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Effect of Agrochemicals on Soil Microbes and Management: An Overview

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ABSTRACT: As of today, more than a thousand agrochemicals or pesticides are commonly used in agricultural practices at various stages of growth, from seed germination to crop flowering. Nowadays, pesticides are a common practice in agriculture. As a result of conventional agriculture systems, practically all crops are treated with herbicides. Herbicides account for the majority of the pesticides used. In order for soil health and fertility, soil microorganisms and their activities play an essential role. The spraying of herbicides might have a harmful impact on microorganisms because of the herbicides. Environmental concerns, weed resistance, as well as significant health risks are some of the most significant drawbacks of pesticide use. A wide variety of pesticides is used in agriculture for a variety of purposes, which include providing nutrients into soils, inhibiting the growth of phytopathogens, and controlling plant diseases. On the other hand, the regular application of chemical fertilizers or pesticides on agricultural lands has a major impact on the texture and productivity of soil, native soil microorganisms, and the surrounding environment. Various pesticides are applied to fruits, vegetables, and crops prior to harvest, and some of the pesticides will remain on various portions of the crops as chemical residues. Ingestion of pesticide residues can cause a variety of health problems in humans, including mutagenic, cytotoxic, and genotoxic effects. Over the past few decades, the intensive and indiscriminate use of pesticides in agriculture has adversely affected soil, food safety, and biodiversity, and has negative implications on nutritional security, human and animal health. An imperative component of the agricultural environment is the soil micro biota. In addition to contributing to basic soil processes, the soil micro biota contributes to crop productivity and soil fertility. A significant part of soil's physical properties has to do with the activity of bacteria, and in some cases, the activity of bacteria can be a good option in conducting environmentally friendly activities in agricultural soils such as phytopathogen bio control and bioremediation. It is, therefore, no surprise that soil microbes - as well as their activity have been recognized as soil health bio indicators.

Keywords: Agriculture, Pesticides, Fertilizers, Fungicides, Soil microbialbiomass.

INTRODUCTION

As mentioned earlier, agrochemicals are chemical compositions used to manage diseases, pests, and provide nutrients back into the soil. There is no doubt that the use of agrochemicals (growth regulators, insecticides, and fertilizers) has increased crop productivity and increased agricultural production. Recent research suggests that the widespread use of these agrochemicals in soils throughout the world may have contributed to soil degradation because of widespread use in recent decades. This is one of the most serious side effects of traditional agriculture. It is estimated that before the industrialization of farming, farming methods were more eco-friendly in maintaining biological pest control, buffer zones around the edges of the farms, and soil nutrients. The crop yield was primarily reliant on existing resources, such as crop rotation and organic matter recycling. In doing so, these farming techniques contribute toward maintaining the balance between the natural environment and agriculture. It was because of this that signs of environmental damage were virtually non-existent. Agriculture has progressed at a time when there has been a lack of understanding of ecological principles, thereby disrupting the balance between agriculture and the environment. Agricultural modernization results in an increase in productivity, although often at the expense of the quality of the environment. It has been proven that when synthetic fertilizers (including nitrogen, phosphorus, and potassium) are excessed and used in combination with organic fertilizers, they have a negative impact on native micro flora, soil productivity, and texture, soil enzyme action, human health, and the environment (Zhang *et al.*, 2015).

Throughout the globe, these compounds are widely used to increase agricultural productivity, manage diseases, pests, viruses, weeds, and minimize crop damage. It has been scientifically established that synthetic agrochemicals are very hazardous and have a negative impact on human and environmental health (Briggs & Courtney 1989). An increase in fertilizer application would ultimately result in groundwater contamination because of fertilizer runoff (Singh *et al.,* 2004).

There are a number of pesticides that have been banned in developed countries, including 1,2,3,4,5,6-hexachlorocyclohexaneand 1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane (DDT). There are still many countries, such as India and South Africa that continue to utilize them despite their low wages (van denBerg *et al.*, 2017; Jayaraj *et al.,* 2016). The pesticide market in India is the second-largest in Asia. There is a major concern in India about pesticide residues, despite the fact that the country's pesticide usage (0.29) is significantly lower than that of developed countries in Latin America such as Japan (11.85 kg/ha), Brazil (4.57 kg/ha), China (13.06 kg/ha) and others. Pesticide use is highest in Uttar Pradesh, Maharashtra, Haryana, and Punjab, out of India's 29 states.

Over the last decade, the use of pesticides has increased in Uttar Pradesh and Maharashtra, whereas in Haryana and Punjab, the use of pesticides has decreased slightly. There is also evidence that pesticide consumption is going down dramatically in Gujarat, Karnataka, and West Bengal, whereas it is going up in Kerala and Chhattisgarh. Nevertheless, according to the ACIA, during 2016-17, Punjab, Haryana, and Maharashtra saw the highest pesticide use per hectare area, while Bihar, Karnataka, Madhya Pradesh, and Rajasthan saw the lowest. Each year, 377.76 thousand tonnes of agrochemicals are shipped, with fungicides accounting for over half (45.99 percent). The five top pesticides reported as exports from India are acephate, chlorpyrifos, sulphur, cypermethrin, and mancozeb, according to the Central Board of Excise and Customs (Abhilash & Singh 2009; Carvalho, 2017; Subash *et al*., 2017). According to the FAO, global fertiliser usage is predicted to increase by 1.0 percent each year between 2015 and 2030, from 138 million tonnes in 1997/98 to 182 million tonnes in 2030 (Bruinsma, 2017).

