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The contributions of fungi in Agriculture and its positive aspects

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Abstract

The contributions of fungi in agriculture are important and also necessary for growing plants. Beside this, fungi contain different-different metabolites and alkaloids which produce several drugs, antibiotics through the approaches used in biotechnology and biochemistry. Fungi make important contributions in health benefits in humans as well as animals. Penicillin is one of the best examples of fungi. Fungi are found the environment friendly and they are important part of our ecosystem. Due to wide range of fungi habitat and the need to compete against a diverse array of other fungi, bacteria and some other organisms; they have developed itself in several survival mechanisms. This is one of the positive aspects of fungi that it can compete with the harmful micro-organism which can cause disease in plants. Fungi collectively play many roles with soil in different physiological processes such as ions and water accumulation, chemical reactions and biosynthesis of compounds which helps in the growth of plants. In agriculture, fungi are a group of useful organisms, sometimes it works as pathogenic organism and sometimes it is a good source of drugs, organic acids, food products, antibiotics, growth promoters, enzymes and alcohols. Thus, there is a need of fungi in agriculture sector and it has diverse positive aspects.

Introduction

Fungi are the member of eukaryotic organism's group. Fungi are very diverse in nature with 4 main divisions and have estimated between 2.2 to 3.8 million species which includes rusts, yeast, molds, lichens and mushrooms **(Fig 1)**. Among all of them (over 1,48,000 are well known) some are pathogenic and some have beneficial aspects to agriculture as well as to humans. Despite being used in drinks, foods, industry and medicines

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for thousands of years, the enhancement of fungal species for humans have to move behind that of plants. According to the report by "*State of the World's Plants and Fungi 2020*" in September 2020, there are 1,942 plants and 1,886 fungi species were newly described by scientists, some closely related to known medicinal species in 2019 alone. Surprisingly, there are about 90 percent of fungi are still to be described. From last two decades, the sequencing of the genomes of more than 3,000 fungal and 500 plant species have been completed yet and these numbers are growing rapidly as sequencing speed and cost also increases more and more. This new field of bioinformatics has enabled scientists to match particular traits and compare their genetic map. Many agricultural scientists and plant breeders search populations of wild or domestic species for different forms of genes, alleles of desirable characteristics with the help of this genomic or transcriptomic data. This field will ease the efforts of scientist working in the agriculture sector.

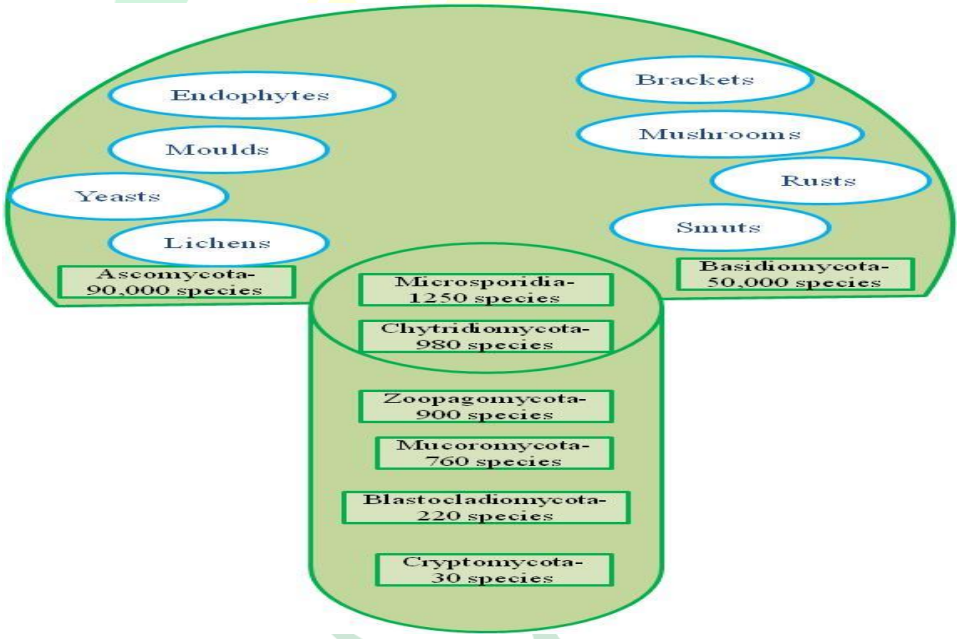

Fig 1: Representation of Kingdom Fungi (in the form of life tree)

