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Sustainable Applications of Mushrooms in Soil Science: A Call for Pictorial and Drawn Articles

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Abstract

The world of mushrooms is very exciting and full of with surprises for the reader. Mushrooms are very important macro-organisms for our agroecosystem, because they are edible and medicinal for human health, on one side, and toxic causing the death of humans, on the other side. Several nutritional, medicinal and pharmaceutical applications of mushrooms are well known besides soil improvement. Mushrooms can improve soil through several approaches such as increasing soil organic matter, controlling soil erosion, improving soil aggregates, enhancing soil nutrition, promoting C, and NPK cycling, and the bioremediation of polluted soils. Like other fungi, mushrooms have strong impacts on soil including both positive and negative. The spent mushroom substrate could be applied to soil as an organic fertilizer or compost, which could increase soil microbial activity and the content of amino acid metabolites in the studied orchard. Mushrooms also could be used as a bioindicator for soil pollution (e.g., toxic elements, heavy metals, organic pollutants, and radioactives/isotopes). Therefore, the main roles of mushrooms in the soil include soil myco-nanoremediation, soil myco-nanomanagement, and soil myco-improvement. This is a call for submission of photographic articles on the roles of mushrooms in soils to publish by Egyptian Journal of Soil Science.

Keywords: Soil pollution, Myco-nanoremediation, Myco-nanomanagement, Soil myco-improvement

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I. Introduction

Mushrooms are wonderful macro-fungi, which have several roles in our like. These roles may include applications in different fields of our life such as in the agriculture as a source for edible mushrooms and organic fertilizers, industry, pharmacology, and medicine (Hanafi et al. 2018). Edible mushrooms are a very vital source for human nutrition, because these vegetables contain many nutritional attributes (mainly protein, fiber, vitamins, and minerals), whereas the medicinal mushrooms have mainly the medicinal properties especially containing bioactive compounds and biological activities (El-Ramady et al. 2022a). As macro-fungi, mushrooms have vital impacts on the soil, which include both positive (by improving many soil properties) and negative (when mushroom wastes cause environmental problem to soil), as reported by Elsakhawy et al. (2022). Mushrooms have distinguished impacts on the soil when they apply as compost (forming from spent mushroom substrate as an organic fertilizer), which could increase soil microbial activity and the content of amino acid metabolites in the studied orchard (Tan et al. 2022). The other applications of mushroom may include using as a bioindicator in polluted soils, like soil polluted with toxic elements (Gwenzi et al. 2021; Karami et al. 2021), heavy metals (Kokkoris et al. 2019; Dowlati et al. 2021), organic pollutants (Golovko et al. 2022), radioactives/isotopes (Wang et al. 2021; Melgar et al. 2021; Andronikov et al. 2022; Ernst et al. 2022; Ronda et al. 2022), as well as for health risk indices (El-Ramady et al. 2021; Keskin et al. 2021). Several mushrooms are also abundant for exploitation in agro-industrial or agro-wastes or such as winery and olive mill wastes, producing many beneficial materials such as bioethanol or biofertilizers (Koutrotsios et al. 2022). Mushroom residues can also be applied to cultivated crops like cucumber to increase their productivity under a continuous cropping regime by regulating the soil microbial communities (Zhou et al. 2021). This is a call for submitting articles on the mushrooms and soil especially in pictorial presentation. This call may include different sustainable applications of mushrooms in soil science as a bioindicator, bio remediation of soil, producing nanoparticles and others.

2. Mushrooms and soil

Here in this section, the photos are talking not the words. The main information about different applications of mushrooms in soil are presented and drawn in Fig. 1. Some common edible mushrooms are reported in Fig. 2, including their taxonomy, and suggested applications.

