Nature & Science
November 2025, Vol. 7, Issue 11, pp. 12–18
DOI: https://doi.org/10.36719/2707-1146/62/12-18

The Effect of Fungi Belonging to the *Trichoderma* Genus on the Biological Productivity of Food Crops

Gulnar Shirinova[1]*, Vusala Suleymanova[1,2], Susan Abdullayeva[3]

Abstract. *The article presents the results of the impact of fungi from the Trichoderma genus on the biological productivity of important agricultural foods. During the research, samples were taken from the relatively clean soils of Absheron, from the rhizosphere of plants there, and from irrigated soils. At the same time, the mycological processes observed in recent years in the transboundary rivers of the Eastern Zangazur economic region (Aras, Okchuchay, Besitchay, Bergushadchay, Agachay), which have been subjected to anthropogenic impacts, have been comparatively assessed in terms of their ecological and biological significance. The conducted studies have shown that the fungal species comprising the microbiota complex formed in soil and water ecosystems are characterized by a high adaptability to the ecological environment, specific associations with the plant rhizosphere, and active metabolic participation in nutrient transformation. In particular, the micromycetes detected in the waters of transboundary rivers (such as* Aspergillus*,* Penicillium*,* Fusarium*, etc.) play a crucial role in decomposition processes, organic matter transformation, and ecosystem self-restoration. Additionally, the characteristics of the species involved in the formation of the microbiota of plants growing there were also determined. Among these microorganisms, both saprotrophic and facultative pathogenic representatives are present, and their balance is considered one of the key factors determining the microecological stability of the plant–soil system. At the same time, in addition to increasing the productivity of plants grown in these soils, they also serve as regulators in the nitrogen and carbon balance of the soils. To optimize plant growth and increase productivity, both biotic and abiotic factors are required. Organic substances influence the life activities of microorganisms present in the soil and plant, and providing these substances to them is considered an essential condition. In addition, the increase in the productivity of areas that are crucial for agricultural purposes can be considered a key indicator, depending on factors such as the interrelations of microorganisms in the soil, the impact of natural climatic and soil conditions on the environment, the rapid progression of microbiological processes, and other factors. When evaluating soils based on microbiological indicators, the main criterion is to assess the microdiversity of the senoz present there, in terms of its species and numerical composition. Taking all these indicators into account, the research has reflected the use of spore suspensions and cultural media obtained from species belonging to the Trichoderma genus to enhance the development ability of various plant seeds and intensify their productivity. Among the species of this genus, strains such as T. harzianum SH-58 and T. asperellum SH-15 can be mentioned as biological control agents, as these strains exhibit antagonistic interactions against several harmful phytopathogens.*

Keywords: *microorganisms, cultural solution, phytosanitary condition, biological productivity, climate-soil conditions*

---

[1] Azerbaijan State Oil and Industry University, Doctor of Philosophy in Biology, Baku, Azerbaijan
[2] Doctor of Philosophy in Biology, Baku, Azerbaijan
[3] Ministry of Science and Education Institute of Microbiology, Baku, Azerbaijan
*Corresponding author. E-mail: gulnar.shirinova@asoiu.edu.az
Received: 20 July 2025; Accepted: 18 October 2025; Published online: 25 November 2025

Introduction

Studies conducted both worldwide and in Azerbaijan have demonstrated that various micromycetes play a significant role in shaping the biological productivity of soils. It should also be emphasized that the biodiversity present in the lower soil layers is richer than that of the upper layers. Thus, when assessing the quantitative composition of soil biota across 20 soil types, it was determined that the number of microorganisms in these soils is three times higher than the total human population on Earth (Boinchan et al., 2016). In the Eastern Zangezur economic region, particularly in the riparian zones of transboundary rivers such as Aras, Oxchuchay, Besitchay, Bergushadchay, and Agachay, studies have shown that the composition of soil and water microbiota in these rivers serves as an indicator of the ecological condition of surrounding areas (Abdullayeva et al., 2025). The micromycetes inhabiting the riparian soils and aquatic systems of these rivers, especially *Trichoderma* strains, play a critical role in maintaining biological balance in the soil and plant rhizosphere. Thus, the rich biodiversity of transboundary rivers in Eastern Zangezur and the application of *Trichoderma* strains interact synergistically, ensuring the optimal sustainability of ecological and biological processes. The activity of microorganisms is directed toward soil formation processes, including the mineralization of plant residues, humification, degradation of various toxic substances present in soil, and the accumulation of compounds with toxic effects. Using these indicators, the determination of biological activity levels of soils and the maintenance of soil fertility are considered essential requirements (Baldrian et al., 2022).

