Impact of Organic Amendments on Soil Structure, Fertility and Growth of Plants

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Abstract

Organic amendments are, in effect, essential for making the soil structure, nutrient composition and microbial diversity more sustainable for agriculture. Retaining water to support the development of roots and nutrient absorption helps increase soil particles' stability, porosity, and soil (fertility). Organic amendments can increase long-term soil fertility by increasing organic nutrient cycling via organic nutrient decomposition rate degradation to decrease reliance on synthetic fertilizers. Their most important benefits include their major positive effect on soil biological properties that promote nutrient and organic matter turnover and decomposition through increases in microbial biomass and enzyme activity. And they have very healthy populations of earthworms and mycorrhizal fungi that add a bonus, refashioning a landscape and cycling nutrients properly. Organic amendments also help keep soil pH in check, make nutrients more available and help buffer against variations that could otherwise restrict plants from taking in the nutrients they need. This chapter focuses on how these amendments change plant attributes to increase the uptake of nutrients, root vigor and resistance to drought and salinity. In this chapter we explain the using organic amendments like humic acids, compost or manures, organic agriculture increases agricultural productivity; along with increasing healthy soil, it involves practicing sustainable agricultural ways.

Keywords: Agriculture, Organic, Lithosphere, Fertility, Nutrients, Crop, Health

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Introduction

The organic amendments have always been a factor that is contributing in the improvement of the physical, chemical, and biological properties of soil as this is related to plant growth and yield (Srivastava et al., 2023). Soil enhancements, which include compost, manure, and biochar, amongst others, are taken to enhance the attributes of the soil; measures to increase nutrient value, moisture retention, and microbiome. The amendments offer nitrogen, phosphate, potassium, and micronutrients to the plant and therefore boost the right farming practices. Even though it is an improvement in the soil texture by increasing levels of organics in the soil it influences aggregation, porosity, water holding capacity, etc., but the component never uses artificial fertilizers (Rincón-Molina et al., 2023) .

A still higher value of the application of organic amendments is that the same provides for the retention or enhancement of the arrangement of the soil. Said materials form aggregates involved in forming lamellae that are well defined positive structural and storage categories in the soil (Mitra et al., 2023). This leads to this reduction of compaction and consequent increment of pore space, which in turn means improved chances of plant roots having water and nutrients. However, addition solves the problem of aggregate stability and soil erosion reduction in such a manner as to act as a binder by the soil with the help of organic matter. Such has been made possible by the organic addition structural benefits, significantly where ground substratum is declining or where veritable fertile ground becomes limited by erosion or compaction for crop production (Domenico Prisa, 2023). Another advantage leads to increased soil productivity since the

slow-release characteristic of the products optimizes the soil so that it remains fertility-rich and increases farming productivity over a long period. Soil microbial actions, therefore, facilitate the cycling of nutrients through which the plants can obtain vital nutrients at any time (Salih Alkobaisy, 2023).

Organic matter supplies nutrients to roots, increases water conductions, and reduces the impact of stressing factors like water shortage on plant life. Therefore, the soils that have been fertilized with organic matter and another supplement to support growth, Barn Well, developed the growth rate and yield of the plants better than the average ordinary soils (Yu et al., 2023).

Besides cementations, which grind particles together and renew the soil and supply it with fertility additions, there are new fulgent types in the soil. since organic matter increases the reproduction rates and diversification of soil microbial populations, including bacteria, fungi, and earthworms, there will be boosted cycling of nutrients and decomposition of organic matter (Zhang et al., 2023). It is such a property that can be very handy in acid or severely alkaline conditions which retard the liberation of plant nutrients. 'Ammoniated manure decomposes into organic acid and humic chemicals which either moderate sourness or alkalinity and help build a good structure for holding root applying nutrients (Suprayitno et al., 2023).

