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# STUDIES ON THE ROLE OF FILAMENTOUS FUNGI IN TERRESTRIAL ECOSYSTEMS

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***Abstract***

*The role of filamentous fungi in terrestrial ecosystems is highlighted by numerous studies and research conducted by researchers around the world. Among the many roles they play we can list a few: filamentous fungi break down organic matter, produce enzymes of biotechnological, agricultural and industrial interest, they are used as biological agents to control plant diseases caused by microorganisms such as bacteria or fungi, phytophagous insects, fungi can establish cooperative relationships with plants – mycorrhiza, and last but not least, fungi have a role in depollution.*
*This paper aims to draw the attention of all people regardless of social category, age, sex or living environment on the importance of the role of filamentous fungi in terrestrial ecosystems. Studying the literature available on online search engines we created a questionnaire with sixteen various questions that highlight the importance of filamentous fungi. In this case study we present a questionnaire addressed to people from different social categories, who have completed gymnasium, bachelor's, master's or doctoral studies, such as pupils, students, masters, doctoral students. The study shows us the extent to which they know about the importance of filamentous fungi in terrestrial ecosystems, the role and benefits of these organisms around us. The poll has accumulated a total of forty-seven responses*

***Key words****: filamentous fungi role in terrestrial ecosystems, opinion poll, questionnaire evolution.*

## INTRODUCTION

The roles of filamentous fungi in terrestrial ecosystems are varied and numerous. Among the many roles they play we can list a few:

**1. filamentous fungi break down organic matter**

Filamentous fungi are ubiquitous in nature, with an important role in maintaining the ecosystems' status quo through decomposition of organic matter, nutrient recycling, and symbiotic interactions (Ferreira et al., 2020).

Filamentous fungi are phylogenetically diverse; however, members of three groups, namely ascomycetes, basidiomycetes, and zygomycetes, are mostly found in association with pollution mitigation research studies, or commercial exploitation, using high-quality medium recipes. Their dominant ecological role, extensive use in research, and commercial exploitation are related to the macroscopic filamentous growth, phylogenetic diversity, array of extracellular and intracellular enzymes, range of potential value-added products, production of surfactants, cell wall sorption, and synergistic possibilities in co-culture approaches (Troiano et al., 2020).

In support of this statement Troiano et al. in the article "Status of filamentous fungi in integrated biorefineries" highlights the role of fungi: waste biomass is complex but may be completely valorized using filamentous fungi; biological methods for biomass conversion are environmentally advantageous; filamentous fungi convert biomass into a myriad of valuable products; filamentous fungi may enhance the economic viability of biomass operations (Troiano et al., 2020).

Fungi have the ability to transform organic materials into a rich and diverse set of useful products and provide distinct opportunities for tackling the urgent challenges before all humans. Fungal biotechnology can advance the transition from our petroleum-based economy into a bio-based circular economy and has the ability to sustainably produce resilient sources of food, feed, chemicals, fuels, textiles, and materials for construction, automotive and transportation industries, for furniture and beyond. Fungal biotechnology offers solutions

for securing, stabilizing and enhancing the food supply for a growing human population, while simultaneously lowering greenhouse gas emissions. Fungal biotechnology has, thus, the potential to make a significant contribution to climate change mitigation and meeting the United Nation's sustainable development goals through the rational improvement of new and established fungal cell factories (Meyer et al., 2020).

**2. filamentous fungi produce enzymes of biotechnological, agricultural and industrial interest**

Many enzymes produced by fungi have relevant biotechnological applications in several industrial areas. The team of researchers coordinated by Guimaraes collected and isolated filamentous fungi from soil and humus, plants and sugar cane bagasse of different regions of the Sao Paulo state. Forty isolates were examined for their ability to produce xylanase, glucose- oxidase, alkaline phosphatase, acid phosphatase, phytase, pectinase and amylase. Among these, twenty three isolate exhibited enzymatic potential. The xylanases produced by two of these isolates (Aspergillus caespitosus and A. phoenicis) showed good potential for pulp bleaching. Among seventeen isolates, at least three produced high levels of glucose-oxidase, being Rhizopus stolonifer and A. versicolor the best producer strains. A. caespitosus, Mucor rouxii, and nine others still not identified were the best producers of phosphatases in submerged fermentation. Pectinase was best produced by IF II and C-8 belong R. stolonifer. Significant levels of amylase were produced by Paecilomyces variotii and A. phoenicis. A remarkable enzyme producer was Rhizopus microsporus var. rhizopodiformis that produced high levels of amylase, alkaline and acid phosphatases, and pectinase. Some morphological structures of this fungus were illustrated using light microscopy (LM) and scanning electron microscopy (SEM). This study contributes to catalogue soil fungi isolated in the state of Sao Paulo, and provides additional information to support future research about the industrial potential of these microorganisms that may produce enzymes and, eventually, also secondary metabolites with anti- microbial or anti- parasitic activities (Guimaraes et al., 2006).