According to the Food and Agriculture Organization (FAO) of the United Nations, there are 15 main crop plants which contribute to 90% of humanity's food intake and more than four billion people rely on just rice, maize and wheat. Thus, there is need to create alternative source of food for feeding the human beings and save the other plant species from many pathogenic organisms as well as fungi responsible for hampering the yield of many crops and trees. Many new species of fungi are associated with plant diseases like 14 species

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of *Colletotrichum* genus which can cause foliar disease, rot and post bloom drop in citrus trees (*Citrus* spp.), peppers (*Capsicum* spp.) and others. Another example is 29 species of *Diaporthe* genus which can cause root, stem and leaf diseases in peach (*Prunus persica*), Manchurian walnut (*Jugulans mandshurica*), lemon (*Citrus limon*), coffee (*Coffea* sp.) and tea (*Camellia sinensis*).

Role in Agriculture

The fungi and plants along regulate several soil processes as well as metabolic pathways and nutrient utilization. The saprophytic fungi which grow on organic matter such as dead leaves, fallen trees maintain the never ending cycle of greenhouse emission that could be the most significant staple for plant chemical processes in nature. They break down the organic matter so that the carbon, nitrogen and other compounds put back into the form that other living things can reuse it. The importance of fungi in the agriculture sector as fungi helps plants to grow. The example is *Mycorrhiza* which provides many minerals like zinc, copper to plants. In exchange, *Mycorrhiza* gets nutrients, such as carbohydrates from the plant roots and this relationship is called mycorrhizae network. Another example is from species of *Trichoderma* which are used to enhance the growth of crops and as a source of enzymes added to improve animal feeds. In agricultural systems, soil is a primary source for the growth of fungus and is interconnected with the roots of all plant species. Fungi can produce a wide range of growth promoters and bioactive compounds, which can boost the growth of plant species. In addition, fungi supply minerals and inorganic substances to plants, like phosphate, ammonium, nitrate etc and they are used as bio-fertilizers. Supportable agriculture is a farming technique on the basis of knowledge of ecosystem services, which interact with fungi or organisms and their physical environment. Fungi are connected with the biodiversity and if biodiversity is going to be lost then nothing will leave. Yet this biodiversity sustains our lives. The reasons for lost of biodiversity are deforestation; global emissions disrupting the climate system, new pathogens or insects attack on our crops. For thousands of years, we have disrupt nature to satisfy our self, cure many diseases, for build our houses, feed plants or animals and makes our lives more comfortable by cutting woods. However, humanity is still a long way from utilizing the full potential of biodiversity, in particular plants and fungi, which play important roles in ecosystem.

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Health and Medicinal Benefits

From last few years, there are 1,789 edible and 798 medicinal fungi reported from China with 561 being both edible and medicinal. Over 100 species of fungi have been domesticated for cultivation and around 60% of them are commercially produced. The research and study on fungus are better in china as compare to India. The history of the cultivation of fungi for food and medicines in China can be traced back to the Tang Dynasty (600–900 ce). Of the 2,189 species of fungi named in 2017, an impressive 179 were fibrecaps from Australia, Europe and India. The database for the *Checklist of Fungi in China* currently contains around 27,900 species and intraspecific names of fungi belonging to 15 phyla, 56 classes, 192 orders, 585 families and 3,534 genera. In addition, over 7,000 specific and intraspecific taxa have been described and many illustrated, in the Flora Fungorum Sinicorum series **(6)**. For example, *Ophiocordyceps sinensis* is a fungus that grows on the larvae of ghost moths. It is used a highly valuable traditional Chinese medicine, it has become the most important source of income in rural Tibet.