Second of all, organic matter reduces the risks of environmental pollution, as artificial fertilizers and chemical pesticides are among the ways soil and water pollution are caused (Ji et al., 2023). They sell two completely different products and which has a tendency of supporting the environmentally friendly disposal of the agricultural and food waste that is used to ameliorate some of the soils conditioners. These amendments expand the concept of maintaining rotation, offering primarily closed nutrient loops, decreasing internal synthetics, which set up stability for the structures of the soil in the future, and promoting the circular economy in agriculture (Nelkner et al., 2023).

2. Types of Soil Organic Amendments

There are several types of organic amendments within the soil, all of which present benefits on soil structure, as well as fertility. Below are many prevalent categories:

2.1 Compost

Obtained from the breakdown of organic matter; compost is an authenticated story in nutrient and microbes. It develops the physical condition of the soil, increases the ability of the soil to hold water, and improves microbial populations. Compost releases nutrients steadily in the soil and therefore enhances the uniform fertility of the soils (Aylaj et al., 2023).

2.2 Manure

Animal manure like cow, poultry and horse manure is used commonly to supply the nutrient needed for nitrogen, phosphate, potassium and so on to the land. Risks of disease, nutrients and balanced, manure well or composted disease and vegetation organisms causing diseases are controlled and/or destroyed (Mutale-Joan et al., 2023).

2.3 Biochar

Biochar is defined as carbonized and stable material produced by the carbonization of organic material in a reduced oxygen environment. The characteristics it improves on the physical aspect of soil include the improvement of its water-holding capacity and also acts as a support to microbial inputs in the addition of carbon stock (Liu et al., 2023).

2.4 Crop Residues

Residues mainly refer to the remaining parts of the plants after crops have been gleaned. For example, straw and stalks can be incorporated back into the soil. Thus, the addition of organic matter, rigorous structure, and improvement of microbial decomposition are key (Kumar & Kumar, 2023) .

2.5 Peat Moss

A material that works slowly, peat moss, commonly found in agriculture, enhances air exchange and water holding capacity. However, the problems concern the environmental impact owing to the subsoil extraction of peat, the power source barely acknowledged for utilization in optimal agricultural processes and techniques (Shi et al., 2023).

2.6 Fish and Bone Meal

Occasionally, treated sewage sludge called biosolids is used, and another soil amendment is referred to less commonly. It contains a lot of organic matter and nutrients but has to be through some complicated processing lest it becomes a source of danger or an impure product (Khan et al., 2023).

3. Impacts of Organic Amendments on Soil Structure

Another essential aspect of organic matter is that it helps enhance the physical characteristics of the soil. Among these, Organic matter is essential for soil and plant health in the following ways. Here are some principal methods by which organic additions enhance soil structure:

3.1 Aggregate Formation and Stability

Any Del addition of composts, manures, and other organic matter that are good for soil particle aggregation is therefore an indication of organic matter. The contribution of the essentials embraces the right positioning of the place for the formation of aggregates of good structure of the soils, appropriate space to the size of the pore of the soil, effective water percolation, and successful aeration (Luan et al., 2023).

3.2 Augmented Water-Holding Capacity

In this aspect, organic inputs are preferable because they enhance the water retention of the soil. It retains water in the soil and makes it accessible to the plant waiters at the right time during the dry season. This setup is especially advantageous because the subsoil formation is sandy, and aerially, this layer does not allow water accumulation, so the added carbon either helps offset water deficit conditions or protects plant life from water calls (Zhao et al., 2023).

3.3 Support for Soil Biota

The inorganic material is not only an innocent base for developing ground beneficial predators for burrowing but also food to other beneficial organisms like bacteria and fungi, worms, and all other decomposers of the ground. These species assist in the mixten development through;

Polysaccharide synthesizing microbes + soil earthworm that dug + forms some channels causing some aired structure of the soil.