**3. filamentous fungi are used as biological agents to control plant diseases caused by microorganisms such as bacteria or fungi, phytophagous insects**

Currently, more than two billion tons of pesticides are used every year all over the world. These pesticides include fungicides, bactericides, herbicides, insecticides and others that are used to eliminate undesirable agents, mainly fungi, weeds and insects, which are considered crop pests, with the aim to guarantee a high yield. The cost of this practice is not only financially high, but also environmentally, because the excessive use of pesticides leads to water bodies, groundwater and soil contamination in addition to affecting human and other animals' health due the toxicity, recalcitrance and the carcinogenic potential of many of these compounds. The biological control of pests has been recognized as an alternative to the use of pesticides (Baron et al., 2019).

In many cases, the control of pathogens can involve direct interaction between fungi and plants. In this case, the fungi are able to act as plant pathogen antagonists, i.e., they can use several different mechanisms, such as the production of metabolites (antibiotics, volatile compounds - ammonia, cyanide, alcohols, esters, ketones, etc. - or enzymes), competition (for space, C, N or mineral sources), parasitism, or the induction of systemic resistance in the plant or an increase in its growth response, resulting in a reduction in the pathogen's activities (Baron et al., 2010)

Insects are the main class of the Arthropoda phylum and are among the most diverse living beings on the planet. Even only a small portion of this group contains species known as agricultural pests; they are responsible for causing considerable damage to crops, devastating approximately 20% of the global annual production. In this context, it arises the practices of biological control using entomopathogenic fungi, a group formed by several species that are able to infect and cause disease in insects and other arthropods (Pell et

al., 2010; Roy and Pell, 2000; Schrank and Veinstain, 2010; Thomas and Read, 2007)

**4. fungi can establish cooperative relationships with plants - mycorrhiza**

Most land plants form symbiotic associations with arbuscular mycorrhizal (AM) fungi. These are the most common and widespread terrestrial plant symbioses, which have a global impact on plant mineral nutrition. The establishment of AM symbiosis involves recognition of the two partners and bidirectional transport of different mineral and carbon nutrients through the symbiotic interfaces within the host root cells. Intriguingly, recent discoveries have highlighted that lipids are transferred from the plant host to AM fungus as a major carbon source (Wang et al., 2017).

Arbuscular mycorrhizal fungi are a kind of beneficial microorganisms in soils, which can establish symbiotic association with ~80% of terrestrial plants, namely, arbuscular mycorrhizas. The symbiosis possesses bidirectional roles in mycorrhizal fungi and host plants: host plants provide photosynthates for the fungal partner; mycorrhizal fungi absorb water and nutrients from soils to plant partner. Mycorrhizal symbiosis has a typical effect on growth performance of host plants. In general, arbuscular mycorrhizas show a promoted effect on plant growth by means of increasing water and nutrient acquisition, soil improvement, phytohormone regulation, and root morphological improvement (Lu et al., 2018).

**5. and last but not least, fungi have a role in depollution**

In support of this statement Kues in the article "Fungal enzymes for environmental management" highlights the role of fungi in terrestrial ecosystems: basidiomycetes produce enzymes useful to attack toxic persistent organic pollutants; mainly laccase and peroxidases are considered for water and soil decontaminations; bioreactor processes with immobilized enzymes for water purification are in tests; bioaugmentation and biostimulation use living fungi and their enzymes *in situ*; but effects on ecosystem functions and local biodiversities are still largely unstudied (Kues, 2015).

