Agricultural Research & Technology
Open Access Journal
ISSN: 2471-6774

Juniper Publishers
key to the Researchers

Review Article
Volume 26 Issue 1 - June 2021
DOI: 10.19080/ARTOAJ.2021.26.556323

Agri Res & Tech: Open Access J
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# Agriculture and Environment Sustainability through Interaction of Microbiology with Soil Chemical Nature

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**Submission**: June 02, 2021; **Published:** June 10, 2021

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**Abstract**

Soil is an unsolidified entity in which microbes are diverse, having mutualistic, antagonistic, synergistic relationships with plants and provides a base for living. The synthetic inputs (fertilizers and pesticides) and anthropogenic practices aimed at agricultural production dramatically enhance the soil chemical reactions. Inorganic chemical reactions that occur in soil pollute the environment after entering into four major environmental compartments including water and air. Presence of radioactive gases in the atmosphere may cause significant changes in the earth's environment, including changes in precipitation and temperature along with increase in the regional and global runoff that causes ecosystem degradation and human health related issues through acid rain. It is a burning topic in today's context since it is vital to conserve the ecosystem in a sustainable manner and as a result it decides whether global food production is increasing or decreasing. Management of these chemical processes by different methods is essential which could be a viable choice for the reduction of environmental emissions and improving growth and yield attributes of agricultural commodities. Among all the strategies, microbial adaptation in synthesizing reactions is crucial as it reduces ecosystem effects and increases the global food production for the growing population.

**Keywords:** Soil; Environment; Synthetic inputs; Microbiology; Sustainability

## Introduction

Soil provides a basis for agricultural crop production and microbial functioning in the ecosystem has a crucial role to play in improving soil health for healthy crop growth because microorganisms function as a complex link among soil-plant continuum. Microorganisms in soil are a dynamic component of the soil system and they perform vast beneficial functions in the system. Microbes aid in different biological transformations such as organic matter decomposition and Biological Nitrogen Fixation (BNF). Moreover, they enhance the availability of nutrients to the plants [1]. Almost all the things that are present in universe are dependent on the soil as it provides basic food, fiber, shelter to humans and to other living organisms for their survival. It is the end product of minerals, gases, organic matter and liquids which is the habitation for mankind and animals [2]. They interact with the plants in many different forms including synergetic, antagonistic and mutualistic relationship depending upon the plant to microorganism and microorganism to plant contact. Therefore, the microbes develop the plant community structure by specific interaction [3, 4, 5] and support growth of flora in many ways that leads it to take part in different processes. The nature of soil is heterogeneous, and its study is very complex. For instance, soil chemical, biological and physical studies are important for enhancing increase in production from limited resources [6] and thus, have various direct and indirect consequences on different ecosystems in which soil biodiversity, resilience and quality in extreme conditions are very sensitive [7]. Synthetic inputs such as inorganic fertilizers, insecticides and other agrochemicals are being used to meet the needs of global food scarcity. These agricultural inputs not only disturb the soil quality, health and microbial communities but also affect the other systems directly and indirectly. The presence of carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$) to the surroundings, for example it affects the entire community, which is generated as a result of decaying, denitrification and methanogenesis. The production of agrochemicals requires energy for manufacturing. In any energy system, it is extensively accredited, having an environmental impact with its consequences. Over last few decades, energy-related environmental concerns have evolved from regional local or primarily issues to universal and international situations of major energy-related environmental issues [8]. Environmental issues are especially evident in developing or recently mechanized republics, where energy demands progress charges are usually too high and ecological administration is not still entirely incorporated into a frame [9]. Anthropogenic or human induced activities are very well known for having a remarkable influence on the surroundings or environment. It significantly contributes to land use and its composition is nearly about total of 38 percent of global portion of soil, food sector that is considered as the most important sector among all other production sectors [10], use of freshwater approximately about 70 percent of all human use [11]. Anthropogenic activities have an impact on marine life/ecosystem as well [12], causing environmental problems. Air is primarily polluted by four gases, namely sulphur dioxide ($SO_2$), nitrogen oxides (NOx: NO, $NO_2$), carbon dioxide ($CO_2$), and ozone ($O_3$), in accordance with their historical significance, concentrations, and its impact on animals, plants and humans. Sulfur dioxide and nitric oxide are the primary contributors [13]. Hydrogen (H) along with carbon (C) in various ratios combines to form fossil fuel, which can be liquid, gaseous or even solid. Carbon and hydrogen both tend to react with oxygen during the combustion process producing $CO_2$ and water ($H_2O$). When the combustion process is incomplete or other substances (such as sulphur, nitrogen, organic compounds and heavy metals) are present in the fuel, other compounds are also formed chemically instead of $CO_2$ and $H_2O$. If the concentration of these chemical composites in the air goes beyond a certain threshold, it will undoubtedly endanger human life and the environment [14]. When there is much more tax on fertilizer it leads to application of manures at a great level. Manures are used as an alternate for expensive fertilizers but as compare to fertilizers they results in slow release of nutrients for plant and crop growth and yield attributes. The farming communities discourage the use of manure due to its slow reaction and benefit [15]. Cultivation based on synthetically produced fertilizers is more intensive as it entirely declines the whole system of the soil and quality of the environment. Organic amendments basically improve soil physical, chemical and biological properties in the tropical region [16]. There are a large number of literatures related to the management of environment to make the agricultural farming system sustainable. Agricultural productivity is mainly determined by the environment as the agricultural systems are chiefly dependent on environmental sustainability. Climate change has a significant impact on agricultural fabrication, which is improved by greenhouse gas discharges; conversely, high rates of fertilizer application to soils are a key source of emissions [17].