Alongside chemical protection methods, biological control strategies are also employed to increase plant productivity. Although chemical treatments against pathogenic fungi show strong efficiency, in many cases such applications lead to additional ecological problems, particularly chemical contamination. Taking these factors into account, the application of biological control methods has increasingly been recognized as a more favorable approach in recent years. Based on these premises, studies have shown that species of the genus *Trichoderma* are successfully used as biological control agents and play a significant role in the restoration of soil fertility. Furthermore, experimental results have demonstrated that these fungi synthesize growth-stimulating phytoactive compounds (Jaroszuk-Ściseł et al., 2019). These fungi are especially prevalent in relatively uncontaminated soils characterized by a high abundance of plant debris. It should also be noted that both the biomass of *Trichoderma* strains and the exogenous metabolites released into the culture medium (CM) are utilized (Mironenka et al., 2021). The antibiotic activity of these metabolites plays a key role in defining their application potential. Thus, during the research process, one of the objectives was to determine optimal conditions for obtaining maximum biomass from *Trichoderma* strains. Under optimal conditions, the biomass and culture filtrates of both strains obtained within four days were assessed. This can be explained by the fact that phytohormones, mycotoxins, and metabolites responsible for antibiotic properties are synthesized as secondary metabolites and simultaneously exert external biological effects (Chen et al., 2023). Consequently, these features contribute to enhanced competitive interactions among various microbial species. *T. harzianum* Sh-58 and *T. asperellum* Sh-15 strains were selected as active producers in our study, which is attributed to the high antibiotic potential of their culture metabolites. Various methodological approaches exist for clarifying their mechanisms of action and targeted applications. The strains *T. harzianum* Sh-58 and *T. asperellum* Sh-15 were selected as active producers in our study, which is attributed to their high antibiotic activity in the culture medium.

Materials and Methods

As previously indicated, samples were collected for the study. The isolation of microscopic fungi from the obtained samples was considered a primary requirement. For this purpose, Czapek medium (CM) and malt extract agar (MEA) were used as nutrient media. Prior to transferring the samples onto these media, suspensions were prepared. Serial dilutions were then performed, and inoculation into the nutrient media was carried out using sterile pipettes.

As previously mentioned, samples were collected from the transboundary rivers of the Eastern Zangezur economic region (Aras, Oxchuchay, Besitchay, Bergushadchay, Agachay), including soil and water from the riverbanks. Isolation of microscopic fungi from these samples was considered an initial stage of the study. Using the same nutrient medium, the inoculation of the isolated microscopic fungi was carried out. At the same time, direct placement of the samples onto the nutrient media was also considered appropriate. Incubation was conducted in a thermostat at 27°C for 3–7 days. Consequently, identification of the fungi was performed based on both macroscopic features (colony diameter, surface structure, color, and hyphal appearance) and microscopic characteristics (hyphal structure, conidiophore, conidia size, and shape).

Results and Discussion

The article presents the characteristic features of species belonging to the genus *Trichoderma* and their effects on improving soil sanitary conditions as well as enhancing plant productivity. These characteristics allow *Trichoderma* species to gain a competitive advantage in the rhizosphere and limit the proliferation of pathogenic microorganisms. They help maintain the balance of soil microflora, limit the proliferation of pathogens, and stimulate the plant immune system. All these effects are associated with the antagonistic interactions of *Trichoderma* against plant pathogenic organisms, which is also supported by literature sources (Polyakova et al., 2017).

On malt extract agar (MEA), *T. harzianum* Sh-58 is characterized by colonies with a white margin and a green, sometimes light green, central region (Fig. 1A). This color change does not affect the pigmentation of the colony's reverse side. Both substrate and aerial mycelia contribute to colony formation, while the conidiophores arise from the aerial mycelia. Species of this genus possess branched conidiophores (Fig. 1B), flask-shaped phialides (Fig. 1C), and ovoid conidia. The conidia are smooth-walled, arranged in chains, and produced in abundant quantities, which facilitates their rapid spread in nutrient-rich media and ensures high sporulation capacity. Furthermore, the interaction between aerial and substrate mycelia regulates the overall colony structure and conidial productivity, thereby enhancing ecological adaptation and competitive ability