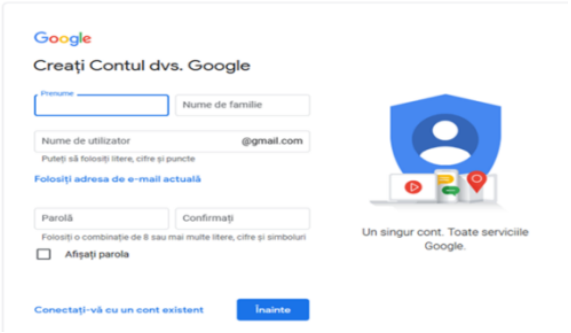
Fungal ligninolytic enzymes have broad biotechnological applications. Particularly laccases and certain fungal class II peroxidases from white-rot basidiomycetes are considered in degradation of persistent organic pollutants. Promising processes with reusable immobilized laccases in special reactors have been developed up to pilot scale for degradation of pollutants in water. Bioremediation of chemically complex soils with their large indigenous microbial communities is more difficult. Living fungi and their enzymes are employed. Bioaugmentation, introduction of for example white-rots for enzyme production into a polluted soil, and biostimulation of suitable resident organisms by nutritional manipulations are strategies in degradation of pollutants in soil. Bioaugmentation has been successfully implemented on small scale for soils in biobeds and for specific materials such as olive mill wastes (Kues, 2015).

## MATERIALS AND METHODS

### Create the Google Drive form and questionnaire

**Step 1**

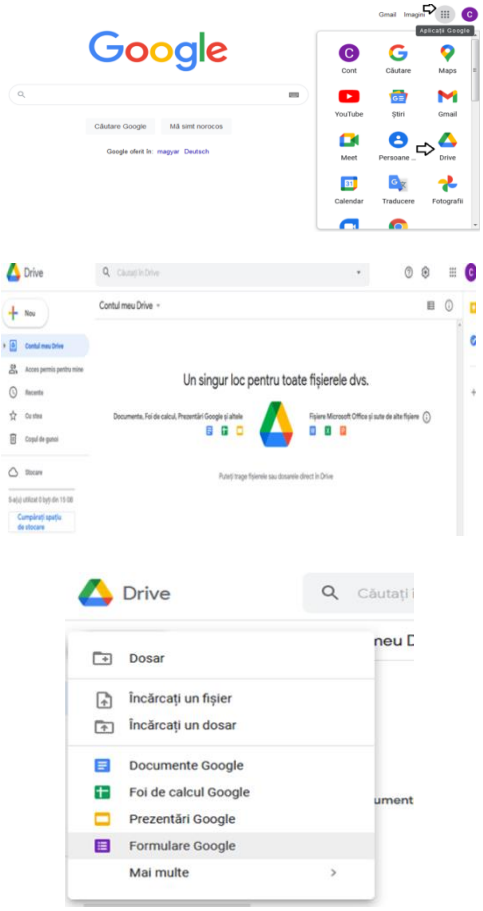
With the browser I created a Google user account, then I went to the G-mail page to create a new account using the "Create an account" option and entered all the necessary data to register and benefit from all Google services offered.




**Step 2**

To enter Google Drive, I clicked the button called "Google Apps". After displaying its window, I clicked on the "New" button that offers the submenus: "File"; "Upload a file"; "Upload a file"; "Google Docs"; "Google Spreadsheets"; "Google Presentations"; "Google Forms"; "More".

I accessed the "Google Forms" window and added the necessary information.

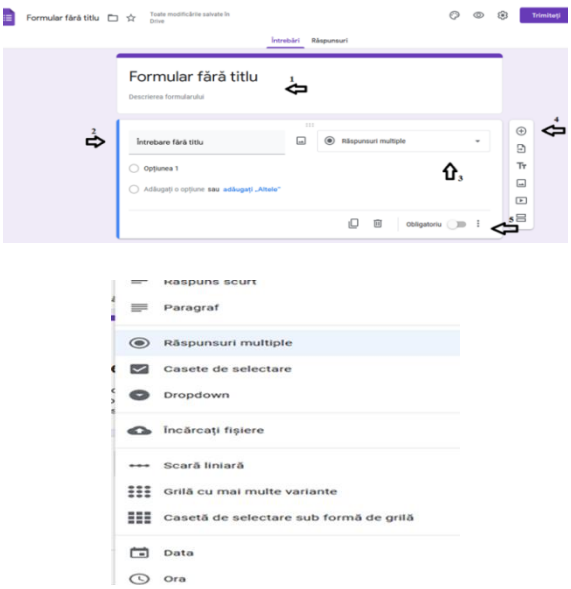



**Step 3**

In this stage, I filled in the title of the topic in the column where it says “Untitled form” (1), then I wrote the question and how many answer options we have (2). In the "Multiple answers" box we have several options on how we want to make the answers (3).

