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Understanding the Effects of Fungicides on Soil Microbial Communities

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ABSTRACT

The extensive use of fungicides may cause serious harm to soil health, agricultural sustainability, and food safety, posing significant risks to the long-term well-being of both humans and animals. These chemicals negatively impact on the diverse microbial communities within the soil, disrupting essential biological processes. This disruption can hamper plant growth and development by reducing the availability of nutrients and increasing vulnerability to diseases. In this article we will discuss how indiscriminate use of fungicides affect the soil microbiota in detail.

INTRODUCTION

The health of soil is affected by various non-living and living factors, including its makeup, temperature, acidity levels, mineral content, presence of organic matter, moisture levels, and the different microorganisms like bacteria and fungi that live in it. These factors interact in complicated ways through physical, chemical, and ecological systems. A thorough understanding of these interactions is necessary for creating comprehensive conservation plans to protect the beneficial relationships between soil and crops, reduce soil damage, and preserve soil biodiversity.

Fungicides are created to stop certain fungi from harming plants, but they can also harm other microorganisms in the soil over time. If fungicides are used a lot during a crop's growth, they could break down faster and cause more harm. In many developing countries, farming methods release harmful pollutants into the soil, air, and water, either directly or indirectly.

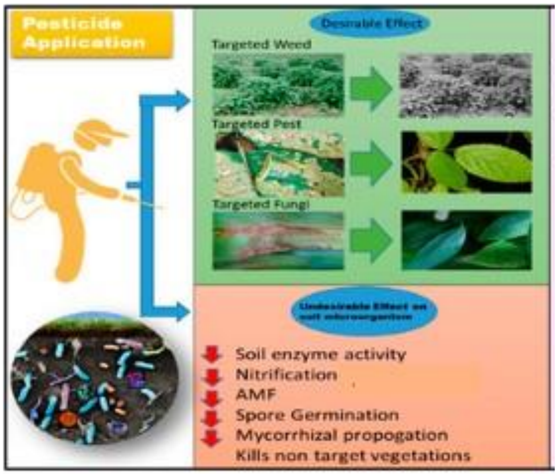

Fig. 1 Impact of Agrochemicals on Soil Microbiota

1. Fungicides and Their Impact on the Soil Microbial Environment

1.1. Impact of Fungicides on N-Fixing and Growth-Promoting Microbes

Copper-based fungicides, including apron, arrest, and captan, have been found to reduce the population of nitrogen-fixing bacteria in the soil. These fungicides can persist in the soil, interacting with organisms and disrupting nitrogen fixation in legume-Rhizobium associations. Mancozeb and chlorothalonil have been observed to decrease nitrification and denitrification processes after at least 48 hours of exposure. Triarimol and captan application can also reduce the occurrence of *Aspergillus* species important for plant growth. Carbendazim shows moderate toxicity to *Pseudomonas fluorescens* and *Bacillus subtilis* but high toxicity to *Trichoderma harzianum*, a biocontrol agent against soil-borne fungal pathogens like *Fusarium*, *Pythium*, and *Rhizoctonia* in various crops. Fungicides such as chlorothalonil and azoxystrobin are known to negatively impact soil microbial activities, affecting biocontrol agents like those used against *Fusarium* wilt.

1.2. Impacts of Fungicides on Soil Microbiota

Several studies have demonstrated negative effects on soil microbes' growth, survival, and activity due to fungicide use. Bavistin, for example, inhibits various soil microbial populations, although the overall impact is considered minor. Arbuscular mycorrhizal fungi (AMF) may react differently to different fungicides, with some showing sensitivity. Benzoyl has been linked to lasting reductions in mycorrhizal associations, as many fungicides can be toxic to hyphal growth, thereby impeding root colonization in peas' AMF associations. Emisan and carbendazim have both been shown to harm AMF in groundnut, although copper applications can stimulate mycorrhizae in groundnut (Meena *et al.*, 2020). The effects of different fungicides on beneficial soil microbiota are summarized in Table 1.

1.3. Impact of Fungicides on Soil Enzymes and Biochemical Environments

Burrows and Edwards (2004) found that carbendazim inhibited the growth of microorganisms in lucerne-planted soil and also observed a significant reduction in soil ammonification, nitrification, and dehydrogenase activity due to carbendazim's inhibitory effects. Fungicides like benomyl, mancozeb, and tridemorph inhibits soil enzymatic activities such as dehydrogenase, urease, and phosphatase. Captan, trifloxystrobin, and thiram fungicides also inhibit phosphomonoesterase and urease enzyme activities in treated soils. However, ridomil fungicide has a negligible impact on phosphatase enzyme activity.

Table 1. Fungicides and their impacts on beneficial processes of soil microbiota.

Fungicides	Effects on Microorganism and Associated Process
Benomyl, Mancozeb	Arrests activity of dehydrogenase, urease, and phosphatase enzymes
Captan and Thiram	Decreases cell growth and nitrogenase activity in *Azospirillum brasilense* even at a lower dose of 10 mg/L
Captan	Inhibits aerobic N-fixing, nitrifying, denitrifying bacteria, nitrogenase activity, phosphate solubilization and other fungi
Captan and Carbendazim	Decreases nitrogenase enzyme activity
Captan, Carboxin, Thiram	Inhibits the activity of bacteria responsible for denitrification
Carbendazin and Thiram	Inhibits nodulation in legumes and thus N-fixation process
Chlorothalonil	Effects bacteria associated with nitrogen cycling
Chlorothalonil, Azoxystrobin	Effects biocontrol agent(s) used against *Fusarium* wilt
Copper fungicides	Decreases population of bacteria, cellulolytic fungal species and Streptomycetes in sandy soil
Dimethomorph	Inhibits nitrification and ammonification process in sandy soils
Dinocap	Inhibits the activity of ammonifying bacteria
Dithianon	Destructs bacterial diversity in soil
Fenpropimorph	Slows down bacterial activity in wetlands
Hexaconazole	Impacts bacteria involved in N-cycling
Metalaxy	Reduces urease activity continuously while phosphatase activity seems stimulated but then reduces
Oxytetracycline	Acts as bactericide
Propiconazole	May retard plant growth-promoting effects of *Azospirillum brasilense* on its host plant
Triadimefon	Deleterious to long-term soil bacterial community
Triarimol and Captan	Reduces frequency of *Aspergillus* sp.

CONCLUSION

Fungicides may persist in soil for a long time and it may affect various activity of soil microbial community. Chlorothalonil generally had more noticeable and lasting effects on soil microbial properties compared to azoxystrobin or tebuconazole. The previous state of the soil played a role in determining how microbial communities reacted to fungicides, probably due to differences in organic matter content and microbial community size, which influenced biodegradation rates and potentially the availability of chemicals, thereby potentially affecting soil community exposure levels. Carefully designed experiments are essential to study the long-term impact of pesticides on microbial communities and their environmental effects on the soil over time.

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