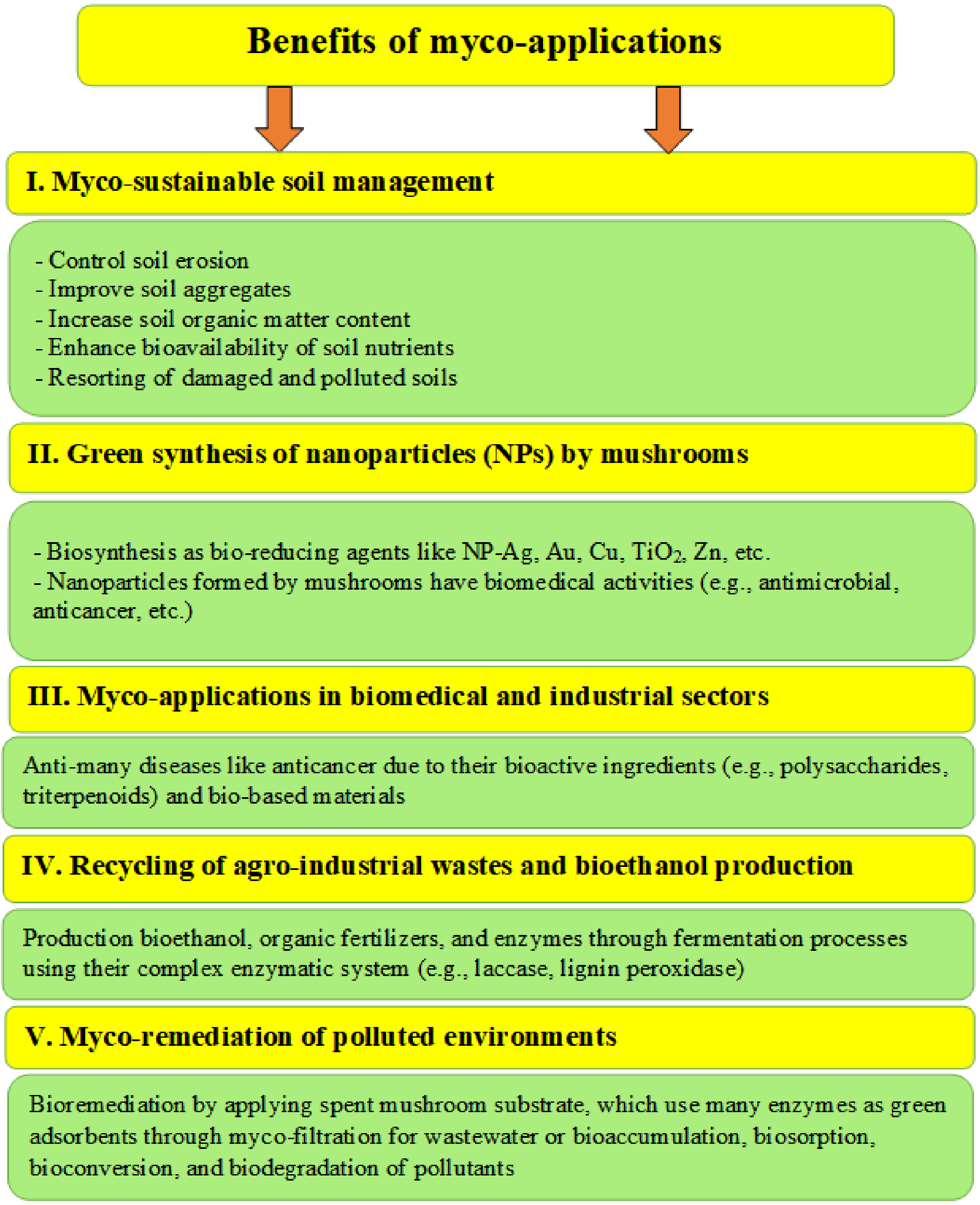

Fig. 1. List of many applications of mushrooms that can be applied in soil and other others (source: Elsakhawy et al. 2022)

Scientific name: *L. edodes* (Berk.) Pegler (1976)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Omphalotaceae
Genus: *Lentinula* Earle
Applications:
- In East Asian cuisine used as fresh and dried,
- In green synthesis of nanoparticles,
- In medicinal attributes,
- Nano-emulsion derived from mushroom

Oyster mushroom: *Pleurotus ostreatus*
Sci. name: *P. ostreatus* (Jacq.) P. Kumm (1871)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Pleurotaceae
Genus: *Pleurotus* (Fr.) P. Kumm., 1871
Applications:
- In cuisine (soups, stuffed, in fry with soy sauce),
- In green synthesis of nanoparticles and,
- In medicinal and myco-remediation attributes
- Producing eco-friendly polymers

King oyster: *Pleurotus eryngii*
Scientific name: *P. eryngii* (DC.) Quél. (1872)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Pleurotaceae
Genus: *Pleurotus* (Fr.) P. Kumm., 1871
Applications:
- Edible, and cooked,
- It is medicinal (immune system; cholesterol-lowering dietary agent),
- can attack nematodes and control parasite