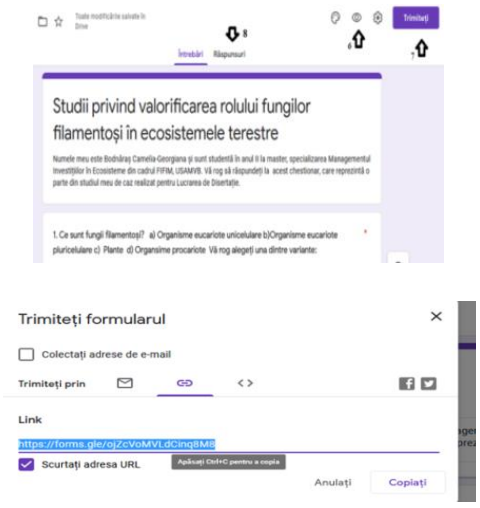
To add more questions we have to press the button with the circled plus sign (4).

If we want the question to be optional, this means that the respondent will answer it only if he wants, we do not tick the "Mandatory" button, but if we do not want to skip the question, we tick the button (5).




**Step 4**

After completing the questionnaire, we can see what it looks like by clicking on the eye icon (6) and if we see that everything is well written we can send it for completion by the general public (7). We have the option to send it by e-mail, on social networks or by creating a link. Finally, to see the number of people who completed the questionnaire, we must click on the Answers option (8).



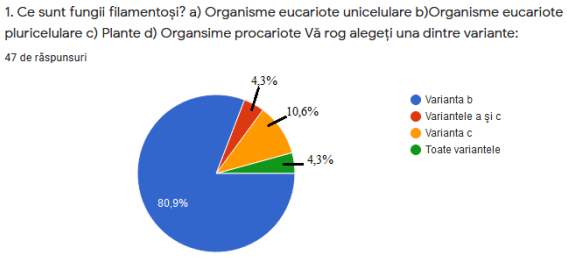

**Step 5**

By accessing the Answers option, we see how many people answered the questionnaire and we have the option to see an overall

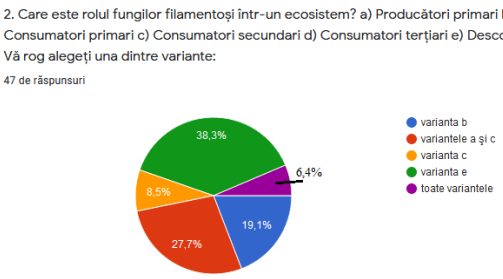
summary drawn in a diagram or we can see how each person answered these questions.


## RESULTS AND DISCUSSIONS

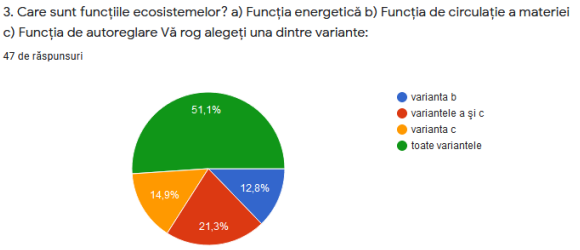
In this case study we present a questionnaire addressed to people from different social categories, who have completed gymnasium, bachelor's, master's or doctoral studies, such as pupils, students, masters, doctoral students. The study shows us the extent to which they know about the importance of filamentous fungi in terrestrial ecosystems, the role and benefits of these organisms around us. The poll has accumulated a total of forty-seven responses.
The first question was, "What are filamentous fungi?"
a) Unicellular eukaryotic organisms
b) Multicellular eukaryotic organisms
c) Plants
d) Prokaryotic organisms
The answer variants are: variant b; variants a and c; variant c; all variants.




We found out that: 80.9% of the respondents answered variant b; 4.3% of respondents answered variants a and c; 10.6% of respondents answered variant c; 4.3% of respondents answered all variants.
The correct variant to this question is variant b. 80.9% of the respondents answered correctly and 19.2% of the respondents answered incorrectly.
The second question was, "What is the role of filamentous fungi in an ecosystem?"
a) Primary producers
b) Primary consumers
c) Secondary consumers
d) Tertiary consumers
e) Decomposers
The answer variants are: variant b; variants a and c; variant c; variant e; all variants.