A B

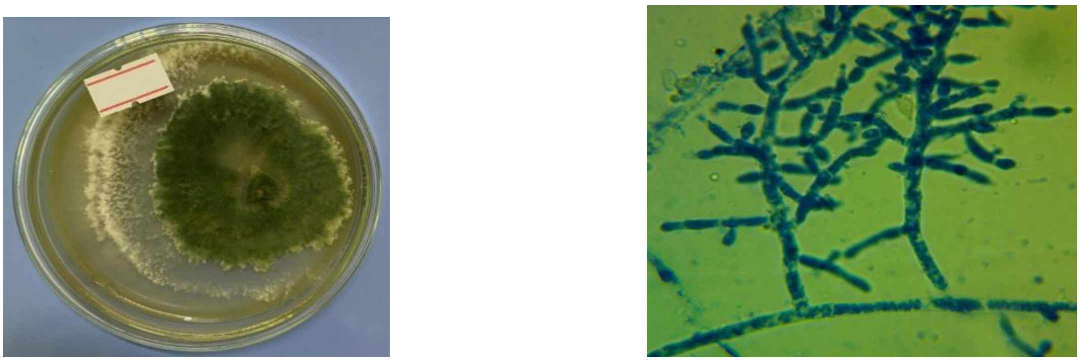

Figure 1. Macroscopic view of *T. harzianum* colony (A) and microscopic appearance of its conidiophores (B)

The use of *T. asperellum* Sh-15 strain in biological control is also appropriate. At the same time, its antagonistic activity against a range of plant pathogenic microorganisms is one of its key distinguishing features. The use of the *T. asperellum* Sh-15 strain in biological control is also appropriate. All these factors make *T. asperellum* Sh-15 strain effective and promising biological control agent and increase its ecological and agronomic significance. Its ecological significance lies in reducing the need for chemical inputs in the soil, limiting the proliferation of pathogenic microorganisms, and maintaining the natural balance of soil microflora, thereby supporting soil health and ecosystem sustainability.

Additionally, research has confirmed that these strains synthesize growth-promoting substances that play an indispensable role in plant development (Kumar et al., 2020). On malt extract agar (MEA), the colony of the fungus initially appears greenish-gray, and after a certain period, the formation of several concentric rings can be observed. A large number of spores are produced. The colony color gradually changes from the margin toward the center, eventually resulting in an aged yellow coloration in the central region (Fig. 2A). A high number of conidia are formed from the phialides (Fig. 2B). This high level of sporulation allows *Trichoderma* species to rapidly colonize nutrient media and promotes the swift development of colonies.

A B

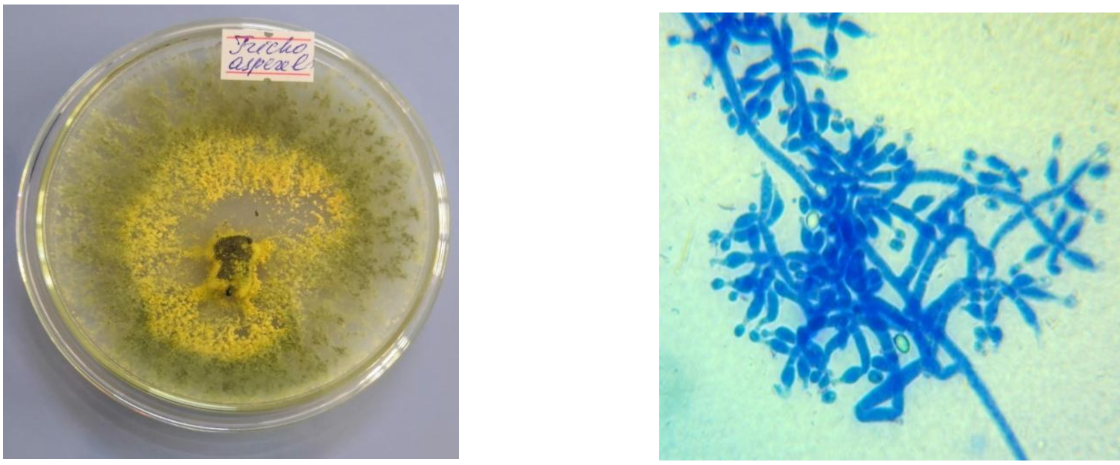

Figure 2. Macroscopic view of *T. asperellum* colony (A) and microscopic appearance of its conidiophores (B)

