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General characteristics of fungal species involved in the formation of mycobiota of some vegetable plants cultivated in Azerbaijan

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Abstract

The mycobiota of tomato and cucumber plants cultivated under covered conditions was studied according to species composition, specific gravity of phytopathogens and endophytes, as well as ecophysiological characteristics of recorded fungi. It became clear that a total of 43 species of fungi participate in the formation of the mycobiota of the mentioned plants, of which 33 are phytopathogens, 6 are endophytes, and the status of 4 species is unknown. Although 15 species of phytopathogens are involved in the formation of the mycobiota of tomato and 8 species of cucumber, 10 species are involved in the formation of the phytopathogenic mycobiota of both plants. It became clear that the spread rate of the disease caused by these phytopathogens is 5.4-7.7% in tomato and 7.6-8.9% in cucumber. Although the noted fungi are characterized by similar indicators according to their ecophysiological characteristics, they are included in species with different characteristics (alcotolerant, microaerophilic, etc.). Endophytes include species that have a positive effect on the growth and productivity of both plants, among which the fungus *Trichoderma harzianum* AEF-2024 is considered more active. Thus, the treatment of plant seeds with the culture solution obtained from the mushroom in Çapek medium for 5 days and diluted 50 times has a positive effect on both the morphometric dimensions of the plants and the productivity.

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Introduction

Although the fact that fungi are similar to both animals and plants due to some characteristics, their place in the systematic division of the living system has been controversial for a long time, but in the division that was first mentioned in 1969 (Whittaker, 1969) and is still used today (http://www.mycobank.org/MycoTaxo.aspx), fungi are characterized as organisms that carry specific characteristics.

Fungi, which are found everywhere where organic substances are found, that is, in air, water, soil, as well as in biotopes with extreme conditions, although they are the third in number (after animals and plants) among living things known to science today, they are considered the first in terms of the number of those that are likely to actually exist in nature (Phukhamsakda *et al.*, 2022; Voigt *et al.*, 2021). This means that they perform, first of all, diverse and complex functions in nature, as well as in human economic activities (Mohammad and Tarquin, 2022). More precisely, it is more logical to characterize fungi as the only group of organisms that actively participate in all ecological functions (production, destruction, regulation and indication) that occur in nature. Nevertheless, fungi can be characterized as useful and harmful in two directions, which are conventional in the practical evaluation of the processes they participate in. So, from a practical point of view, fungi, which are characterized as harmful organisms, take part in ensuring the sustainability of ecosystems by participating in the regulation of biodiversity in nature.

The positive characteristics of mushrooms are related to their being active producers of biological and pharmacological active substances for various (food, fodder, medical and technical) purposes, transformation of renewable plant waste into various substances, etc. (Hyde *et al.*, 2019).

The negative characteristics of fungi from a practical point of view are related to the fact that they cause various diseases in plants, animals and humans, and cause poisoning by enriching food and feed products with the toxic metabolites they produce as a result of their life activities which the amount of damage caused by them is measured in billions of dollars every year (Jain *et al.*, 2019). Prevention of this is one of the urgent problems of the modern era. The relevance of the research conducted in this direction gains new shades in the modern era, when there are environmental problems (global climate change, biodiversity loss, etc.) of a global nature. This is firstly due to global problems, primarily changes in the migration of fungi that cause diseases or have other harmful properties in a particular animal, against the backdrop of global climate change. Thus, it is an accepted fact that the "movement" of fungi around the world, that is, their migration, is the result of anthropogenic factors, and pathogenic fungi brought into a particular country in this way cause epidemics. From this point of view, it is dangerous that when geographically isolated fungi fall to another place as a result of an anthropogenic factor, they may appear as new or more persistent disease agents that have not been encountered before by exchanging certain genetic material with each other.