Almond mushroom: *Agaricusblazei*
Scientific name: *Agaricusblazei*Murrill (1945)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Agaricaceae
Genus: *Agaricus* Linnaeus, 1753
Applications:
- Edible food
- Alternative medicine
- It is supposed anti-cancer effect

Cultivated Mushroom: *Agaricusbisporus*
Sci name: *A. bisporus* (J.E. Lange) Imbach (1946)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Agaricaceae
Genus: Agaricus Linnaeus, 1753
Applications:
- Nutraceutical activities
- Production of chitin nano-paper

Lacquered Bracket: *Ganoderma lucidum*
Sci. name: *G. lucidum* (Curtis) P. Karst. (1881)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Polyporales
Family: Ganodermataceae
Genus: Ganoderma P. Karst., 1881
Applications: - Inedible, as a bitter-tasting tea,
- In green synthesis of nanoparticles and,
- In medicinal attributes

Branching Oyster: *Pleurotus cornucopiae*
Sci name: *P. cornucopiae* (Paulet) Rolland (1910)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Pleurotaceae
Genus: *Pleurotus* (Fr.) P. Kumm., 1871
Applications:
- Edible mushrooms,
- Myco-bioremediation of polluted soils with heavy metals

Pleurotus abalonus
Sci name: *P. abalonus* Y.H. Han, K.M. Chen & S. Cheng (1974)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Pleurotaceae
Genus: *Pleurotus* (Fr.) P. Kumm., 1871
Applications:
- Edible mushrooms as nutritional supplement,
- Traditional medicinal can reduce cancer risks

Pleurotus ferulae
Sci. name: *P. ferulae* (Lanzi) X. L. Mao (2000)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Pleurotaceae
Genus: *Pleurotus* (Fr.) P. Kumm., 1871
Applications:
- Biological activities, including anti-tumor, antimicrobial, antioxidative, and immune modulatory activities

Pleurotus citrinopileatus
Sci name: *P. citrinopileatus* Singer (1942)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Pleurotaceae
Genus: *Pleurotus* (Fr.) P. Kumm., 1871
Applications:
- Edible mushroom,
- Antitumor and immunoenhancing effects

Pleurotus rhodophyllus
Sci. name: *Pleurotus rhodophyllus*Bres. (1905)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Tricholomataceae
Genus: Phyllotopsis E.-J.Gilbert&Donk ex Singer
Applications:
- Nutritional and medicinal benefits
- Edible mushrooms

Golden needle mushroom: *Flammulinavelutipes*
Sci. name: *F. velutipes* (Curtis) Singer (1951)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Physalacriaceae
Genus: *Flammulina* P. Karst.
Applications:
- Cultivated for functional foods,
- Antioxidant, anti-inflammatory, anti-tumor, and cholesterol-lowering effects

White jelly mushroom: *Tremella fuciformis*
Sci. name: *Tremella fuciformis* Berk. (1856)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Tremellales
Family: Tremellaceae
Genus: *Tremella* Linnaeus, 1753
Applications:
- Antioxidant, antitumor, antidiabetic, anti-inflammatory, and immunomodulatory activities
- Its extract is used in women's beauty products

Auricularia peltata
Sci. name: *Auricularia peltata* Lloyd (1922)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Auriculariales
Family: Auriculariaceae
Genus: *Auricularia* Bull., 1780
Applications:
- Special nutrition and medicinal value in prevention of diabetes and heart attacks

Cloud ear fungus: *Auricularia polytricha*
Sci. name: *A. polytricha* (Mont.) Sacc. (1885)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Auriculariales
Family: Auriculariaceae
Genus: *Auricularia* Bull., 1780
Applications:
- Biological functions: hypoglycemic, anti–proliferative, and anti–inflammatory activities
- Antioxidant properties

Pholiotaaegerita
Sci. name: *P. aegerita* (V.Brig.) Quél. (1872)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Strophariaceae
Genus: *Cyclocybe*Velen.
Applications:
- Edible mushrooms
- As a diuretic in traditional Chinese medicine

Hypsizigusmarmoreus
Sci. name: *H. marmoreus* (Peck) Bigelow
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Lyophyllaceae
Genus: *Hypsizygus* Singer
Applications:
- Antioxidant and hepatoprotective activities
- Edible, nutritional and medicinal mushroom

Bamboo mushroom: *Dictyophoraindusiata*
Sci. name: *D. indusiata*(Vent.) Desv. (1809)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Phallales
Family: Phallaceae
Genus: *Phallus* Junius ex L., 1753
Applications:
- Best-known edible mushroom around the world
- Use for immunity, tyrosinase inhibition, sedation, and neuroprotective activities