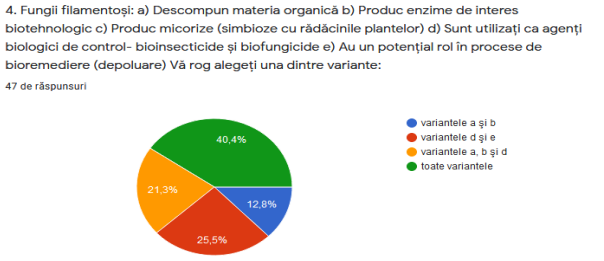



We found out that: 19.1% of the respondents answered variant b; 27.7% of respondents answered variants a and c; 8.5% of the respondents answered variant c; 38.3% of the respondents answered variant e; 6.4% of respondents answered all variants.
The correct variant of this question is variant e. 38.3% of the respondents answered correctly and 61.7% answered incorrectly.
The third question is, "What are the functions of ecosystems?"
a) The energetic function
b) The circulation function of matter
c) The self-regulation function
The answer variants are: variant b; variants a and c; variant c; all variants.

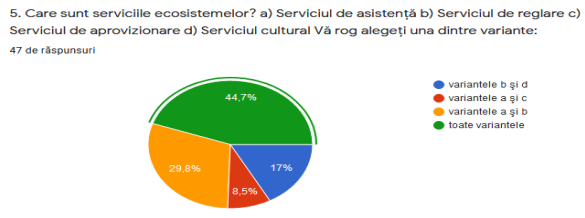



To this question: 12.8% of respondents chose option b; 21.3% of the respondents chose variants a and c; 14.9% of the respondents chose variant c; 51.1% of respondents answered all variants.
The correct variant of this question is all variants. 51.1% of respondents answered correctly and 49% of respondents answered incorrectly.
In the fourth heading, the statement is worded as follows:
Filamentous fungi:
a) They break down organic matter

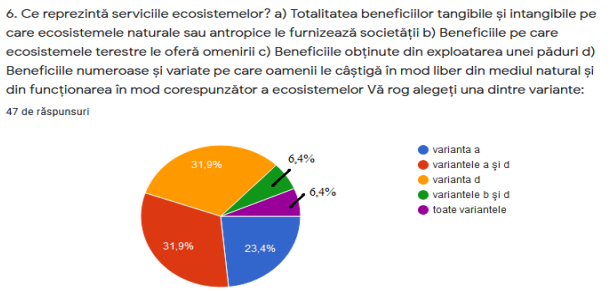
b) They produce enzymes of biotechnological interest
c) They produce mycorrhizae (symbiosis with plant roots)
d) They are used as biological control agents - bioinsecticides and biofungicides
e) They have a potential role in bioremediation processes (depollution)
The answer variants are: variants a and b; variants d and e; variants a, b and d; all variants.




In this case, the percentages are as follows: 12.8% of respondents answered variants a and b; 25.5% of the respondents answered variants d and e; 21.3% of the respondents answered variants a, b and d; 40.4% of respondents answered all variants.
The correct variant of this question is all variants. 51.1% of respondents answered correctly and 49% of respondents answered incorrectly.
Question number five is the following: "What are ecosystem services?"
a) Assistance service
b) Regulation service
c) Supply service
d) Cultural service
The variants are: variants b and d; variants a and c; variants a and b; all variants.