The Republic of Azerbaijan as a whole has natural climatic conditions that provide opportunities for the formation of multi-field and productive agriculture. The plains and foothills of the country are suitable for developing irrigated agriculture, and the mountainous areas are suitable for developing non-irrigated agriculture and animal husbandry. This determined that the most common areas in most regions of the country are both vegetable growing and livestock farming (Abbasov, 2013). Although the natural soil and climate of Azerbaijan allows for the development of most areas of plant growing, vegetable growing is one of the most extensive areas in Azerbaijan and covers almost all parts of the country. Currently, vegetables such as tomatoes, cucumbers, eggplants, peppers, onions, cabbage, carrots and others are grown all over the country and millions of tons of crops are harvested every year. The amount of this or that product produced both in Azerbaijan and in the world may be greater, but the product in question cannot always be produced. Among the reasons for this, diseases caused by various organisms, primarily fungi, play an important role in those plants (Yusifova *et al.*, 2020). It is worth noting only one fact that every year a significant part of the agricultural crops produced on earth is lost (Steinberg and Gurr, 2020). This is an unacceptable loss in modern times, as the number of people currently experiencing food shortages on Earth is estimated at 100 million and there is no doubt that this number will increase against the background of global problems (global climate change, loss of biodiversity, etc.). Therefore, it is important to develop preventive control measures against fungi that negatively affect the productivity indicators of vegetable plants as a result of the diseases they cause, and for this it is important to first of all determine their species composition, ecophysiological characteristics, evelopment cycles and other characteristics (Bakshaliyeva *et al.*, 2020; https://www.fsinplatform.org/report/global-report-food-crises-2024).

Considering the above, in the presented work, the aim of the study was to study the mycobiota of tomato and cucumber plants cultivated in Azerbaijan on the species composition, the specific weight of endophytes and phytopathogens involved in its formation, the ecophysiological characteristics of some phytopathogens, as well as the effect of endophytes on the productivity of tomatoes and cucumbers.

Materials and methods

The studies were conducted in the greenhouses of the Scientific Research Institute of Vegetables of the Ministry of Agriculture of the Republic of Azerbaijan in 2022-2024. The samples for the study were taken from the vegetative and generative organs of the investigated plants, which are supposed to be fungi. Sampling, passporting, preparation for laboratory analysis and removal to pure culture were carried out according to known mycological and phytopathological methods (Methods of experimental mycology, 1982). The species composition of the fungi extracted from the research samples for pure culture, the identification of the diseases caused by them were carried out using the classical method based on the known determinants(Kirk *et al.*, 2008; Seifert, 2011; Watanabe, 2011).

The study of the effect of the culture solution obtained from endophytic fungi on the cultivation of tomato and cucumber plants was carried out according to the general principles and approaches accepted in mycology and vegetable growing, as well as according to the known methods used in our previous works (Allahverdiyev *et al.*, 2019; Muradov, 2019).

The study of the ecophysiological characteristics of fungi (temperature, pH, humidity, etc.) was carried out in the liquid Çapek nutrient medium (Methods of experimental mycology, 1982), and the methods and approaches used in our previous works (Bakshaliyeva *et al.*, 2020) were taken as the basis.

Results and discussion

As a result of the analysis of about 200 samples taken from the above-ground and underground parts of tomato and cucumber plants according to the fungal biota, it was determined that 43 species of fungi are involved in the formation of the mycobiota of both plants (Table 1). Apparently, the number of species involved in the formation of the mycobiota of the tomato plant is slightly higher than that of the cucumber plant, among the recorded fungi there are species that are included in the mycobiota of both plants. More precisely, both different and identical species are involved in the formation of the mycobiota of the studied plants, which indicates that each of them is characterized by a specific mycobiota in a certain sense.

Most of the fungi recorded in the studies are of the species recorded in Azerbaijan at different times and in the studies conducted by different authors, that is, they are known species specific to the nature of Azerbaijan. Nevertheless, the same cannot be said about the fungi *Cercospora citrullina* recorded on the cucumber plant, as there are no research materials related to its distribution in Azerbaijan. Among the registered fungi were also found endophytes that is, those that have the ability to penetrate the tissues of the host plant, but do not harm it. Among those corresponding to this characteristic, species such as *Mucor hiemalis* and *T. koningii* were found to be distributed only in tomato, while species such as *Mucor mucedo, T. harzianum* and *T. viridii* were found in cucumber.

In addition, the distribution of *Trichoderma hamatum* fungi was determined in both plants. More precisely, only 6 species of fungi recorded in the studies can be attributed to endophytes. The vast majority of other species are prone to phytopathogenicity in one form or another. A specific opinion cannot be given about species such as *Mucor mucedo*.