Soil Micro flora in Agriculture. As far as microbial diversity is concerned, the soil is the black box. There are a number of microorganisms that are found in this environment, including bacteria, fungi, protozoa, algae, and viruses, among others. There is a much greater diversity and quantity of microorganisms present. The findings from a study conducted by Torsvik *et al.* (1996), indicate that there are approximately 6000 separate bacterial genomes per gram of soil, based on the size of the genome of *Escherichia coli* as an example genome size of *Escherichia coli* as a unit. It seems that there are quite so many almost one million bacterial genes per gram of soil that modern analytical tools have recently been able to show (Gans *et al.,* 2005; Handelsman & Tiedje 2007).

Microorganisms and nutrient cycles in the soil are extremely complicated and poorly defined. Despite the fact that bacteria are the most prevalent microorganisms in the soil, they are followed by actinomycetes, fungus, algae, and protozoa in that order (Sylvia *et al*., 1998). Microorganisms play an important role in basic soil processes and participate actively in nutrient cycling, which helps to improve soil health and crop productivity (Jacoby *et al*., 2017). Different patterns of bacterial and fungal dominance can be seen in cultivated soils. Bacteria and fungi make up the majority of microbial biomass in soil, which accounts for roughly 1–4% of total organic matter (Brookes 2001). In cultivated fields, however, large variations in the ratio of fungal and bacterial biomass were observed, which are influenced by, land management strategies, environmental factors, Nutritional content in soil, and biomass assessment methodologies. According to de Vries *et al.,* 2006 and Strickland & Rousk 2010, bacterial biomass dominates in traditional tillage systems, whereas fungi are dominant in no-tillage agricultural systems. Soil microbial diversity refers to the whole spectrum of microorganisms that live in all of the macro and microhabitats that make up the soil ecosystem. It comprises genetic differences, species ecological and evolutionary adaptations, abiotic and biotic interactions, and ecosystem complexity, as well as diversity between and within species. Microbe genetic diversity is described as the amount and distribution of genetic information within microbial species, or, to put it another way, the richness and evenness of soil micro flora (Nannipieri *et al.*, 2003).

A variety of biotic and abiotic factors have been linked to changes in microbial activity and diversity, including soil management strategies such as monotype agriculture, nutrient amendments such as organic manures or inorganic fertilizers, land use patterns, and environmental conditions (Sun *et al.*, 2004; Li *et al.*, 2007; Nautiyal *et al.,* 2010). Despite substantial evidence shows chemical fertilizers and pesticides impact soil microorganisms, the limited quantity of material available shows a highly varied pattern. Fertilizers and pesticides can affect soil micro flora in the short and long term, both through direct influence on microorganisms and indirectly through unfavourable changes in the environment (Seymour, 2005).

As a result, given the relevance of soil micro flora in ecologically soil activities like detox reactions, and evaluation of the functional and structural properties of microbial populations can be used to track the influence of agrochemicals on the soil environment.

It seems as though most microbes prefer to live in the soil since the soil is one of the most diverse habitats that they have, as well as being the most conducive. Cultivated soil contains a wide variety of micro flora species that can be found on the surface. There are estimated to be about 1048 microbial species in one gram of soil, which is quite a significant number. A single gram of soil contains around one million bacterial genomes (Trevors, 2010). A number of important soil processes are compromised by soil micro flora (bacteria, algae, fungi, viruses, and protozoa), including the breaking down of organic and inorganic compounds, soil fertility, nutrient cycles, and a range of other important functions. The micro flora in the soil plays an important role in soil properties such as structure, aeration, porosity, and water permeability. As the result of human activity, soils that have been contaminated with undesirable compounds can become contaminated with undesirable microbes, and it is important for the microbial population to play a key role in the bioremediation of those soils. There is also evidence that various soil microbes are involved in phytopathogen biocontrol (Ampofo *et al.*, 2009; Prashar & Shah 2016). Some of the benefits of soil microbes are shown in Fig. 1.

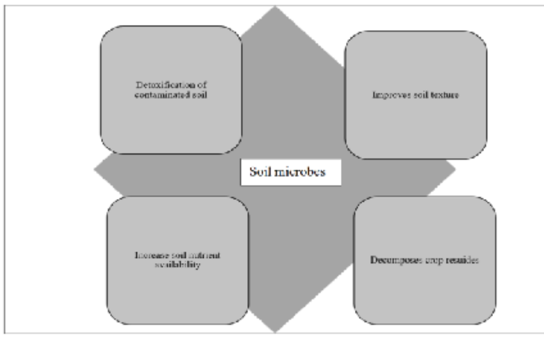

Fig. 1. Benefits of Soil Microbes for Agro ecosystem.