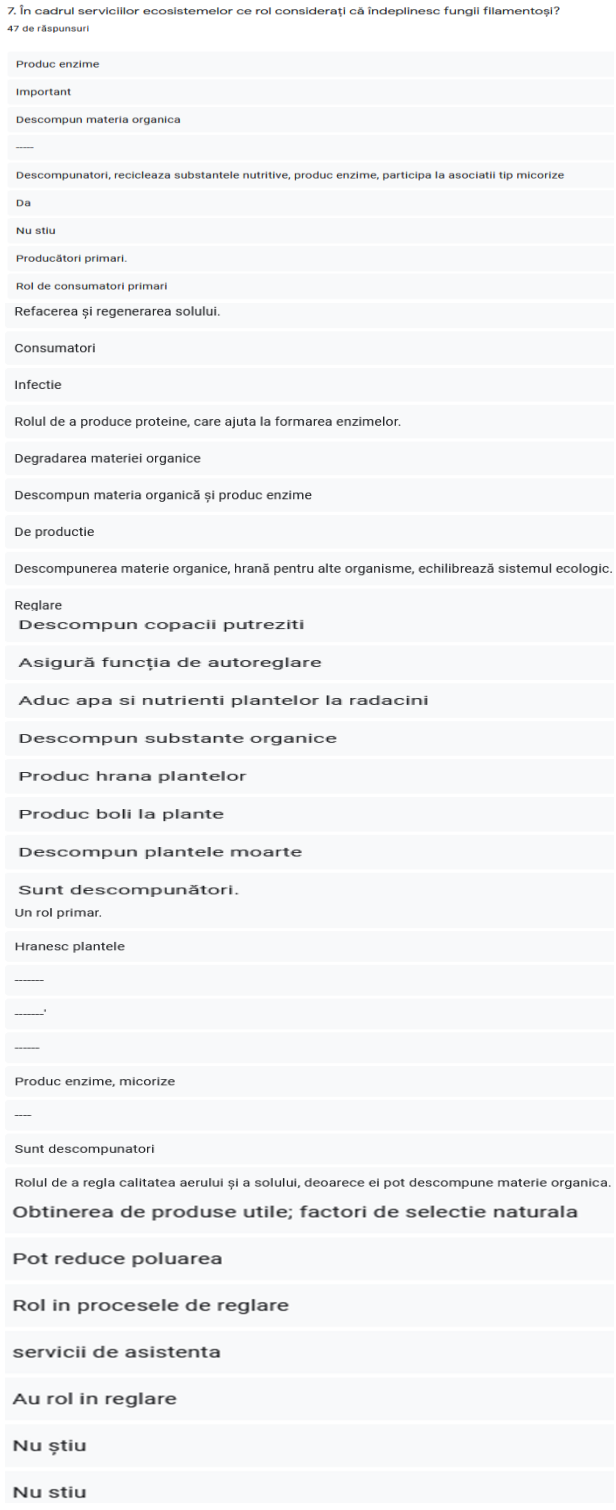



The percentage in question five is as follows: 17% of respondents answered variants b and d; 8.5% of respondents answered variants a and c; 29.8% of respondents answered variants a and b; 44.7% of respondents answered all variants.
The correct answer to this question is all the options. 44.7% of respondents answered correctly and 55.3% of respondents answered incorrectly.
The sixth question is: "What are ecosystem services?"
a) The totality of the tangible and intangible benefits that natural or anthropogenic ecosystems provide to society
b) The benefits that terrestrial ecosystems offer to humanity
c) The benefits obtained from the exploitation of a forest
d) The many and varied benefits that humans freely gain from the natural environment and from the proper functioning of ecosystems
The answer variants are: variant a; variants a and d; variant d; variants b and d; all variants.




The results are: 23.4% of the respondents answered variant a; 31.9% of the respondents answered variants a and d; 31.9% of the respondents answered variant d; 6.4% of the respondents answered variants b and d; 6.4% of respondents answered all variants.
The correct variant to this question is variant d. 31.9% of the respondents answered correctly and 68.1% of the respondents answered incorrectly.
To the seventh question: "In ecosystem services, what role do you think filamentous fungi play?" ; people have the option to write what they think is the role of filamentous fungi.
Given this aspect, the answers are: they produce enzymes; decompose organic matter; decomposers, recycle nutrients, produce enzymes, participate in mycorrhizal associations; primary producers; role of primary consumers; soil restoration and regeneration; consumers; infection; the role of producing proteins that help form enzymes; degradation of organic matter; of production; the decomposition of organic matter, food for other organisms, balances the ecological system; adjustment; decompose rotten trees; provides self-regulation function; bring water and

nutrients to the plants to the roots; produce plant food; produce plant diseases; decompose dead plants; they are decomposers; a primary role; the role of regulating air and soil quality because they can decompose organic matter; obtaining useful products, natural selection factors; can reduce pollution; assistance services; I do not know.




The correct answer is: filamentous fungi have a role in the descomposition of organic matter, produce enzymes of biotechnological interest, can be used as biological agents to control plant diseases, insects, can be used as biopesticides have the role of producting mycorrhizae and not least row have a role in depollution. 24 respondents answered correctly and 23 respondents answered incorrectly.

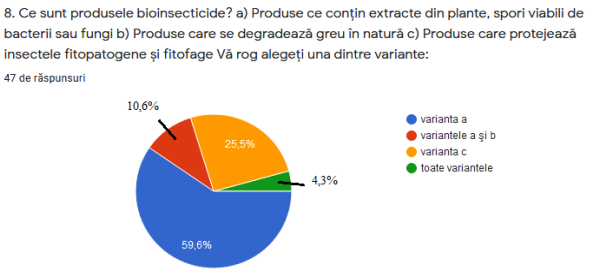
Question eight is worded as follows: "What are bioinsecticides?"

a) Products containing plant extracts, viable spores of bacteria or fungi

b) Products that are difficult to degrade in nature

c) Products that protect phytopathogenic and phytophagous insects

The answer variants are: variant a; variants a and b; variant c; all variants.