4. Impacts of organic Amendments on soil Fertility

Soil amendments alter the world within which plant growth occurs the media and indeed the very fabric of the soil; some with organic matter bring elemental changes (Diacono & Montemurro, 2011). Here are some principal methods by which organic additions enhance soil structure:

4.1 Aggregate Formation and Stability

Organic matters include manure and compost, which are other organic matter that usually produce a stick that holds soil particles to form aggregate. Consequently, aggregates are a key factor in the evaluation of the right structure of the soil, help in the enhancement of the porosity level of the soil, help in the enhancement of water permeability of the soil, and last but not least, they play a major role in the aeration of the soil (Xue et al., 2023).

4.2 Enhanced Porosity and Drainage

The transformation of the organic matter into the soil also increases the size of the pore space, and so provides another case of improving the air and water soil profile (Sofo et al., 2023). Loamy which is well-structured sandy but with more pore space is preferable for admitting oxygen and nutrients into the root part of plants. Internal drainage impacts the likelihood of waterlogging, even more in heavy clay soil in which compaction coupled with poor internal drainage is very common (Zeng et al., 2023).

4.3 Improved Water Retention

The use of organic inclusions also enhances the soil's efficiency of both water and properties at the same time. Facilitating the provision and storage of water in the interstitial spaces in the soil makes water available to plants at some time when this product is not available (Jiang et al., 2023). This is quite advantageous, especially regarding growing conditions afforded by the arid zones where the holding capacity of sand for water is very poor; this means that by applying organic matter to improve the status of the soil, water stress and, therefore, poor crop yields among those grown in the dry season can be improved (Goldan et al., 2023).

Table 1: Impacts of Organic Amendments on Soil Properties (Sharma et al., 2024)

Soil Property	Impact of Organic Amendments	Mechanisms and Benefits	References
Soil Structure	Enhances aggregation, porosity, and reduces compaction	Organic matter binds soil particles, improves root penetration, and reduces erosion	(Wang et al., 2021)
Water-Holding Capacity	Increases ability to retain moisture	Organic matter acts as a sponge, beneficial in sandy soils and drought-prone areas	(Salnikova & Makarenko, 2021)
Soil Fertility	Increases nutrient availability and retention	Provides essential nutrients, enhances cation exchange capacity (CEC), supports microbial nutrient cycling	(Raina et al., 2021)
Soil Microbial Activity	Boosts microbial biomass and enzyme activity	Organic matter provides carbon and nutrients, promoting beneficial microorganisms and enzymes	(Wang et al., 2021)
Soil pH Stability	Buffers and moderates soil pH	Organic acids and humic substances buffer pH, prevent extreme pH shifts, optimize nutrient availability	(Muthukumar, 2021)
Disease Suppression	Reduces soil-borne pathogens	Supports beneficial microorganisms that outcompete pathogens, reducing pesticide need	(Sharma & Kaur, 2021)
Carbon Sequestration	Stores carbon in the soil, reducing greenhouse gases	Organic carbon builds soil organic matter, aiding in carbon storage and climate change mitigation	(Jian et al., 2021)
Plant Health and Growth	Improves nutrient uptake, root health, resilience to stress	Enhances root development, supports biomass growth, increases resilience to drought and salinity	(Omirin et al., 2021)

Several scholars have agreed that a deeper charge on the ground with organic matter raises the CEC and overall capacity for holding up charged fragments that are to be exchanged. This raises cation exchange capacity (CEC)-and thus the ability of the soil to retain nutrients that are cations, such as Ca^{2+}, Mg^{2+}, and K^{+} Soil contains silicate and aluminum hydroxide in order to remove additional acidity. moreover, it has a buffer against fluctuations in pH levels (table 1 & table 2).

Mitigation of Aluminum Toxicity: All type of Al^{3+} which are soluble in acid are toxic at high values of soil solution and the substance is toxic for the plant also. Organic additions have been found to either increase soil pH or ameliorate it, thus resulting in a decrease in soil solubility and aluminum toxicity. They also reduce the effects on plants through an interaction between the active organic matter Al and Aluminum.