Mushroom cultivation plays a very important role in medicine and social development in China as well as in India. Many Basidiomycota, such as *Cyclocybe aegerita*, C. *cylindracea*, *Agaricus bisporus* and *Tremella fuciformis* are used as medicine for the treatment or prophylaxis of type 2 diabetes. These mushrooms help patients avoid high levels of glucose because they contain the least amount of digestible carbohydrates in the diet. Fungi are an importance source for natural product discovery, albeit most anticancer drugs are retrieved from plants and bacteria. Irofulven is a semi-synthetic derivative of illudin S, a natural toxin isolated from *Omphalotus illudens* (*Omphalotus illudens* is a type of mushroom) **(Table -1)**. Aphidicolin is a tetracyclic diterpene (used as antiviral) was originally isolated from *Cephalosporium aphidicola* (currently name: *Akanthomyces muscarius*) and also reported from *Nigrospora sphaerica* species. Many of the medicinal properties of fungi have given in **table-1**.

Table-1: Some important medicinal mushrooms used in traditional medicine

S. No.	Fungal species	Diseases
1.	*Agaricus Subrufescens*	Anticancer, Anti-inflammatory, Anti-allergic, Hepatoprotective, Diabetes
2.	*Cordyceps*	Anticancer, Antioxidant, Antibacterial, Antifungal,

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	Militaris	Anti-viral, Anti-hypertensive, High B.P.
3.	*Ganoderma Lingzhi*	Immunostimmulatory, Asthma or Bronchial, Anticancer, Anti-inflammatory,Anti-viral, Anti-oxidant, Antibacterial, Anti-fungal,
4.	*Ganoderma Sinense*	Immunostimmulatory, Anticancer, Anti-viral, Antiinflammatory, Anti-oxidant, Antibacterial, Antifungal
5.	*Ophiocordyceps Sinensis*	Anticancer, Antiviral, Anti-inflammatory, Antioxidant, Antibacterial, Antifungal, Anti-Angiogenetic, Antiproliferative
6.	*Trametes Versicolor*	Antitumor, Antiviral, Anti-inflammatory, Antimalarial activity, Diabetic and Hepatitis (treat kidney disease, diabetes, malaria and HIV)
7.	*Grifola Frondosa*	Anticancer, Antiviral, Anti-inflammatory, Antihypotensive, Hepatoprotective and Diabetic (treat liver, therapy of HIV, low blood pressure, and high blood sugar levels)

(*Source:* https://doi.org/10.1007/s13225-019-00430-9)

Fungi – Organic Acids Relationship

Organic acids are those compounds which contain functional groups with acidic properties such as carboxyl, thiol and alcohol groups. Organic acids have a vast array of applications in this field of agriculture as they are also extracted from different-different fungi. As an example Aspergillus genus (consisting a few hundreds of mould species) are well known for their potential to overproduce a variety of organic acids. These funguses have an intrinsic ability to accumulate organic acids and it is generally assumed that this ability provides the fungi with an ecological advantage. Other species of Aspergillus, such as *A. fonsecaeus, A. nidulans, A. awamori, A. saitoi A. phoenicis* and *A. wentii*, have also been reported to accumulate citric acid in considerable quantities **(Fig 2)**. Fumaric acid was isolated from *Rhizopus arrhizus, Rhizopus Formosa, Rhizopus nigricans* and *Rhizopus oryzae*. Gluconic acid is produced by surface or submerged fermentation procedures using *Aspergillus niger* strains. During the fermentation process, glucose in the medium is converted extracellularly by the enzymatic reaction of glucose oxidase by *A. niger*. However, the exploitation of *Rhizopus oryzae* has shown promising outcomes by producing higher amount of lactic acid **(Fig 2)**. Commercial scale production of organic acids is highly dependent on strain performance. Thus, some strains don't produce organic acids and there is a need to modify the strains according to the requirement. At last, oxalic acid synthesis is widespread among fungi and not just restricted to those forming *Mycorrhizas*, but it has been suggested that the phenomenon might have special significance in the symbiotic context. *Paxillus involutus, G. Weberianum* and *A. Niger* are the good source of oxalic acid

