

Organic Soil Amendments for Sustainable Agriculture: A Comprehensive Review

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ABSTRACT

The sustainability of agriculture is thought to be threatened by the scarcity of water resources in arid and semiarid regions. Modernization and industrial pollution have increased and polluted the soil. Modern agriculture with the help of inorganic fertilizer and pesticides degrades the soil quality resulting in the decrease yield in the agriculture. Soil amendment is one of the approaches to improve the quality of the soil in the natural process. Organic wastes are collected, processed and used as a soil amendment. This review focused on the different types of organic soil amendment used to increase the physio-chemical properties of the soil.

Keywords: Sustainable agriculture, organic soil amendment, nutrient cycling, water retention.

INTRODUCTION

An extremely thin layer on the top of the earth's surface is called soil, a layer that serves as the interface between the living and the non-living. Soil health is important for nature because it plays an important role in the sustainability of life on earth. Soil possesses the world's most intricate and varied ecosystem on earth. Soils not only supply 98.8% of the world's food, but they also perform a wide range of other functions, such as regulating greenhouse gases, storing carbon, preventing flooding, and supporting our vast cities. However, soil is a limited resource, and the intensification of agricultural production to increase crop yield per unit area of soil due to rapid human population growth and rising consumption is putting previously unheard-of strain on soils (1).

Nutrients present in soil:

Healthy soil forms the foundation of the food system in India. Healthy crops are produced by healthy soil. Farmers must take care of and work hard to maintain a healthy soil. Soil is one of the limited resources needed to maintain the quality of life in earth. Society is being forced to acknowledge the value of its soil resources in order to protect many limited natural resources and enhance our quality of life. However, soil quality and land management both have direct influence on water and atmospheric quality and, by extension, on human and animal health (2). The nutrients present in the soil are divided into micronutrients and macronutrients based on the requirement. The soil macronutrients namely nitrogen (N), phosphorus (P), and potassium (K) are essential elements for crop growth. Nutrients required in lower quantities but very essential are called micronutrients. These micronutrients have various functions in the development of plants (Table 1). Apart from the growth of the plants, micronutrients are essential for the microbial consortium of the soil. Deficiencies of micronutrients are common and have been found in many different types of soil around the world. A lack of vital micronutrients causes abnormal plant tissue size, shape, and pigmentation, lowers leaf photosynthetic rates, and results in a number of harmful conditions (3).

Table 1: Micronutrients and its function (Rahman et al., 2020)

S.No	Micronutrient	Functions
1	Boron	Helps to facilitate the movement and metabolism of sugar in the plant. Helps in the formation of lignin in the cell wall.

2	Chlorine	Essential to maintain the osmotic and ionic balance. It is also important for photosynthesis.
3	Copper	It is essential for cell wall formation. Involved in the photosynthesis, respiration, and nitrogen fixation process.
4	Iron	Helps in many essential process of the plants like photosynthesis, respiration, chlorophyll formation and many enzymatic reactions
5	Manganese	It is a component of enzymes and is also involved in photosynthesis and root growth. It is involved in nitrogen fixation.
6	Molybdenum	It is involved in nitrogen fixation and nitrification
7	Iron	It is a component of organic complexes and DNA proteins. It is an important enzyme.
8	Zinc	Growth of the harmonic production and seed development.

Table 1: Micro and macronutrients present in the soil.

Soil degradation

Climate change accelerates soil degradation, decreases water quality and renewability, exacerbates biodiversity loss, and provides feedback to climate change. It is occurring mainly due to extreme events that cause permafrost to thaw and desertification of arid and semi-arid regions. The deposition or application of anthropogenic waste containing chemicals like heavy metals, toxic organic compounds, pesticides, plastic, and biological pathogens can contaminate soil, making it a serious worldwide problem of the twenty-first century (4). According to estimates from the Indian Council of Agricultural Research show that land degradation due to several factors affects 37% of India's land. India loses roughly 5.3 billion tons of soil annually due to soil erosion, which is a serious issue. Soils lack many of the major and micronutrients, such as nitrogen, zinc, iron, copper, manganese, and boron, which affect the soil quality. In order to guarantee food and nutrition security and stop additional land degradation, effective management of natural resources is essential (5). The foundation of sustainable agriculture is the idea of producing more high-quality agricultural products in a safe and effective manner while protecting the environment and supporting the habitat of plants and animals. Additionally, it raises the farmer's socioeconomic standing and advances both financial success and social justice.

Soil amendment is one of the choices for increasing the nutrition value of the soil using naturally available waste products. Soil amendments are the substances used to increase the growth of the crop yield without compromising the fertility of the soil. The primary goal of soil amendment is to enhance soil fertility by making more nutrients and water available to plants, preventing soil drying out, preserving high microbiological activity in the soil, and boosting plant uptake of nutrients (6).

Organic Source for Soil Amendment

Organic soil amendments are the various organic compounds in combination used in the soil to improve the physical, chemical and biological properties. These substances provide essential organic nutrients for plant growth and improve the soil macro- and micronutrition. Increased nutrient availability, better soil structure, greater water-holding capacity, and improved soil biodiversity are some of the advantages that organic amendments offer to soil and plants. Organic amendments help to improve the soil quality and thus benefit the environment by encouraging the recycling of organic waste materials and lowering the need for synthetic fertilizers. The use of soil amendments enhances the long-term health and productivity of agricultural soils, which is the prime factor for the organic farming and sustainable agriculture (7).