## Impacts of Agricultural Inputs on Soil Chemical Behavior

Inputs that are used for production of crops externally like chemical fertilizers, organic amendments, microbe inoculants and synthetic pesticides for getting the higher yield and economic return, but some of these have adverse impacts on the soil and these are usually neglected. The objective of this study is to summarize how these inputs (used for production of crops) influence the condition of soil (physical, chemical and biological). Chemical fertilizers have little effect on soil physical properties, while organic additions improve soil biological properties by increasing system productivity, crop residue return and organic matter in soil. Some indirect effects like use of nitrogen fertilizer cause acidification in soil that affects the health of soil adversely, for example, total number, action and diversity of soil organisms. Organic amendments are considered as the main C reservoir for organisms in soil and secondary source of C for the growth of plants and plant residue return. These organic amendments are manures, different composts, bio-solids and some other humic substances. Influence of non-target application of microbial inoculants is small. Herbicides have shown effects on the health of topsoil considerably, amongst all other kind of pesticides. Negative impacts of other pesticides like insecticide and the fungicides are most common and so they are applied under strict regulations [18].

According to inhabitants around the globe are expected to increase about 9-10 billion in near future (2050), so production of food is the prime goal of nearly all countries over the world. The rate of population growth in developing countries is approximately 3 percent per year, and food demand is increasing at a rate of 3.8 percent per year. But production of food is increasing at very fast speed i.e. 1.2 percent per annum. Whereas the production of food across the world needs to be increased by 70 percent in order to fulfill the food requirements of the growing global population [19]. The production of food is linked to many challenges, among which the most important is the area for the farming of food crops which is limited [20]. The soil fertility of most of developing countries has totally been deteriorated [21], infestations by pest are also at alarm [22]. Farming systems are bearing a huge pressure because of ever increasing world food demand along with certain additional provocations to meet the need of food which differ from different assets i.e. land and water etc. [23]. To meet the global food demand, production of crops must be increased and for this process some inputs of crop production in a proper recommendation like pesticides and chemical fertilizers along which organics must be used in a balanced rate without hindering any system [24].

## Environment Contamination

When nitrogen is lost from soil or plant surface, it not only decreases the production of crops and negatively impacts on potency of soils but also has a huge impact on its surrounding. When nitrogen ammonia form is emitted into air it contributes with water and forms acid rain and is considered as an in-direct source of Greenhouse Gas (GHG) release in nitrous oxide form. When nitrous oxide is emitted into the air, it causes ozone depletion


