thus, toxins, entering strong compounds with certain components of the plant, can form substances that are dangerous to human health. On the other hand, toxins, by binding heavy metals, remove them from vital organs and functional systems of plants and paralyze the activity of various metal-containing enzymes. This results in the plant losing its ability to absorb oxygen and carbon dioxide, which leads to a disorder of photosynthesis and respiration. The predominance of Ca in fruits enhances plant growth and makes tissues more elastic, thus lengthening their lifespan (while a lack of Ca accelerates the physiological aging of fruits), and the hardness of fruits increases resistance to rotting diseases. The lack of moisture during the growing season contributes to a decrease in chlorophyll in the leaves and a deterioration of photosynthesis, weakening the synthesis of substances. The process of regeneration of damaged roots is inhibited, the phases of deep rest are shortened, the winter hardiness of trees, their immunity to diseases and pests is sharply reduced, and the commercial quality and storage quality of fruits deteriorate. Excessive moisture worsens the soil structure, washes out motile nutrients or delays their absorption. It negatively affects the color of fruits, and leads to fruit filling by the time of ripening, etc. Waterlogging of the soil affects most fruit crops even worse than the lack of moisture. External factors have a great influence on the process of infection of fruits. Humidity plays an important role in the process of infection of fruits. The presence of humidity or drip-liquid moisture determines the initial development of the pathogen. Elevated degree of humidity of the environment up to full saturation facilitates the infection of plants. We also note that currently, the value of humidity in the further course of the disease is especially pronounced of sporulation. In some cases, the formation of dew at night is sufficient, so that infection can occur at a sufficiently high air temperature. it was noted that the main role among climatic factors is played by temperature, humidity, precipitation, and their distribution during the day and by seasons. However, some authors still believe that the value of the temperature factor is far inferior to the value of humidity. In the present study, we proposed a diagnostic study of plants for early detection of the disease for the rational use of protective equipment, destruction of plant residues after harvest, and careful tillage. In the USA, due to legislative restrictions on the use of synthetic fungicides to control post-harvest diseases of fruits and vegetables, searches for antagonist microbes capable of suppressing the activity of pathogens were undertaken. In the present study, we note that apple and pear scab, powdery mildew, common (open) canker, and fruit rot are most often found in the orchards of Uzbekistan. One of the main preventive measures is the eradication spraying of trees and soil, which is carried out in late autumn after leaf fall or early spring before budding. In Turkmenistan, to control scab and powdery mildew of apple trees, shoot blight of stone fruit crops and fruit rot, sanitary pruning and uprooting of diseased trees and shoots with their subsequent burning is recommended, otherwise, the focus of infection persists. Spraying against scab and powdery mildew in winter is also recommended. However, in recent years, there has been a proliferation of fruit rot in the apple orchards of the Almaty region. During route surveys of orchards, It was noted that moniliosis occurs everywhere. The maximum damage to fruits (up to 20-30%) was noted on varieties Aport, Zarya Alatau, Belyi naliv, and Pestrushka. The disease was not detected in the foothill zone of the former Taldykorgan region. Long-term research on diseases of apple and pear fruits in storage conditions at the Kazakh Research Institute of Fruit Growing and Viticulture more than 50 species of fungi living on rotting fruits, including *M. fructigena* were described.

CONCLUSION

Our comprehensive investigation into fruit resistance to rot damage and the ecological factors governing the prevalence of fungal diseases in apple and pear orchards shed light on the intricate dynamics at play. The factors affecting fruit resistance, the production of toxins and enzymes, the influence of moisture and irrigation, and the role of environmental variables were examined in detail. Our experiments showed that from our research objects, the Maksat variety is more susceptible to fruit rot than the Voskhod. This may be because the selection of apple varieties for resistance to fruit rot is associated with difficulties, in particular, the association of this disease with generative organs and the biological characteristics of the apple tree. There are no Kazakh varieties immune to fruit rot, which may be due to the pH of the juice; other factors do not matter. For future research, assessing the impact of climate change on disease prevalence and fruit resistance is essential. The evolving climate may alter the dynamics of pathogenic fungi and their interactions with fruit crops, necessitating adaptive strategies. Furthermore, the development and application of eco-friendly disease management strategies, such as the use of biological preparations and immunomodulators, and deserve continued exploration. Research into innovative, sustainable approaches to disease control can benefit both growers and consumers.

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