A pesticides' impact on microorganisms is large as a result of ambient conditions, soil quality, and the amount of pesticide that's being used. In the soil, pesticides can be degraded, desorption, adsorption, and transported in a variety of ways, depending on specific soil characteristics and the chemicals present in the pesticide. There is some evidence that pesticides might alter the physiology and metabolism of soil microorganisms (Ramakrishnan *et al*., 2019). There is a possibility that pesticides might negatively affect the diversity of soil microorganisms because they reduce the quality of organic matter in the soil. Considering the fact that all these microbes participate in a variety of nutrient recycling operations as well as processing operations, any variation in their number or composition can significantly alter the soil fertilizing properties. There is no doubt that pesticides interfere with the essential functions that microorganisms perform, such as cell division, cell growth, photosynthesis, molecular composition, biosynthesis, and respiration, in a manner that antibiotics do not. It is believed that some pesticides increase microbial growth, while others suppress it. There is some evidence suggesting that pesticides and fertilizers applied on the field may affect a few specific bacterial species, but the overall impact on the population of microbes is insignificant (Ryan, 1999). On the other hand, there is some evidence suggesting that pesticides can adversely affect soil microorganisms (Gupta et al., 2000).

Effect of Herbicides on Soil microbes. The overall microbial population is greatly reduced by herbicides 7-30 days after spraying, depending on the type of herbicide used (Milosevic & Govedarica 2002) and following spraying herbicides systematically disrupt the physiology or biosynthetic pathways of microbes, negatively affecting their biodiversity indirectly (Kremer *et al.*, 2009). The increased enzymatic activity in soil has an impact on cellular membrane composition, soil enzyme activity, plant growth regulators (*i.e*. gibberellin production, transportation of IAA, the concentration of ethylene, etc.), and protein synthesis. There has been evidence that many sensitive microorganisms die as a result of the administration of excessive levels and increasing levels of herbicide (Milosevic & Govedarica 2002).

Herbicides may also have different herbicidal effects based on the type of soil they are applied to. Herbicides can have a significant effect on soils with coarse textures. As an example, researchers found that when used on sandy-clay loam soils, herbicides had an overwhelmingly negative impact on microbial interactions and chickpea survival (Khan *et al*., 2006). Atrazine has been shown to dramatically reduce soil microorganisms' activity when repeatedly applied to the soil. As a result, atrazine and metolachlor are able to adversely impact soil biodiversity in the form of bacteria and actinomycetes (Seghers & Verthé 2003). The herbicide glyphosate, which is a nonselective organophosphate herbicide, has been shown to reduce phosphate enzyme activity by up to 98 percent (Sannino & Gianfreda 2001).

Effect of Fungicides on Soil Microbes. There have been a number of studies that have demonstrated that soil temperature and moisture can negatively impact soil microbes, their growth and survival, and their activity (Cyco *et al.*, 2006). In fact, fungicides like bavistin can exhibit a variety of effects on the soil microbe population such as affecting the bacterial flora in different ways. Some fungicides that have been found to be affected by AMFs have been found, although this is not the case for all fungicides. A number of fungicides are toxic to hyphal growth, resulting in the root system being colonized by AMF organization in pea (Cyco *et al*., 2006). Benzyl is reported to be a major contributor to the decline in mycorrhizal associations (Smith *et al*., 2000). It is understood that some types of groundnuts are particularly sensitive to the effects of carbendazim (an antifungicide that belongs to the benzimidazole family) and Emisan (a fungicide containing 6% 2-methoxyethylmercury chloride). As an alternative, a Cu treatment can help stimulate the development of the mycorrhizal fungi in peanuts. A substance called metalaxyl is beneficial to the colonization of soybeans and maize roots by AM. An analysis conducted by scientists from the University of New Mexico revealed that seed-applied fungicides in combination with fludioxonil are most likely to encourage AM colonization in non-fumigated soils due to reduced competition from aggressive pathogens such as *Rhizoctonia* spp., the organism targeted by this fungicide (Murillo-Williams & Pedersen 2008). Some of the commonly used fungicides are listed below (Table 1).

Table 1: Effect of Fungicide on soil microbes.

Sr. No.	Fungicides	Effect on Soil Microbes	References
1.	Benomyl	Effects mycorrhizal associations and also nitrifying bacteria	(Chen *et al.*, 2001)
2.	Carbendazin and Thiram	Hinders nodulation in legumes	(Niewiadomska 2004).
3.	Mancozeb	In soil it effects bacteria which are associated in N & C cycle.	(Černohlávková *et al*,. 2009)
4.	Metalaxyl	Nitrifying, ammonifying bacteria's actions are disrupted.	(Monkiedje & Spiteller 2005)
5.	Propiconazole	Azospirillum brasilense's growth-promoting actions on the host plant can be inhibited.	(Pereyra *et al.*, 2009)
6.	Hexaconazole	Effects bacteria involved in N cycling	(Madhuri *et al.*, 2003)
7.	Oxytetracycline	Acts as Bactericide	(Qingxiang *et al.*, 2009)

Impacts of pesticides on Soil Micro biota. The most common reason for crop failure in the world is plant diseases, which represent a significant threat to global food security. As much as ten to fifteen percent of the production of the world's major crops, such as rice, wheat, maize, and potatoes, is lost to pest-induced plant diseases every year (Pinstrup-Andersen, 2001). Chemical pesticides have been the most common method of eliminating phytopathogens in the past, mainly due to the fact that they are the most efficient and most practical to use. This has resulted in a gradual increase in the use of chemical pesticides over the years.