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that contributes significantly towards climate change. The soil cation exchange reaction electrostatically attracts ammonium ions to the surface of clay and organic matter. As ammonium is deposited in soil through this mechanism, the concentration of ammonium in soil solution substantially declines. A soil with higher cation exchange capacity (CEC- clayey soils) have lower potential to volatilize ammonia as compare to soil with lower CEC like sandy soils [25]. Soil with calcareous environment has higher soil pH that can easily lead to loss in huge amounts of ammonia gas, whereas a significant quantity of ammonia gas from soils with neutral or acidic pH is lost when animal urine or urea is applied [26,27]. When the nitrification process begins, the soil pH decreases significantly, resulting in lower rates of volatilization. Dropping level of phosphorus (P) from agricultural lands may raise the productiveness of natural waters which may accelerate the development of algae and other marine plant species. P is typically the nutrient that regulates the eutrophication process in renewed waters. The United States Environmental Protection Agency (USEPA) has recommended a governing limit for eutrophication of 0.05 ppm for total P in streams that arrive into the lakes and 0.1 ppm for total P in flowing streams. P is removed from the soil through the following processes:

a. runoff and erosion;

b. crop uptake and removal; and

c. leaching. From the field and soil harvested crops P removal takes place. Concentrations of P in plant cells usually vary between 0.1 to 0.5 percent on a basis of dry biomass and maximum plant take up and consumption of about 20 and 90 pounds of P2O5 every year. Moreover, the inorganic sewage sludge phase is predominantly composed of $P_2O_5$ and $SiO_2$ oxides. The extra oxides $Fe_2O_3$, CaO, $Al_2O_3$, $K_2O$ and $Na_2O$ are present in lesser amounts depending on the sludge origin. The high behavior of temperature, the liquid or solid transitions of this inorganic combination and the phosphorus volatilization are serious operating restrictions, but they remain poorly identified. The $P_2O_5$ present in the biomass affects the liquid manufacturing of inorganic phase and in the inorganic formation of vapors disturbing the wear of lining refractory, the degradation of metallic assemblies and the high temperature of the gasification reactor. During thermo-chemical conversion, thermodynamic controls at altered temperatures help us fix the biomass behavior [28]. Longer greenhouse gas emission results in higher concentrations in the atmosphere. Concentrations of greenhouse gas are measured in parts per million (ppm), parts per billion (ppb), and even Parts Per Trillion (ppt). One ppm is the same as one drop of diluted water into about 13 gallons of liquid (approximately the fuel tank of a dense car). $CO_2$ is emitted through soil respiration from the land, which comprises three biological procedures, i.e., microbial respiration, faunal respiration and root respiration mainly on the soil surface [29]. Micro-flora within the soil adds 99 percent of the $CO_2$ rising from the decay of organic matter [30] as compared to the contribution of soil fauna which is much lower [31]. However, root respiration accounts for half of total respiration. Sewage sludge incineration generates a number of secondary pollutants, including heavy metals volatilization, metal-chemical complexes volatilization and nitrogen oxides. Between these pollutants, release of heavy metal cannot be efficiently declined by drain gas cleaning devices [32].

## Effects of Agricultural Management on Soil Organic Matter (SOM)

The most frequently defined attribute is Soil Organic Carbon (SOC) and is chosen as the utmost significant soil quality indicator and agricultural sustainability. In this manuscript, we precised in what way crop alternation, cultivation, tillage and residue managing, monoculture and fertilization influence on the features of soil, C transformation and SOM. The outcomes ratify that SOM is a sink for sequestration of C and also a source of C. Tillage and cultivation may decrease SOC content and results in the degradation of soil. Cultivation has a significant impact on C and N distribution, as well as the rates of Organic Matter (OM) decomposition and N mineralization. Crop rotation can help to maintain, improve the quality and amount of OM in the soil, as well as improve the physical and chemical properties of the soil. Proper application of fertilizers in conjunction with Farmyard Manure (FYM) can improve soil nutrients and SOC content. Crop residue or manure only cannot be sufficient to maintain SOC levels [33,34]. Tillage is also used to ventilate and blend the soil, as well as to incorporate crop cover, crop residue, manure, pesticides, and fertilizers into the rhizosphere [35]. Tillage management in soil can influence soil respiration controlling factors such as substrate accessibility, soil temperature, water content, oxidation-reduction potential, pH, number and type of microorganisms, and soil ecology [36, 37]. Second, crop rotation may have a significant impact on soil health due to the development of soil environmental processes and connections over time. These include increasing soil structural stability and nutrient use efficiency, increasing crop water use efficiency and SOM levels, providing better weed and disease control and disrupting insect life cycles [38, 39]. Crop rotation can also increase yields and nitrogen availability when nitrogen-fixing legumes are included [40,41]. Additionally, in crop production, fertilization is one of the most important practices for improving soil nutrient availability. According to [42], fertilizer uses significantly higher concentrations of P and K in the soil and the concentrations of SOC and N, P, K were higher in the plough layer than in the subsoil. As proper plant growth and improvement are inextricably linked to nutrient sources. Several nutrients affect biochemical processes in the plant's body and play an important role in soil fertility making it more useful for plant growth [43].