5. Impacts on plant growth and Development

As organic amendments, they encourage plant growth and, therefore, development by improving the soil's structure, fertility, and water-conserving capacity and the life processes taking place in the soil. The principal methods by which organic amendments stimulate plant development are as follows:

5.1 Improved Nutrient Accessibility

Of the organic amendments: N, P, and K, these being Nitrogen, phosphorus, and potash elements in which 'K' is a stringent necessity in the growth process, and some of the microelements beneath are amongst the most vital inputs for plant require in large scale . Organics remain in the soil for a period of time, and nutrients are released slowly to the plant at a time. This helps the plant develop roots, shoots, flowers, and hence yield. This progressive solubilization avoids the loss of nutrients and ensures that plants have vital nutrients for most of their development (Agegnehu et al., 2016).

Table 2: Impacts of Organic Amendments on Soil Properties (Zhang et al., 2024)

Nature	Details	Impacts	References
Compost	Decomposed organic matter, rich in nutrients and microbes	Improves soil structure, water retention, and microbial activity; slow-release nutrient source	(Mao et al., 2021)
Manure	Animal waste, e.g., cow, poultry, horse manure	Provides essential nutrients (N, P, K), enhances soil fertility, and reduces disease risk when composted	(Pang et al., 2021)
Green Manure	Cover crops grown to be incorporated into the soil	Adds organic matter, increases nitrogen content, improves soil structure	(Khan et al., 2020)
Biochar	Carbon-rich material from pyrolyzed organic matter	Enhances soil structure, water-holding capacity, and carbon sequestration	(Tsolova et al., 2021)
Cover Crops	Crops grown to protect or restore soil	Prevents erosion, adds organic matter, and supports beneficial organisms	(Zhao et al., 2021)
Crop Residues	Remnants of harvested crops, e.g., straw, stalks	Adds organic matter, improves structure, supports microbial activity	(Liu et al., 2021)
Peat Moss	Slow-decomposing organic material	Enhances soil aeration and water retention, often used in acidic soils	(Farooqi et al., 2021)
Fish & Bone Meal	By-products from fish/meat processing industries	High in phosphorus; promotes root growth and flowering	(Kim et al., 2021)
Biosolids	Treated sewage sludge	Rich in organic matter and nutrients but requires careful handling	(Wang et al., 2021)
Wood Chips/Sawdust	Slow-decomposing wood-based materials	Improves soil structure, requires nitrogen supplementation	(Müller-Inkmann & Fründ, 2021)

5.2 Enhanced Root Development

Organic additions are a plus for the ground structure to increase the depth and width of the rooting, which incidentally increases the root area and the capability to grasp nutrient constituents and liquids. However, it works as a base material for constructing the soil structure or soil crumb, which are small particles of soil. It also reduces soil compaction and leads to the development of an increased and strong branched root system. Taproot systems always provide plant vigor in bearing stresses such as drought and hence enhance the plant's growth and yields (Agegnehu et al., 2016).

5.3 Enhanced Water Retention

Organic farming has similar utilization and utilizes water holding capabilities in the soil. It is beneficial for plants in dry, hot areas or areas with sandy loam in the soil. Soil amendment increases water availability, and in so doing, it also decreases pre-specified Water for irrigation and increases plant water use efficiency during water deficit. It also enhances the function of the hydration and structural coupling processes that occur in body cells, supports developmental actions, and guards against stress-damaging consequences (Bezerra et al., 2021).

5.4 Improved Disease Resistance

Organic amendments influence the quality, number, and kinds of native microorganisms to suppress soil-borne diseases and pathogens. Improved bacteria in the bodies of enriched soil are more numerous than pathogenic bacteria and form a natural barrier around the plant root . The bacteria attached to the organic amendments have qualities of natural antibiotics and plant hormones aiming to protect plants and reduce the number of insecticides used (Agegnehu et al., 2016).

5.5 Improved Nutrient Accessibility

Organic amendments act as nitrogen sources, phosphorus, potassium and all those necessary micronutrients required for the plant. Those Chemical fertilizers include Calcium, potash and magnesium. They are sometimes released as organic matter decomposes, so nutrients are available throughout the growing period. It prevents the balding of nutrient reserves and actually ensures that every part can grow to its full potential, hence strengthening the health of the whole plant (Agegnehu et al., 2016).