The cultivation of fungi in an optimized medium, ensuring the formation of a large amount of biomass, was considered a primary requirement based on key indicators. During this period, the growth of the fungi, the macro and microscopic characteristics of the colonies, as well as the intensity of sporulation, were systematically monitored. All these features make the biomass suitable for use in both laboratory and applied settings, serving as a biological control agent and a preparation that promotes plant development. The cultivation period can be considered favorable for these indicators. The use of the biomass and culture medium (CM) of the two strains selected as active producers in this study was deemed appropriate. CM derived from these microbial strains reduces the need for chemical pesticides and fertilizers, preventing soil and environmental contamination. It stimulates plant growth, increases productivity, and improves crop quality.

Table 1.
Optimal conditions required for the cultivation of *T. harzianum* Sh-58 and *T. asperellum* Sh-15 strains

Producent	Carbon source (g/l)	Nitrogen source (g/l)	Breeding T^0C	pH	Planting material
T.harzianum Sh-58	$C_6H_{12}O_6$ (24,0)	NH4NO3 (1,7)	27^0C	5,4	ASSH
T.asperellum Sh-15	$C_6H_{12}O_6$ (27,0)	NH4 NO3 (1,8)	27^0C	5,4	ASSH

It is also evident from the table that, as a result of medium optimization, the biomass yield of both strains reached its maximum. In addition, it has been noted that the biological active compounds (BAC) synthesized by *Trichoderma* fungi contribute to significant increases in the productivity of agriculturally important crops (Herrera et al., 2020). Specifically, the initial step involved treating the seeds with the culture medium (CM) prior to sowing. Subsequently, the seeds are mixed with the prepared biomass or culture medium (CM) and kept in contact with this medium for a specific period. During this time, the *Trichoderma* strains adhere to the seed surface and establish stable colonization. Occasionally, additional protective measures are applied to the seeds. These experiments were conducted using tomato plants as a model. The results demonstrated that treating tomato seeds with the culture medium (CM) led to significant changes in plant height and flowering time. Moreover, phytohormones and other biologically active compounds synthesized by *Trichoderma* improve nutrient uptake by plants. At the same time, it provides a promising foundation for agronomists and farmers to apply biological agents and disease management tools effectively. Nowadays, by putting chemical control methods in the background, the use of this biological control approach provides ecologically clean, sustainable, and efficient production opportunities for agriculture.

Table 2.
Effect of cultural medium (CM) obtained from fungi
on tomato plant height, flowering time, and overall yield

№	Producent	Plant height (start/end, cm)	Flowering time of the plant (days)	Yield per unit of plant (kg)
1	*T.harzianum Sh*-58	13±1/96±2	30±1	4,5±0,16
2	*T.asperellum* Sh-15	13±1/95±2	31±2	4,8±0,04
3	Control	13±1/86±2	32±1	4,0±0,16

Research findings demonstrate that significant increases were observed in the morphometric parameters of tomato plants compared to the control group. It should be particularly emphasized that the results obtained across all biometric indicators confirm the positive impact of the application of the cultivation medium (CM) derived from the *T. harzianum* strain Sh-58 on the yield potential of the plants. In both settings, the application of CM exhibited similarly positive effects, which were manifested in accelerated vegetative growth, advancement of the flowering phase, and, consequently, an increase in yield parameters. These findings not only demonstrate the high efficacy of the *T. harzianum* strain Sh-58 as a phytostimulator and a potential biocontrol agent but also scientifically substantiate its agrobiotechnological application prospects. The strain also participates in processes such as nitrogen fixation and the coordination of microelements in the soil environment, which enhances the efficiency of nutrient utilization by plants (Crowther et al., 2016). *T. harzianum* Sh-58 synthesizes hormone-like compounds such as auxins, gibberellins, and cytokinins, which strengthen root system development, accelerate vegetative biomass accumulation, and ultimately increase productivity (Li et al., 2017). In addition, studies conducted in the transboundary rivers of the Eastern Zangezur economic region (Aras, Okhchuchay, Besitchay, Bergushadchay, Agachay) have shown that *T. asperellum* SH-15 plays a crucial role in supporting microbial balance in both water and sediment environments (Ismayilov, 2021).