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production. Division *Basidiomycota*, two strains produced oxalic acid and six strains of *Aspergillus* producing high concentrations of oxalic acid.

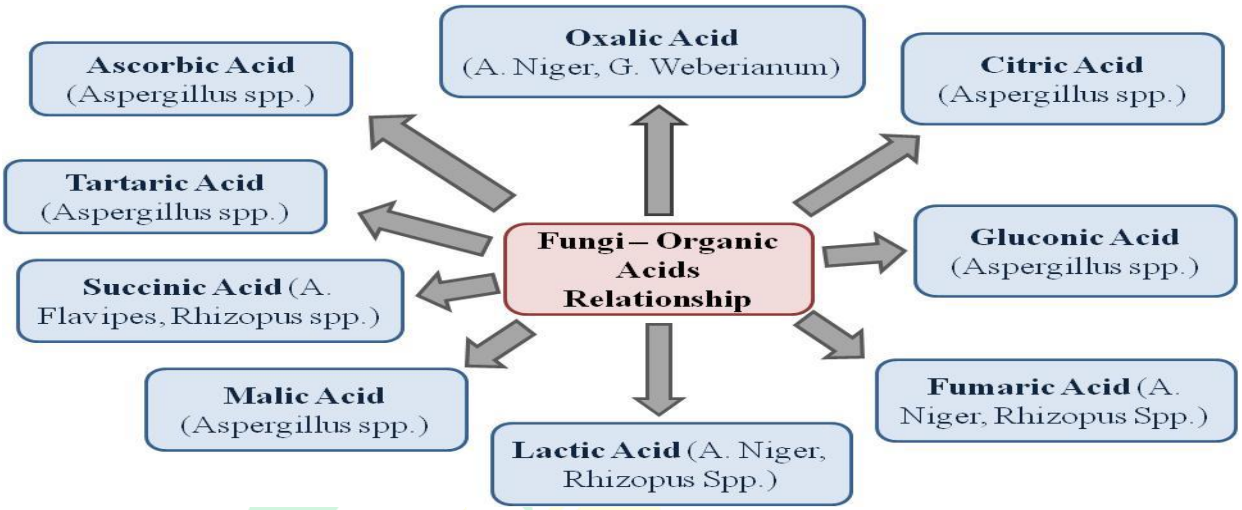

Fig 2: Representation of fungi – organic acid relationship with its strains

Conclusion

The output generated by fungi like compounds successfully developed into drugs or are under research include antibiotics, anti-cancer drugs and other products such as organic acids, chemicals for pest control and food products shows its positive aspects and its economic importance. In agriculture, fungi have significant value and it also has positive characteristics which is beneficial to our plants and ecosystem. The food web would be incomplete without organisms that decompose organic matter. Habitat loss and fragmentation, out-of-control introduced species, pollution, exploitation and climate change are having a significant effect on Earth's natural environments. Recent studies indicate that 75% of terrestrial lands

worldwide have experienced some type of land-use change. And, in 2020, the World Economic Forum ranked biodiversity loss as the third highest risk to the global economy. In this situation, effective use of fungi to protect the ecosystem and generate the food and food products with the help of fungi can give the alternative to support our world economy as well as biodiversity. In this situation, all the policy makers, economists, social workers and scientists, should work together for the cause of the safety of our environment by keeping the positive side of fungi.