Types of organic amendment

Based on the source of the materials, organic amendments are classified as 6 types (Fig 1).

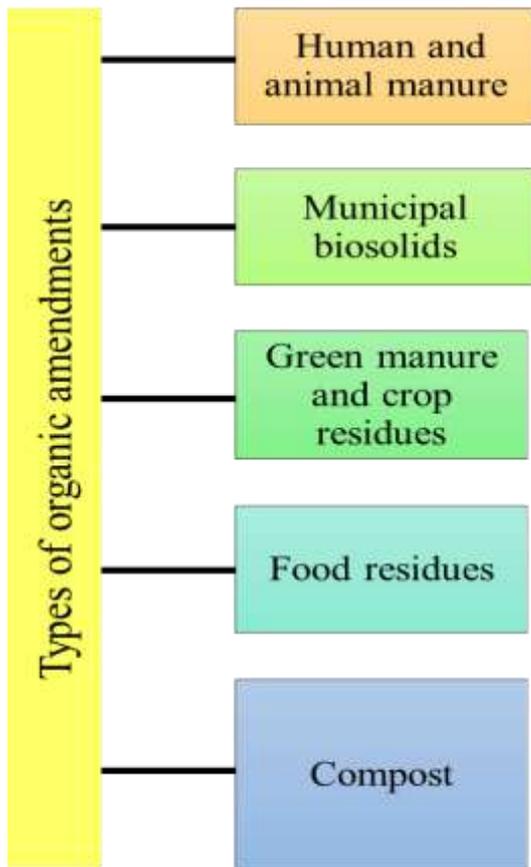


Fig 1: Types of organic soil amendment

Soil amendment prepared using organic waste is one of the approaches to convert the organic waste into manure.

Biochar:

Biochar is one of the processes in the soil amendment. Biochar is a substance highly rich in carbon that is created when biomass is pyrolyzed at a high temperature without oxygen. The physical and chemical characteristics of biochar, which include a highly stable carbon-based structure, a large surface area, an accommodating pH, high porosity, a large cation exchange capacity, and a high-water holding capacity, enhance soil properties and interact with soil biota. The alkaline property of the biochar can uptake the more acidic cations and reduce the acidification of the soil (8).

Human and animal manure as soil amendment:

Organic waste is the major source of pollution and causes major environmental problems if left without rapid control. When the organic waste is properly managed as a soil amendment, it can enhance the soil's vital functions, including food production, water filtration, and climate regulation. The amount of organic matter and trace elements in the soil can be improved by using the organic waste as a soil amendment, which lessens the need for inorganic fertilizers. Use of an organic waste improves the water retention and water filtration properties of the soil (9). Addition of animal manure in the compost preparation increases the total organic carbon content in the soil in the long and short term. Increased total organic carbon in soils may boost the soil's ability to exchange cations, which would increase nutrient adsorption. It may also encourage the complexation of exchangeable aluminum, which could lead to higher pH and more grain crop production. Stability of the aggregation of soil is more noticeable when the organic materials with a higher C:N ratio are used (10). Darwish et al, (1995) showed the application of animal waste manure in the surface soils of Virginia for the longer duration and found that liquid and plastic limits, wet aggregate stability, aggregate size distribution, dispersible clay percentage, percentage of water retention, and organic content of the soil were increased in the manure-treated

soil when compared to the other soils (11). Bashir et al (2021) used soil amendment rich in animal manure in the cadmium-rich soil to prevent the cadmium entry from soil to maize. The study confirmed the accumulation of cadmium in the various plant parts was reduced in the soil containing animal manure when compared to the control (12).

Municipal biosolids as soil amendment:

The semi-solid residue from sewage treatment or industrial wastewater is referred to as municipal sewage sludge. It is primarily made up of organic matter, residual heavy metals or contaminants, and microorganisms that help treat wastewater. The production of domestic and industrial wastewater has been concentrated into centralized sewage collection channels. Due to the rapid urbanization of the world over the past century, the accumulation of biosolids is enormous, which led to exponentially growing volumes of biosolids, or sewage sludge, that need to be handled sustainably (13). The treated municipal waste is termed as biosolids, which is highly rich in nitrogen and provides the nitrogen to meet the need of the crop. Apart from nitrogen, biosolids are rich in phosphorus and small amounts of trace elements. Therefore, biosolids may have an impact on soil by increasing the levels of soil pH, soil organic matter content, and soil trace element concentrations in addition to their effects on soil and crop nitrogen content. The goal of biosolids in soil is to maintaining soil pH and organic matter levels within desired ranges, as well as to providing enough nutrients for crop production while reducing the possibility of nutrient loss from the soil. Tracking the concentration of trace element additions to soil is also necessary while using biosolids because many trace elements tend to accumulate in soil (14). A study by Desjardins et al (2025) showed the application of biosolids for the long duration in semi-arid dryland improved the soil organic carbon, increases the nitrogen content, increased water holding capacity and nutrient cycling (15).

CONCLUSION

Organic soil amendments in soil cause significant differences in soil properties including, organic carbon and nitrogen content, water holding properties, maintain the proper nutrition value, removes the transport of heavy metal in to the soil, and reduce the drought stress of the soil. Use of organic soil amendment for long duration helps to convert the non-agricultural land to the agricultural land.

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