Pesticides, which remain in the soil for a long time, slowly degrade and become a cause of contamination in the soil and groundwater (Pe´rez-Lucas *et al.*, 2018). It is true that pesticides have been used in agricultural soils steadily since the turn of the century, in order to combat pest-induced crop losses and keep up with the ever-expanding food demand. Pesticides are the most heavily used products in the world, followed by Europe and Asia, whereas China is the global leader in pesticide production and consumption, closely followed by the United States. Some of the commonly used pesticides are listed below *i.e* (Table 2).

Table 2: Impact of pesticide on soil microbes.

Sr. No.	Pesticides	Effect on soil microbes	References
1.	Imidacloprid and Diazinon	The bacterium that produces urease is restrained (*Proteus vulgaris*)	(Ingram *et al.*, 2005)
2.	Chlorpyrifos, Quinalphos	Diminishes ammonification process	(Madhuri, 2002)
3.	Validamycin	Urease and phosphatase enzymes are negatively affected, but they improve subsequently.	(Qian, 2007)
4.	Carbofuran	Hinders nitrogenase action of Anabaena doliolum was reduced by 38% Within 48 hours of treatment	(Kalam & Mukherjee 2001)
5.	Organophosphate insecticide	Reduces the rate of N-mineralization via affecting the soil enzymes activity, the fungal species and beneficial soil microbes	(Pandey & Singh 2004)
6.	DDT	As a result of their longer survival in soil, microbial biomass production and enzyme reactions decreases.	(Singh & Singh 2005)

The potential for soil and agro-ecosystems to suffer direct or indirect adverse impacts is of great concern when it comes to the use of chemical pesticides since they are bioactive, poisonous chemicals. The Food and Agriculture Organization of the United Nations (FAO) describes a pesticide as a chemical substance that is used to control one or more animals or plants. It includes insecticides, fungicides, herbicides, rodenticides, nematodes, growth regulators, defoliants, fruit thinners, desiccants, and the like. Also, it is used to prevent premature crop damage, especially during harvest. A pesticide should, from a concept standpoint, not affect non-target soil species, have a short shelf life, be biodegradable, and be inexpensive. The majority of them, however, have chronic and acute toxicity as well as being classified as biocides. This means that they can be harmful to all living things except for the target pest species (Zacharia, 2011). There are many of them that can penetrate the cell walls of non-target soil microorganisms, disrupting their normal metabolisms and causing cell death. It has become apparent that pesticides, in their many forms, pose a serious threat to the biodiversity of soils and their natural habitats, as well as their associated negative effects including contamination of groundwater and soil, their enrolment in the food chain, posing a health risk to higher organisms such as humans, and the development of pest-resistant crops (Sattler *et al*., 2006). As a result, pesticides' adverse effects on non-target soil species have become a major topic of concern.

Management Options. In spite of this, studies on the detrimental effects of pesticides and their derivatives have been conducted for more than a decade. In addition, various legislative measures and pesticide problems have also been reported (Pandey & Singh 2004). By developing quick and accurate analytical procedures, it has been possible to provide a more effective implementation of pesticides' long-term effects as well as mitigating their long-term effects on soils and natural ecosystems. The result of this is that as our understanding of pesticides and their impact on health and the environment improves, existing current legislation acts are being altered or improved at a rapid rate. This implies that there has been a significant improvement in the effectiveness and efficiency of the control of that pest (Enserink *et al*., 2013). This paper describes a method that has been reported to be remarkably effective for limiting the negative effects of pesticides, their implementations, and their by-products (Owen *et al.,* 2015). In order to tackle the danger of chemical pollution, a number of eco-friendly techniques are emerging, including biological pest control. Here are some of the most effective management approaches to help tackle chemical pollution.

Bio pesticides. It has been shown that microorganisms or plants can produce bio pesticides that are bio pesticides (microbial pesticides), or they can produce biological pesticides (plant incorporating pesticides or PIPs), or other naturally occurring products (biochemical pesticides, or BCPs). It is feasible to develop more bio pesticides that are being used for a number of reasons, including the need to provide an alternative to conventional pesticides. This alternative must be not only environmentally friendly but can also increase soil productivity, prevent soil contamination, and provide a better solution for microbial soil ecosystems of higher society. It is imperative that bio pesticides are used in agricultural production in order to make it environmentally sustainable. Bio pesticides ensure that soil health and environmental sustainability are enhanced. The introduction of helpful microbes into any living system is essential if a person wishes to have a dominant influence over disease-causing microbial communities. Generally, it is accepted that bio-products can boost soil nutrient uptake efficiency and improve the productivity of plants when they are directly sprayed on soil or when sprayed on the leaves of plants. While pathogenic microorganism-based bio pesticides are particular to a specific pest, bio pesticides derived from useful interactors are a superior and more environmentally friendly option. As a result, unlike conventional chemicals pesticides, bio pesticides do not have a harmful effect on a range of ecosystems or soil microorganisms (Gupta *et al.,* 2010).