Conclusion

1. The results of the study showed that the application of CM obtained from *T. harzianum SH-58* and *T. asperellum SH-15* strains had a positive effect on the morphometric parameters of plants.
2. Treatment of tomato seeds with CM before sowing resulted not only in significant changes in plant height and flowering duration but also had a notable impact on the yield per plant.
3. Based on the results of the study, it was determined that the CM obtained from *T. harzianum SH-58* and *T. asperellum SH-15* strains had a positive effect on the morphometric parameters of plants. In particular, the application of this CM in agricultural areas surrounding Basitchay and other transboundary rivers in the Eastern Zangezur economic region enhanced plant growth and productivity. This significantly contributes to the preservation of soil and water ecosystem health along the riverbanks and ensures the maintenance of microbiological balance in the plant rhizosphere.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Abdullayeva, S., & Shirinova, G. (2025). Study of the ecological and biological status of transborder rivers of the Eastern Zangazur Economic Region (on the example of the Bargushad River and Agachay).
2. Boinchan, B. P. (2016). *Prakticheskoe rukovodstvo po ekologicheskomu zemledeliyu (polevye kultury)*. Kishinev: Eco-TIRAS.
3. Baldrian, P., Bell-Dereske, L., Lepinay, C., Větrovský, T., & Kohout, P. (2022). Fungal communities in soils under global change. *Studies in Mycology, 103*, 1–24.
4. Chen, W., Wang, J., Song, J., et al. (2023). Exogenous and endophytic fungal communities of *Dendrobium nobile* Lindl. across different habitats and their enhancement of host plants' dendrobine content and biomass accumulation. *ACS Omega, 8*(13), 12489–12500.
5. Crowther, T. W., Todd-Brown, K. E. O., Rowe, C. W., et al. (2016). Quantifying global soil carbon losses in response to warming. *Nature, 540*, 104–108.
6. Herrera, W., Valbuena, O., & Pavone-Maniscalco, D. (2020). Formulation of *Trichoderma asperellum* TV190 for biological control of *Rhizoctonia solani* on corn seedlings. *Egyptian Journal of Biological Pest Control, 30*, 44. https://doi.org/10.1186/s41938-020-00246-9
7. Ismayilov, R. (2021). *Assessment of the ecological safety of Azerbaijani rivers: The case of rivers flowing directly into the Caspian Sea* (*Azərbaycan çaylarının ekoloji təhlükəsizliyinin qiymətləndirilməsi: Xəzər dənizinə birbaşa axan çayların timsalında*). Retrieved from: https://www.sukanal.az/wp-content/uploads/2021/06/Rashail-Ismailov.pdf
8. Jaroszuk-Ściseł, J., Tyśkiewicz, R., Nowak, A., Ozimek, E., Majewska, M., Hanaka, A., Tyśkiewicz, K., Pawlik, A., & Janusz, G. (2019). Phytohormones (auxin, gibberellin) and ACC deaminase in vitro synthesized by the mycoparasitic *Trichoderma* DEMTkZ3A0 strain and changes in the level of auxin and plant resistance markers in wheat seedlings inoculated with this strain conidia. *International Journal of Molecular Sciences, 20*(19), 4923. https://doi.org/10.3390/ijms20194923
9. Li, J., Gu, F., Wu, R., Yang, J., & Zhang, K. (2017). Phylogenomic evolutionary surveys of subtilase superfamily genes in fungi. *Scientific Reports, 7*, 45456. https://doi.org/10.1038/srep45456
10. Mironenka, J., Różalska, S., & Bernat, P. (2021). Potential of *Trichoderma harzianum* and its metabolites to protect wheat seedlings against *Fusarium culmorum* and 2,4-D. *International Journal of Molecular Sciences, 22*(23), 13058. https://doi.org/10.3390/ijms222313058

11. Polyakova, M. A., & Revkova, E. V. (2017). Issledovanie zavisimosti antagonisticheskikh svoistv gribov roda *Trichoderma* spp. ot kolichestvennogo soderzhaniya istochnika ugleroda v pitatelnoy srede. *Vestnik OrelGAU, 2*(65), 57–61.
12. Kumar, S., Thakur, M., & Rami, A. (2014). *Trichoderma*: Mass production, formulation, quality control, delivery and its scope in commercialization in India for the management of plant diseases. *African Journal of Agricultural Research, 9*(53), 3838–3852.