Pholiotanameko
Sci. name: *P. nameko* (T. Itô) S. Ito & S. Imai (1933)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Strophariaceae
Genus: *Pholiota* (Fr.) P.Kumm.
Applications:
- Functional activities, like antitumor, anti-inflammatory and immunostimulatory
- Edible mushroom

Hen-of-the-woods: *Grifolafrondosa*
Sci. name: *Grifolafrondosa* (Dicks.) Gray (1821)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Polyporales
Family: Grifolaceae
Genus: *Grifola* Gray
Applications:
- It used as a health food for a long time
- Biological activities: antitumor, immune-modulatory, antioxidant, hypoglycemic

Shaggy ink cap: *Coprinus comatus*
Sci. name: *C. comatus* (O. F. Müll.) Pers. (1797)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Agaricaceae
Genus: *Coprinus* Pers., 1797
Applications:
- Edible mushrooms, have hypoglycemic activity
- Myco-remediation of heavy metals

Tremella aurantialba
Sci. name: *T. aurantialba*Bandoni& M. Zang (1990)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Tremellales
Family: Naemateliaceae
Genus: *Naematelia* Fr.
Applications:
- Traditional edible and medicinal mushroom
- It has immune-stimulating, antioxidant, antidiabetic, and antihyperlipidemic function

Clitocybe maxima
Sci. name: *C. maxima* (P. Gaertn., G. Mey. &Scherb.) P. Kumm. (1871)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Tricholomataceae
Genus: *Infundibulicybe*Harmaja
Applications:
- Myco-bioremediation of soils polluted with heavy metals and organic pollutants
- Increases biological activities soils planted with this mushroom

White matsutake: *Tricholomagiganteum*
Sci. name: Tricholomagiganteum Massee (1912)
Kingdom: Fungi
Phylum: Ascomycota
Class: Dothideomycetes
Order: Agaricales
Family: Tricholomataceae
Genus: *Macrocybe* Pegler & Lodge
Applications:
- An edible species and rarely found in nature
- Has medicinal attributes like antitumor activity

Fig. 2. List of some common mushrooms including their taxonomy, and application. The information of taxonomy was extracted from https://www.gbif.org/species/and https://www.mushroomexpert.com/taxonomy.htmlaccessed on 30.6.2022. All photos from the international workshop about JUNCAO 2015 FAFU University, Fujian, China, with kind permission

3. Sustainable applications of mushrooms in soil

Several reports have been discussed the sustainable applications of mushrooms in soil such as Hanafi et al. (2018), Elsakhawy et al. (2022), El-Ramady et al. (2022a, b, c), Fawzy et al. (2022a), and Tello Martín et al. (2022). Mushrooms and their relations to soil science wereillustrated in **Fig. 2** with focus on the myco-bioremediation, myco-biotechnology and myco-nanotechnology.