We have the following results: 59.6% of the respondents answered variant a; 10.6% of respondents answered variants a and b; 25.5% of the respondents answered variant c; 4.3% of respondents answered all variants.

The correct variant of this question is variant a. 59.6% of respondents answered correctly and 40.4% of respondents answered incorrectly.

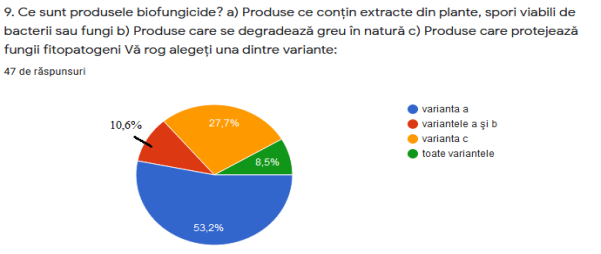
Question number nine is: "What are biofungicides?"

a) Products containing plant extracts, viable spores of bacteria or fungi

b) Products that are difficult to degrade in nature

c) Products that protect phytopathogenic fungi

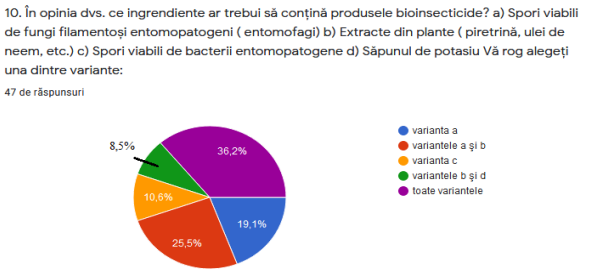
The variants to choose are: variant a; variants a and b; variant c; all variants.



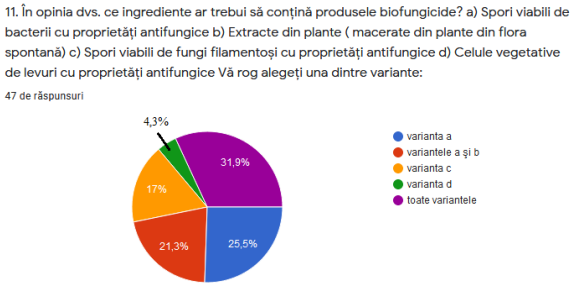

The results are: 53.2% of the respondents answered variant a; 10.6% of respondents answered variants a and b; 27.7% of the

respondents answered variant c; 8.5% of respondents answered all variants.

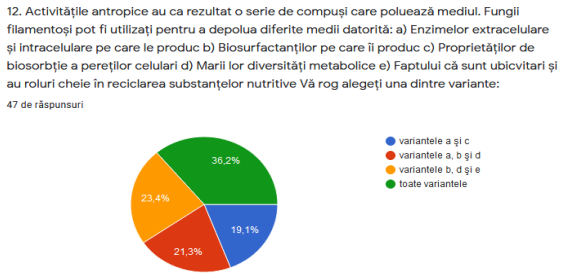
The correct variant to this question is variant a. 53.2% of the respondents answered correctly and 46.8% answered incorrectly.
Question number ten is: "In your opinion, what ingredients should bioinsecticides contain?"
a) Viable spores of filamentous entomopathogenic fungi (entomophagous)
b) Plant extracts (pyrethrin, neem oil, etc.)
c) Viable spores of entomopathogenic bacteria
d) Potassium soap
The variants are: variant a; variants a and b; variant c; variants b and d; all variants.




We have the following answers: 19.1% of the respondents answered variant a; 25.5% of the respondents answered variants a and b; 10.6% of respondents answered variant c; 8.5% of respondents answered variants b and d; 36.2% of respondents answered all variants.
The correct variant of this question is all variants. 36.2% of respondents answered correctly and 63.7% answered incorrectly.
Question number eleven: "In your opinion, what ingredients should biofungicide products contain?"
a) Viable spores of bacteria with antifungal properties
b) Plant extracts (macerated plants from spontaneous flora)
c) Viable spores of filamentous fungi with antifungal properties
d) Vegetative yeast cells with antifungal properties
The variants are: variant a; variants a and b; variant c; variant d; all variants.