## Role of Microbes in Environmental Remediation

Microorganisms have extended the ecosystem where they reside in, through acquiring enzymes that enable them to metabolize various anthropogenic manufacturing compounds (xenobiotics) [44]. The usage of microbes or microbial mechanisms for inactivating and deteriorating the ecological pollutants is


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known as bioremediation. Over many years, microbes have been used for regular treatment and alteration of waste materials [45]. Microorganisms that degrade the wastelands that enter the treatment plan rely on the metabolic processes of fixed-film and activated sludge treatment systems. Many such waste management plants are specialized with designated and accustomed microbial species that are frequently used to tackle industrial wastewater. Microorganisms can even be catalyzed by a variety of metal transforms which can help with waste management. Oxidation, reduction, and alkylation interactions are the examples of these transformations. Fungi, bacteria, algae Soetan 113, and protozoa may store manganese and ferrous ions during oxidation processes. Geobacter metallireducens is a bacterium that eliminates uranium, a radioactive waste, from mined groundwater sources and contaminated water. For oil extraction, prevention of pollution, mineral leaching and restoration, microorganisms may now be genetically modified using rDNA techniques. Microbes may also be genetically modified to manufacture compounds effective in enhanced oil recovery mostly in petrochemical industries [46]. Oil spill cleanup may be delegated to genetically modified bacteria in the future [47]. Microbes with improved leaching capacity may be engineered for use in the mining industry. Metals may bind to the microorganism surfaces and be concentrated internally.

## Role of Microbes in Agricultural Science

Agricultural land is an essential component for food production, shelter and fiber for mankind [48]. In the economic growth of several developing countries farming plays a dynamic role and also provides self-employment opportunities [49]. Many plant physiologists believe that soil is the primary source of plant nutrients; however, good soil quality is required for agricultural production, and quality is improved by soil bacteria, fungi, and protists [50]. The microscopic biosphere is the major pool of biodiversity on earth [51]. In other words, microorganisms can be considered as soil machinery in recycling of the nutrients [52]. The quality of soil and its conservation can be improved by soil microbes within the soil system. Soil microorganisms will allow the breakdown of OM such as animal and plant remains, as well as the formation of soil structure and the rate of biogeochemical cycling [53]. Improvement in soil quality, plant nutrition and maintenance of plant health is a fundamental function of soil microorganisms in agriculture [54]. Generally, people think that microbes are disease-causing agents. The decomposition of organic matter will be done through the help of these microorganisms in the soil [55].