Bacillus huringiensis (Bt), *Baculoviruses*, *Trichoderma*, and *Azadirachta indica* are among the most extensively utilized bio pesticides. There are several strains of *Bacillus thuringiensis* that are used for controlling insect larvae in plants, with some of them being particularly effective against mosquito and fly larvae (Meena *et al.,* 2016).

Plant-Based Products. It has been found that the active synthesis of chemicals by the roots of plants has a significant impact on the microbial community in soil (Neal *et al.,* 2012). Strigolactones are known to be plant sesquiterpenes that remarkably enhance the symbiotic relationship between plants and fungi by stimulating Glomeromycota mycorrhizal fungi, for example (Akiyama and Hayashi 2006). Flavonoids are believed to be produced by legumes and to act as signalling molecules that attract N-fixing bacteria to the rhizosphere and facilitate the formation of symbiotic rhizobial associations with them (Broughton *et al*., 2003; Pathan *et al.,* 2018). A group of rhizobacteria known as plant-growth-promoting rhizobacteria (PGPR) has the capability of releasing organic acids into the soil, which is beneficial for other soil microbes. In one study, it was determined that tomato roots emit fumaric acid and citric acid, and both of these are able to attract *Pseudomonas fluorescence* (Gupta Sood 2003). Neem cake oil is another example of a bio pesticide in use and is an excellent product for managing a wide range of pests, as well as providing nourishment to soil microbes as well as improving soil physicochemical properties Gopal *et al.*, 2007). A well-known pesticide, azadirachtin (an allelochemical from the plant neem), has been well documented for its antifungal and antimicrobial properties for quite some time now, both of which have been well documented in scientific studies. According to the findings of a recent study conducted to evaluate the effects of azadirachtin granules at 10% concentration combined with China clay, an alcoholic extraction of the kernels of neem plants, on microbacterial communities and enzyme activities, it has been determined at all concentrations that azadirachtin reduces microbacterial communities and enzyme activities.

CONCLUSION AND FUTURE SCOPE

Among other things, chemical fertilizers and pesticides affect soil properties such as soil enzyme activity, dominant soil species, nutrient content, microbial and biochemical diversity, and the structural and functional diversity of microbial communities, among others. The consequences of any impact can range in scope from short-term changes to long-term changes, depending on the circumstances. However, all of these chemicals have a lot of long-term detrimental effects for soil microbial communities, despite the fact that they may appear to yield immediate benefits, such as increased crop production due to increased nutrient supply and pest control. In addition to organic fertilizers, manures, and bio control agents, which are known to increase the overall fertility and quality of soil, organic fertilizers and manures have also been increasingly used to boost long-term farming methods. For a sustainable approach, organic additions, unlike agrochemicals, are an affordable and environmentally friendly alternative to moving forward with an agrochemical-based approach.

Current changing climatic circumstances, global warming, and the need to prevent the rise in environmental contamination necessitate sustainable agriculture techniques. Agricultural productivity has increased in all parts of the world over the last few decades, but the quick and continual application of agrochemicals during pre- or postharvest has proven to be a serious issue for both researchers and farmers. Pesticides have been used in agriculture areas in the form of chemical fertilisers, fungicides, insecticides, herbicides, and other agrochemicals, but their continued use has a negative influence on soil micro flora, texture, and productivity. The constant use of agrochemicals has an impact on soil micro flora, and abnormalities in native microbial populations have been identified as the key indicator of soil disturbance. As a result, it is vital to monitor and investigate novel techniques to controlling the persistence and degradation of toxic agrochemicals in soils in order to conserve the natural texture and productivity of soils, as well as the native micro flora.

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List of Abbreviations: DDT – Dichlorodiphenyltrichloroethane; IAA - (Indole-3-Acetic Acid); AMF - Arbuscular mycorrhizal fungi; FAO - Food and Agriculture Organization; PIP - plant incorporating pesticides; BCP - biochemical pesticides; BT - *Bacillus thuringiensis*; PGPR - plant-growth-promoting rhizobacteria.

REFERENCES

Abhilash, P. C., & Singh, N. (2009). Pesticide use and application: an Indian scenario. *Journal of hazardous materials*, *165*(1-3): 1-12.

Akiyama, K., & Hayashi, H. (2006). Strigolactones: chemical signals for fungal symbionts and parasitic weeds in plant roots. *Annals of botany*, *97*(6): 925-931.

Ampofo, J. A., Tetteh, W., & Bello, M. (2009). Impact of commonly used agrochemicals on bacterial diversity in cultivated soils. *Indian Journal of Microbiology*, *49*(3): 223-229.

Briggs, D. J., Courtney, F. M., (1989). Agriculture and Environment, 1. Longman, New York, 26-37.