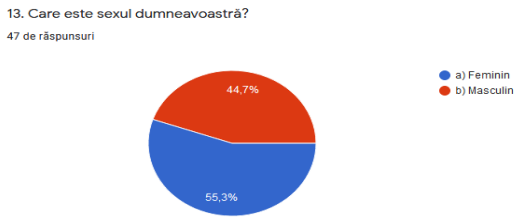



The answers obtained are: 25.5% of the respondents answered variant a; 21.3% of the respondents answered variants a and b; 17% of respondents answered variant c; 4.3% of respondents answered variant d; 31.9% answered all variants.
The correct variant is all variants. 31.9% of respondents answered correctly and 68.1% answered incorrectly.
To question number twelve, people must choose one of the options:Anthropogenic activities result in a number of compounds that pollute the environment.Filamentous fungi can be used to depollute different environments due to:
a) The extracellular and intracellular enzymes they produce
b) The biosurfactants they produce
c) Biosorption properties of cell walls
d) Their great metabolic diversity
e) The fact that they are ubiquitous and have key roles in the recycling of nutrients
People can choose one of these options: options a and c; variants a, b and d; variants b, d and e; all variants.

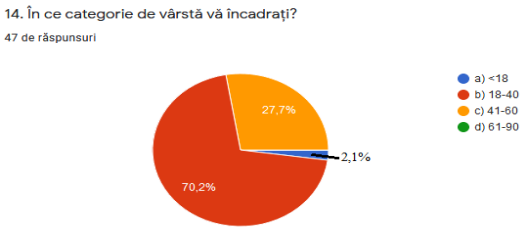



The answers received are: 19.1% of the respondents answered variants a and c; 21.3% of the respondents answered variants a, b and d; 23.4% of the respondents answered variants b, d and e; 36.2% of respondents answered all variants.

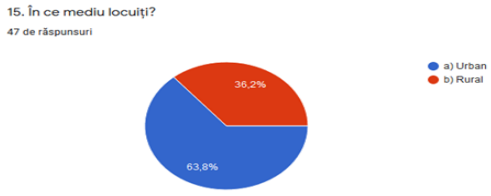
The correct variant is all variants. 36.2% of respondents answered correctly and 63.8% answered incorrectly.
Question thirteen concerned the gender of the person completing the questionnaire, female or male.
We find that 55.3% of respondents are female and 44.7% of respondents are male.



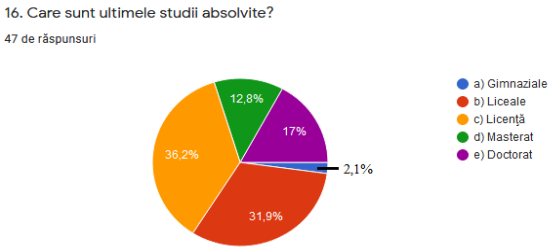

The next question with number fourteen concerns the age category of the person completing this questionnaire.
Here we have a percentage of 2.1% of respondents are under 18, 70.2% who fall between the ages of 18 and 40 and 27.2% of respondents are between 41 and 60 years old.




Question number fifteen is, "In what environment do you live?"
The variants are urban and rural.
63.8% of respondents live in urban areas and 36.2% of respondents live in rural areas.




The last question number sixteen concerns the last studies completed.
They can choose between:
a) Gymnasium
b) High school
c) Bachelor's degree
d) Master's degree
e) Doctorate
- 2.1% of respondents answered middle school
- 31.9% of respondents answered high school
- 36.2% of respondents answered license
- 12.8% of respondents answered master's degree
- 17% of respondents answered doctorate




This concludes the questionnaire with the 16 questions related to the knowledge or not about the importance and role of filamentous fungi in the terrestrial ecosystem.

## CONCLUSIONS

This study is part of the first part of the Dissertation, the documentation part and the study of the specialized literature, and the questions of the questionnaire are based on the study of the specialized literature.
Basically, the goal is to see the degree of knowledge and perception of humans about the role of filamentous fungi in terrestrial ecosystems.
Following this aspect, it is found that most of the respondents who completed the questionnaire know what role filamentous fungi play in an ecosystem, how these organisms interact and what benefits they bring to the soil and plants.
Filamentous fungi are important because they have a potential role in bioremediation processes; produce mycorrhizae and are used as biological control agents- bioinsecticides and biofungicides.
In conclusion, respondents understand the importance of filamentous fungi.

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