Table 1. Species composition of mycobiota of the studied plants

Tomato	Cucumber
Alternaria alternata, A. solani, Botrytis cinerea, Cladosporium fulvum, Colletotrichum coccodes, C. dematium, C. lagenarium, Cladosporium fulvum, Didymella lycopersici, Erysiphe communis, Fusarium moniliforme, F. oxysporum, F. solani, Leveillula taurica, Mucor hiemalis, Penicillium cyclopium, P. oxalicum, Phoma destructiva, Phytophthora infestans, P. Parasitica, Pythium debryanum, Rhizobus stolonifer, Rhizoctonia solani, Sclerotinia sclerotiorum, Septoria lycopersici, Stemphylium solani, Trichoderma hamatum, T. koningii, Verticillium dahliae and *V. lycopersici*	*Alternaria alternata, A. cucumerina, A. solani, Aspergillus ustus, Ascochyta cucumis, Botrytis cinerea, Cercospora citrullina, Cladosporium cucumerinum, Erysiphe cichoracearum, Fusarium oxysporum, F. solani, Mucor mucedo, Penicillium oxalicum, Phytophthora infestans, Pseudoperonospora cubensis, Rhizoctonia solani, Sclerotinia sclerotiorum, Sclerotium rolfisi, Stemphylium solani, Trichoderma hamatum, T. harzianum, T. Viridii* and *V. dahliae*
30	23

Penicillium cyclopium, P. lanosum and *P. oxalicum,* as neither our research nor the literature data confirm that these fungi are either endophytes or phytopathogens. For this reason, the full clarification of their status should be the subject of future research. The remaining 33 species have phytopathogenic activity, 15 of which cause disease only in tomato (*Cladosporium fulvum, Colletotrichum coccodes, C. dematium, C. lagenarium, Cladosporium fulvum, Didymella lycopersici, Erysiphe communis, Fusarium moniliforme, Leveillula taurica, Phoma destructiva, P.parasitica, Pythium debryanum, Rhizobus stolonifer, Septoria lycopersici* and *V. lycopersici*), 8 only in cucumber (*Alternaria cucumerina, Ascochyta cucumis, Aspergillus ustus, Cercospora citrullina, Cladosporium cucumerinum, Erysiphe cichoracearum, Pseudoperonospora cubensis, Sclerotium rolfisi*), and 10 in both plants (*Alternaria alternata, A. solani, Botrytis cinerea, Fusarium oxysporum, F. solani, Rhizoctonia solani, Phytophthora infestans, Sclerotinia sclerotiorum, Stemphylium solani* and *Verticillium dahliae*). Among the diseases caused by the registered fungi, the most common ones are wilting, spotting (different colors), fusarium, dry rot, white rot, powdery mildew, root rot, false powdery mildew, phytophthora and others. The overall prevalence of these diseases was 7.6-8.9% in tomato and 5.4-7.7% in cucumber.

During the study of the ecophysiological characteristics (relation to temperature, pH, light, metabolites from endophytic fungi and other issues) of some fungi recorded in the research and which can be taken out for pure culture, it became clear that the recorded fungi have general characteristics as well as specific characteristics that depend on their biological characteristics and the natural-soil climatic conditions of the environment where they spread. This information can be considered important for the preparation of preventive measures aimed at full or partial limitation of their activities. For example, although the initial pH of the medium between 5.0 and 6.0 was found to be favorable for all recorded fungi, alcoholtolerant species such as *Aspergillus fumigatus, Mucor corymbifer* and *M. hiemalis* are also found among the recorded fungimt hat their growth, albeit weak, occurs under conditions of pH=9. In addition, it became clear that *M. himealis, M. cornealis* and *Rhizomucor miehei*, among the fungi involved in the formation of epiphytic mycobiota of vegetable plants, also have characteristics of microaerophiles.

Analogous results were observed in the same species isolated from the soil (Bakshaliyeva *et al.*, 2020) in our previous work, which allows us to note that the mentioned characteristics are not specific to individual strains, but specific to the species.

In addition, it was determined that the culture solution obtained after cultivation of *T. harzianum* AEF-2024 fungus, which was identified by the classical method and belongs to endophytes, in liquid Çapek medium for 5 days affects the germination ability of both tomato and cucumber seeds. It was also determined that the obtained solution has a positive effect on the morphometric dimensions of the stems, and the processing of the seeds after rinsing the culture solution 50 times with ordinary water has a positive effect on the productivity of the plants during the cultivation of the seedling. Thus, as a result of planting cuttings obtained from seeds soaked with Cultural Solution, the flowering of the plant occurs 3-4 days earlier, and the final yield obtained is 18.6% higher in tomato and 21.5% higher in cucumber compared to cultivation by the traditional method (compared to the control).

Conclusion

Phytopathogens, endophytes and fungi, the status of which is still unknown, participate in the formation of the mycobiota of cucumbers and tomatoes grown in closed ground in Azerbaijan. Among them, in addition to species that cause various diseases in plants and cause a decrease in their productivity, there are also species that synthesize metabolites that cause an increase in the productivity of both plants. This type of species can be a significant contribution to the expansion of the possibilities of use in increasing crop production in the future, as well as to the solution of the problem of food shortage, which is clearly felt in certain parts of the world.

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