Brookes, P. (2001). The soil microbial biomass: concept, measurement and applications in soil ecosystem research. *Microbes and Environments*, *16*(3): 131-140.

Broughton, W. J., Zhang, F., Perret, X., & Staehelin, C. (2003). Signals exchanged between legumes and Rhizobium: agricultural uses and perspectives. *Plant and Soil*, *252*(1): 129-137.

Bruinsma, J. (2017). *World agriculture: towards 2015/2030: an FAO perspective*. Routledge.

Carvalho, F. P. (2017). Pesticides, environment, and food safety. *Food and energy security*, *6*(2): 48-60.

Černohlávková, J., Jarkovský, J., & Hofman, J. (2009). Effects of fungicides mancozeb and dinocap on carbon and nitrogen mineralization in soils. *Ecotoxicology and Environmental Safety*, *72*(1): 80-85.

Chen, S. K., Edwards, C. A., & Subler, S. (2001). Effects of the fungicides benomyl, captan and chlorothalonil on soil microbial activity and nitrogen dynamics in laboratory incubations. *Soil Biology and Biochemistry*, *33*(14): 1971-1980.

Coventry, E., & Allan, E. J. (2001). Microbiological and chemical analysis of neem (*Azadirachta indica*) extracts: new data on antimicrobial activity. *Phytoparasitica*, *29*(5): 441-450.

Cycoń, M., Piotrowska-Seget, Z., Kaczyńska, A., & Kozdrój, J. (2006). Microbiological characteristics of a sandy loam soil exposed to tebuconazole and λ-cyhalothrin under laboratory conditions. *Ecotoxicology*, *15*(8): 639-646.

Cycoń, M., Piotrowska-Seget, Z., Kaczyńska, A., & Kozdrój, J. (2006). Microbiological characteristics of a sandy loam soil exposed to tebuconazole and λ-cyhalothrin under laboratory conditions. *Ecotoxicology*, *15*(8): 639-646.

Datta, R., Anand, S., Moulick, A., Baraniya, D., Pathan, S. I., Rejsek, K., ... & Formanek, P. (2017). How enzymes are adsorbed on soil solid phase and factors limiting its activity: A Review. *International agrophysics*, *31*(2): 287.

De Vries, F. T., Hoffland, E., van Eekeren, N., Brussaard, L., & Bloem, J. (2006). Fungal/bacterial ratios in grasslands with contrasting nitrogen management. *Soil Biology and Biochemistry*, *38*(8): 2092-2103.

Enserink, M., Hines, P. J., Vignieri, S. N., Wigginton, N. S., & Yeston, J. S. (2013). The pesticide paradox. *Science*, *341*(6147): 728-729.

Gans, J., Wolinsky, M., & Dunbar, J. (2005). Computational improvements reveal great bacterial diversity and high metal toxicity in soil. *Science*, *309*(5739): 1387-1390.

Gopal, M., Gupta, A., Arunachalam, V., & Magu, S. P. (2007). Impact of azadirachtin, an insecticidal allelochemical from neem on soil microflora, enzyme and respiratory activities. *Bioresource technology*, *98*(16): 3154-3158.

Govindachari, T. R., Suresh, G., Gopalakrishnan, G., Masilamani, S., & Banumathi, B. (2000). Antifungal activity of some tetranortriterpenoids. *Fitoterapia*, *71*(3): 317-320.

Gupta Sood, S. (2003). Chemotactic response of plant-growth-promoting bacteria towards roots of vesicular-arbuscular mycorrhizal tomato plants. *FEMS Microbiology Ecology*, *45*(3): 219-227.

Gupta, A., Aggarwal, A., Mangla, C., Kumar, A., & Tanwar, A. (2011). Effect of herbicides Fenoxaprop-P-ethyl and 2, 4-D Ethyl-ester on soil mycoflora including VAM fungi in wheat crop.

Gupta, R. P., Singh, J., Sultan, M. S., Hujan, R. K., Gosal, S. K., Sahota, H., & Sharma, S. (2000). Impact of pesticides on soil biota and non-target organisms in rice wheat cropping system. In *41st Annual Conference of AMI. Birla Research Institute, Jaipur, India*.

Gupta, S., & Dikshit, A. K. (2010). Biopesticides: An ecofriendly approach for pest control. *Journal of Biopesticides*, *3*(Special Issue), 186.

Handelsman, J., Tiedje, J. M., Alvarez-Cohen, L. I. S. A., Ashburner, M. I. C. H. A. E. L., Cann, I. K., DeLong, E. F., ... & Reid, A. H. (2007). Committee on metagenomics: challenges and functional applications.

Imfeld, G., & Vuilleumier, S. (2012). Measuring the effects of pesticides on bacterial communities in soil: a critical review. *European Journal of Soil Biology*, *49*: 22-30.

Ingram, C. W., Coyne, M. S., & Williams, D. W. (2005). Effects of commercial diazinon and imidacloprid on microbial urease activity in soil and sod. *Journal of Environmental Quality*, *34*(5): 1573-1580.