5.6 Improved Resistance to Pests and Diseases

Organic amendments enhance the growth of other excellent soil microorganisms that can hinder dreadful diseases. Occasionally create intrinsic antibiotics or stimulate plant immune response, thereby reducing operator the level of pathogenic microorganisms and, in general, disease probability. Based on the type of organic matter that the improved structure of the soil comprises, it may be argued that plants grown in such type of soils have native pathogen and pest management mechanisms that would help to reduce the use of chemical inputs and enhance the health of plants (Singh et al., 2020).

5.7 Advancement of Symbiotic Associations

Maine is a useful instrument in obtaining access to satisfactory mycorrhizal fungi. Of course, these fungi are mycorrhizal with plant roots and thus improve the uptake efficiency of nutrients and water. This type of relationship improves the floristic potential of phosphorus, which is crucial in root formation and energy conduction in the plant (Pandey et al., 2023).

5.8 Enhanced Plant Hormone Synthesis

Some organic amendments are composed or promote the synthesis of the indigenous growth hormones of the plant part, which includes auxins and cytokinin's. These hormones promote the formation of roots and increase stem growth and branching of the leaves to increase the vigor and mechanical strength of the plant. Shooting and humic substances release hormone-like substances that assist the plant to grow.

6. Challenges

Nutrient composition variation in compost, manure, and crop residues depends on the type, source, processing, and storage methods used. This variability prevents nutrient deficit or uneven distribution, necessitating further analysis and precision. Organic additives release nutrients slowly in the soil, unlike synthetic fertilizers soluble in water (Noutcheu et al., 2024). Farmers may require supplementary organic fertilizers during the early stages of the planting cycle for optimal nutrient input. Organic amendments can be a potential source of pathogens, such as raw manure containing E. coli, Salmonella, and parasitic cysts. Organic amendments need proper treatment or ageing to address this risk, which can be time-consuming and resource-intensive. Weed seeds can also enter fields through organic soil conditions, requiring weed management. Proper composting at higher temperatures or sourcing compost from recognized retail outlets can help reduce or eradicate weed seeds. The frequency of organic matter application can influence nutrient solubility, affecting soil productivity and output. Frequency and span are crucial for applying IDEM and specialization in nutrients, along with the absence of pollutants in the soil (Verma & Pradhan, 2024).

7. Recommendation and Conclusion

Storage and Handling Requirements: Some experienced manpower refers to these as organic additives, but they are many folds heavier and denser than most synthetic fertilizer and, therefore, may require large-volume storage vessels. Choosing the accurate feeder bunker reduces the rates of nutrient spoilage, minimizes bad smell formation, and mitigates the effects on the nearest water source. Those not composted physically may warrant specialized applicators, which can be expensive or unavailable to some SHAs . It is also not easy to shorten the time to perform organic modifications or to increase the number of alterations per volume because the majority of organic updates are large, and, therefore, substantial time is needed for integration to occur and integration work. This technique makes it equally clear to differentiate between synthetic fertilizers and organic amendments. This means that if time is allowed for decomposition and mixture with the soil, the efficiency of the organic supplement increases substantially, and thus, even more time for the composite's breakdown into the ground is even better. The condition may also disadvantage farmers who may not afford adequate labor or time, especially during preferred planting seasons for perishable produce .

Likewise, additional organic matter can be expected to have less of an environmental issue than artificial fertilizers; moreover, it could produce methane and nitrous oxide gases from the decomposition of incorporated organic matter If it is ill-applied or overused. Otherwise, if applied, processed organics from animals, such as manure, lead to nutrient leaching, water pollution, and eutrophication, among others. In some cases, high-quality organic manure may also not be available or expensive if obtained from a faraway place. However, there is no limiting severe factor for smallholders or resource-poor farmers. The transportation cost of organic supplements and their application may also be relatively high, with the increased quantity required to feed the crops.

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