### Interactions between Plant and Soil Microbes along with Stressed Agriculture

According to [23] plant-soil microbe relationship affects crop growth and competitive capacity which is critical for the structure of terrestrial ecosystems. Abiotic factors such as nutrient concentrations or environmental stress have been shown in several studies that change the course and extent between the interactions of plant and microbes. Considering this frame of reference, it's likely that the consequences of changing climate, such as altering the availability of water might alter the consequence of plant-microbe interaction that could influence plant species interaction. They used a managed greenhouse experiment on 3 species of plants: Plantago lanceolata, *Schizachyrium scoparium* and Rudbeckia hirta, to see whether the availability of water regulated the influence of soil microbes on pair-wise plant interactions throughout the Texas coastal prairie. Plants were grownup under living or germ-free soil treatments including high, medium, and least availability of water to see whether there was an association amongst water availability and soil organisms. They discovered that the existence of soil microbes enhanced intra-specific competitiveness in comparison to inter-specific competition, and therefore this impact was dependent on water availability. With the presence of microorganisms, the intensity of intraspecific competition rose as the availability of water lowered. Their findings indicate that the soil microbial communities, particularly in drier environment can perform a key function in stabilizing co-occurrence by raising conspecific negative density dependency. Changing microbial composition of the land community or the plant-microbial interactions can results in alteration in the structure of the plant community. Legate effects of drought and rainfall have been observed to reduce native biomass in soil microbial species, but have no impact on non-native biomass. While availability of water affects interaction between plant-plant and plant-soil, limited studies explored if the availability of water controls soil microbe effects on plant collaborations. If water deficit reduces the diversity of microorganisms in soil, so they can be estimated to perform poorer in modulating plant interactions than wet environments under dry conditions. Conversely, as the impact of soil microorganisms on plant output increases with dry conditions, then soil microorganisms might also perform a better role in facilitating plant interaction under desiccated conditions. This might be crucial to recognize how specific groups of soil microorganisms react to accessibility of water to improve our power to foresee how plant-microbial contacts alters with the alteration in environment [56]. According to [57], the estimated increase in heat and reduced rate of precipitation due to alteration in climate and undiminished human activities supplement to agricultural industry complications and uncertainties. The world is constantly investigating the effects in terms of food safety, the soil nutrient imbalances, poorly managed use of pesticides, high temperatures, floods, or drought, soil salinity and heavy metal pollutants. They explain the importance of soil-plant-microbe associations with organic manure for all the solutions of troubled problems in agriculture. Plant-associated advantageous microorganisms are believed to enhance plant growth and increase resistance mechanisms of plants to biotic (diseases) and abiotic stresses like (salinity, drought, waste etc.). The Plant Growth Promoting Rhizobacteria (PGPR) and mycorrhizae are crucial elements of the microbial communities and have the vital


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function in maintaining plant fitness and soil health in extreme circumstances. Addition of organic manures to strained soil together with appropriate bacterial strains may further improve plant-microbe contact and enhance agricultural crop productivity. A mixture of plant, stress resistant microbe and organic modification is the tripartite association that provides hospitable environmental conditions for the propagation of advantageous rhizospheric microorganisms which in turn improve the growth output of plants in a disrupted agro-ecosystem. The agricultural soil-used patterns, with plant microbe interactions properly and using appropriate advantageous microbial agents is perhaps one of the most successful management technique in the agricultural land concerns [58,59].

## Conclusion

Soil is a necessary basic need towards agricultural crop production and microbe's activity in the system has a unique and essential role to play as in improving soil health in a sustainable manner for healthy crop growth due its complex link among the soil-plant continuum. Microbes have an intrinsic role to play in different biological transformations such as organic matter decomposition, biological nitrogen fixation and enhancement of the availability of nutrients to the plants for its growth and development. Several inputs that are used for crop production purposes like chemical fertilizers, organic amendments, microbe inoculants and synthetic pesticides in order to attain the required yield and economic return all have adverse effect on the soil and these are usually neglected by most of the countries. Synthetic fertilizers have little effect on soil physical properties whereas organics improve soil biological properties by increasing system productivity, crop residue return and organic matter in soil. The use of nitrogen fertilizer leads to acidification in soil that affects the health of soil. Soil organic carbon is regarded as the utmost significant soil quality indicator and agricultural sustainability. Soil organic matter is a sink for the sequestration of carbon and also a source of carbon. The quality of soil and its conservation can be improved by soil microbes within the soil system. Soil microorganisms allow the decomposition of organics such as animal and plant remains, as well as the formation of soil structure, supply plant nutrients and the control the rate of biogeochemical cycles. Improving soil health, plant nutrition and maintenance of plant health is a fundamental function of that is controlled by the soil microorganisms in the field of agriculture. Plant-soil microbe relationship affects crop growth and competitive capacity which is critical for the structure of terrestrial ecosystems. Abiotic factors change the course and extent between interaction of plant and microbial biomass. It is necessary to understand the dynamics between microbes and its environment especially its processes in relation to agriculture and soil health.

## Acknowledgment

All the authors are highly thankful to Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad 38040, Pakistan for their moral support.

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**How to cite this article:** Aqarab H G, Shamal S K, Muhammad D T, Hooria Z, Asma Z. Lynn K. Agriculture and Environment Sustainability through Interaction of Microbiology with Soil Chemical Nature. Agri Res & Tech: Open Access J. 2021; 26 (1): 556323.
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DOI:10.19080/ARTOAJ.2021.26.556323

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