Jacoby, R., Peukert, M., Succurro, A., Koprivova, A., & Kopriva, S. (2017). The role of soil microorganisms in plant mineral nutrition—current knowledge and future directions. *Frontiers in plant science*, *8*, 1617.

Jayaraj, R., Megha, P., & Sreedev, P. (2016). Organochlorine pesticides, their toxic effects on living organisms and their fate in the environment. *Interdisciplinary toxicology*, *9*(3-4): 90.

Kalam, A. & Mukherjee, A. K. (2001). Influence of hexaconazole, carbofuran and ethion on soil microflora and dehydrogenase activities in soil and intact cell.

Khan, M. S., Zaidi, A., & Rizvi, P. Q. (2006). Biotoxic effects of herbicides on growth, nodulation, nitrogenase activity, and seed production in chickpeas. *Communications in soil science and plant analysis*, *37*(11-12): 1783-1793.

Kremer, R. J., & Means, N. E. (2009). Glyphosate and glyphosate-resistant crop interactions with rhizosphere microorganisms. *European Journal of Agronomy*, *31*(3): 153-161.

Lacey, L. A., & Georgis, R. (2012). Entomopathogenic nematodes for control of insect pests above and below ground with comments on commercial production. *Journal of Nematology*, *44*(2): 218.

Li, Z. P., Wu, X. C., & Chen, B. Y. (2007). Changes in transformation of soil organic C and functional diversity of soil microbial community under different land uses. *Agricultural Sciences in China*, *6*(10): 1235-1245.

Madhuri, R. J., & Rangaswamy, V. (2002). Influence of selected insecticides on phosphatase activity in groundnut (*Arachis hypogeae* L.) soils. *Journal of Environmental Biology*, *23*(4): 393-397.

Madhuri, R. J., & Rangaswamy, V. (2003). Influence of selected fungicides on microbial population in groundnut (*Arachis hypogeae* L.) soils. *Pollution Research*, *22*(2), 205-212.

Meena, A. K., & Meena, A. K. (2016). Characterization and antagonistic effect of isolated *Trichoderma* sp. against pathogens under clusterbean (*Cyamopsis tetragonoloba* L.). *Indian Journal of Agricultural Research*, *50*(3): 249-253.

Milošević, N. A., & Govedarica, M. M. (2002). Effect of herbicides on microbiological properties of soil. *Zbornik Matice srpske za prirodne nauke*, (102): 5-21.

Monkiedje, A., & Spiteller, M. (2005). Degradation of metalaxyl and mefenoxam and effects on the microbiological properties of tropical and temperate soils. *International Journal of Environmental Research and Public Health*, *2*(2): 272-285.

Monkiedje, A., & Spiteller, M. (2005). Degradation of metalaxyl and mefenoxam and effects on the microbiological properties of tropical and temperate soils. *International Journal of Environmental Research and Public Health*, *2*(2): 272-285.

Murillo-Williams, A., & Pedersen, P. (2008). Arbuscular mycorrhizal colonization response to three seed-applied fungicides. *Agronomy journal*, *100*(3): 795-800.

Nannipieri, P., Ascher, J., Ceccherini, M., Landi, L., Pietramellara, G., & Renella, G. (2003). Microbial diversity and soil functions. *European journal of soil science*, *54*(4): 655-670.

Nautiyal, C. S., Chauhan, P. S., & Bhatia, C. R. (2010). Changes in soil physico-chemical properties and microbial functional diversity due to 14 years of conversion of grassland to organic agriculture in semi-arid agroecosystem. *Soil and Tillage Research*, *109*(2): 55-60.

Neal, A. L., Ahmad, S., Gordon-Weeks, R., & Ton, J. (2012). Benzoxazinoids in root exudates of maize attract *Pseudomonas putida* to the rhizosphere. *PloS one*, *7*(4): e35498.

Niewiadomska, A. (2004). Effect of Carbendazim, Imazetapir and Thiram on nitrogenase activity, the number of microorganisms in soil and yield of Red Clover (*Trifolium pratense* L.). *Polish Journal of Environmental Studies*, *13*(4).

Owen, M. D., Beckie, H. J., Leeson, J. Y., Norsworthy, J. K., & Steckel, L. E. (2015). Integrated pest management and weed management in the United States and Canada. *Pest Management Science*, *71*(3): 357-376.

Pandey, S., & Singh, D. K. (2004). Total bacterial and fungal population after chlorpyrifos and quinalphos treatments in groundnut (*Arachis hypogaea* L.) soil. *Chemosphere*, *55*(2): 197-205.

Pandey, S., & Singh, D. K. (2004). Total bacterial and fungal population after chlorpyrifos and quinalphos treatments in groundnut (*Arachis hypogaea* L.) soil. *Chemosphere*, *55*(2): 197-205.

Pathan, S. I., Větrovský, T., Giagnoni, L., Datta, R., Baldrian, P., Nannipieri, P., & Renella, G. (2018). Microbial expression profiles in the rhizosphere of two maize lines differing in N use efficiency. *Plant and Soil*, *433*(1): 401-413.