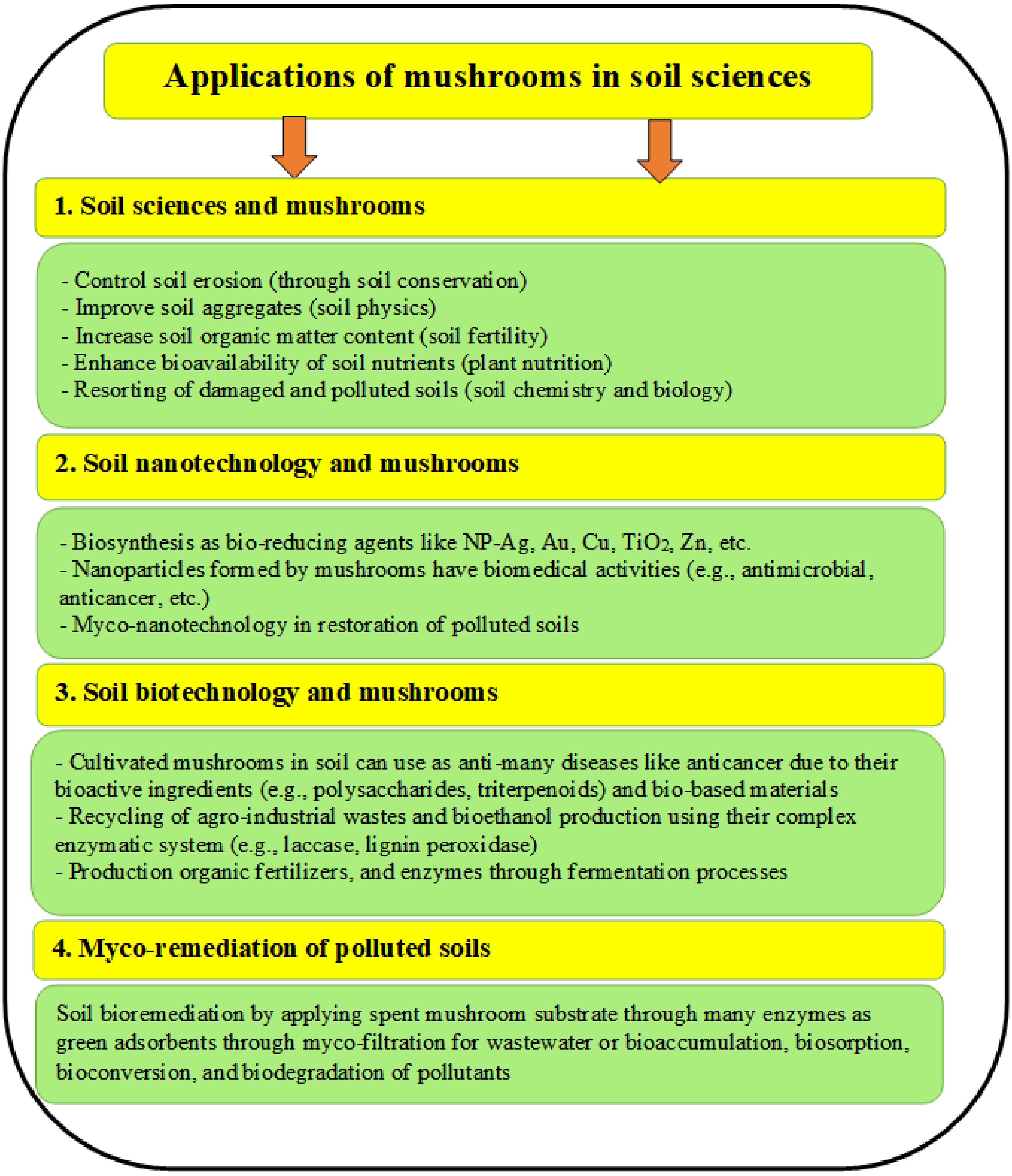

Fig. 3. The direct and indirect relationships between mushrooms and different soil sciences

4. A call for submission articles

This is a call for submission photographic articles on the roles of mushrooms in soils to publish by Egyptian Journal of Soil Science (EJSS). This is a new strategy of EJSS to adopt new approaches by a call for the hot topics like this call. We published some previous photographic manuscripts on the soil and humans (El-Ramady et al. 2022d), management of Salt-Affected Soils (El-Ramady et al. 2022e). More photographic also were published to be focus on different themes such as the comparative study on higher plants and mushrooms (El- Ramady et al. 2022c), the soil-water-plant-human nexus (Brevik et al. 2022), nano-grafting of vegetable crops (Bayoumi et al. 2022), soil and humans (El-Ramady et al. 2022d), applications and challenges of smart farming

(Fawzy and El-Ramady 2022), from farm-to-fork: on nano-farming of vegetables (Fawzy et al. 2022). Some specific mushroom species also were handled with more concern like *Pleurotus ostreatus* L. or oyster mushroom (Törős et al. 2022), and *Lentinula edodes* L. or shiitake (Hajdú et al. 2022).

5. Conclusions

Mushrooms are very important macro-fungi, which have been cultivated since ancient times especially in the eastern nations. Mushrooms have been consumed for their flavor, their nutritional and medicinal value. Thousands of species of mushrooms are believed to have varying degrees of edibility, and more than 3000 species of 231 different genera are considered to be major edible mushrooms. Mushrooms have relative high protein content and contain minerals, vitamins, fiber, and many bioactive compounds. The relationship between mushrooms and soil is very complicated including the positive and negative sides. Therefore, this is a call for discovering these relationships through using the drawn and pictorial manuscripts to be publish by the EJSS.

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication

All authors declare their consent for publication.

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Conflicts of Interest

The author declares no conflict of interest.

Contribution of Authors

All authors shared in writing, editing and revising the MS and agree to its publication.

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