Pereyra, M. A., Ballesteros, F. M., Creus, C. M., Sueldo, R. J., & Barassi, C. A. (2009). Seedlings growth promotion by *Azospirillum brasilense* under normal and drought conditions remains unaltered in Tebuconazole-treated wheat seeds. *European journal of soil biology*, *45*(1): 20-27.

Pérez-Lucas, G., Vela, N., El Aatik, A., & Navarro, S. (2019). Environmental risk of groundwater pollution by pesticide leaching through the soil profile. *Pesticides-use and misuse and their impact in the environment*, 1-28.

Pinstrup-Andersen, P. (2000). The future world food situation and the role of plant diseases. *Canadian Journal of Plant Pathology*, *22*(4): 321-331.

Prashar, P., & Shah, S. (2016). Impact of fertilizers and pesticides on soil microflora in agriculture. In *Sustainable agriculture reviews* (pp. 331-361). Springer, Cham.

Qian, H., Hu, B., Wang, Z., Xu, X., & Hong, T. (2007). Effects of validamycin on some enzymatic activities in soil. *Environmental monitoring and assessment*, *125*(1): 1-8.

Qingxiang, Y. A. N. G., Zhang, J., Kongfang, Z. H. U., & Zhang, H. (2009). Influence of oxytetracycline on the structure and activity of microbial community in wheat rhizosphere soil. *Journal of Environmental Sciences*, *21*(7): 954-959.

Ramakrishnan, B., Venkateswarlu, K., Sethunathan, N., & Megharaj, M. (2019). Local applications but global implications: Can pesticides drive microorganisms to develop antimicrobial resistance ? *Science of the Total Environment*, *654*: 177-189.

Ryan, M. (1999). Is an enhanced soil biological community, relative to conventional neighbours, a consistent feature of alternative (organic and biodynamic) agricultural systems?. *Biological agriculture & horticulture*, *17*(2): 131-144.

Sannino, F., & Gianfreda, L. (2001). Pesticide influence on soil enzymatic activities. *Chemosphere*, *45*(4-5): 417-425.

Sattler, C., Kächele, H., & Verch, G. (2007). Assessing the intensity of pesticide use in agriculture. *Agriculture, Ecosystems & Environment*, *119*(3-4): 299-304.

Seghers, D., Verthé, K., Reheul, D., Bulcke, R., Siciliano, S. D., Verstraete, W., & Top, E. M. (2003). Effect of long-term herbicide applications on the bacterial community structure and function in an agricultural soil. *FEMS Microbiology Ecology*, *46*(2): 139-146.

Seymour, N. P. (2005). Impacts of pesticides and fertilisers on soil biota.

Singh, B. K., Walker, A., Morgan, J. A. W., & Wright, D. J. (2004). Biodegradation of chlorpyrifos by Enterobacter strain B-14 and its use in bioremediation of contaminated soils. *Applied and environmental microbiology*, *70*(8): 4855-4863.

Singh, J., & Singh, D. K. (2005). Dehydrogenase and phosphomonoesterase activities in groundnut (*Arachis hypogaea* L.) field after diazinon, imidacloprid and lindane treatments. *Chemosphere*, *60*(1): 32-42.

Smith, M. D., Hartnett, D. C., & Rice, C. W. (2000). Effects of long-term fungicide applications on microbial properties in tallgrass prairie soil. *Soil Biology and Biochemistry*, *32*(7): 935-946.

Strickland, M. S., & Rousk, J. (2010). Considering fungal: bacterial dominance in soils–methods, controls, and ecosystem implications. *Soil Biology and Biochemistry*, *42*(9): 1385-1395.

Subash, S. P., Chand, P., Pavithra, S., Balaji, S. J., & Pal, S. (2018). Pesticide use in Indian agriculture: trends, market structure and policy issues.

Sun, H. Y., Deng, S. P., & Raun, W. R. (2004). Bacterial community structure and diversity in a century-old manure-treated agroecosystem. *Applied and Environmental Microbiology*, *70*(10): 5868-5874.

Sylvia, D. M., Fuhrmann, J. J., Hartel, P. G., & Zuberer, D. A. (2005). *Principles and applications of soil microbiology* (No. QR111 S674 2005). Pearson.

Torsvik, V., Sørheim, R., & Goksøyr, J. (1996). Total bacterial diversity in soil and sediment communities—a review. *Journal of Industrial Microbiology and Biotechnology*, *17*(3-4): 170-178.

Trevors, J. T. (2010). One gram of soil: a microbial biochemical gene library. *Antonie Van Leeuwenhoek*, *97*(2): 99-106.

Van den Berg, H., Manuweera, G., & Konradsen, F. (2017). Global trends in the production and use of DDT for control of malaria and other vector-borne diseases. *Malaria journal*, *16*(1): 1-8.

Zacharia, J. T. (2011). Identity, physical and chemical properties of pesticides. *Pesticides in the modern world-trends in pesticides analysis*, 1-18.

Zhang, X., Dong, W., Dai, X., Schaeffer, S., Yang, F., Radosevich, M., & Sun, X. (2015). Responses of absolute and specific soil enzyme activities to long term additions of organic and mineral fertilizer. *Science of the Total Environment*, *536*: 59-67.

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