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Effect of Organic Amendments on Soil Structure: A Review

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Annotation: Organic additions are prominent in the enhancement of physical aspects of soil and the agricultural output of the land. Recent scientific research on the effects of organic material on the soil properties, specifically physical structure, aggregate forming, structural stability, porosity, elasticity and water holding capacity is synthesised in this review. The literature reveals that the addition of farmyard manure, plant and animal residues, compost, and biochar has a significant positive impact on soil structural stability and physical properties. The extent of the enhancement is governed by the nature of organic amendment, application rate as well as the inherent properties of soil. In general, the evidence implies that the rational and science-based application of organic amendments can help to make the soils productive in the short term and minimise the soil degradation in the long term.

Keywords: Soil Structure Improvement, Soil Physical Properties, Aggregate Stability, Water-Holding Capacity, Organic Amendments.

1. Introduction

One of the most valuable natural resources in the determination of the ability of land to generate food and sustain biodiversity is soil. It is the major means of growth of plants and accumulation of water and nutrient. The performance of soil can be defined as a combination of physical, chemical and biological features which in combine determine its productivity and long-term sustainability (Brady and Weil, 2010). The physical structure of soil is one of them and it

dictates how well the soil can sustain the plants, prevent erosion and compaction processes, as well as keep global conditions favourable to root growth and microbial activity.

The physical characteristics of soil that make up the physical structure are the size of the particles, aggregation, inter-particle bonding strength, porosity, elasticity, structural stability, and the ability of soil to hold and transfer water. Unsustainable agricultural activities that have negatively affected the physical characteristics of the soil in most Arabian nations include frequent deep tillage, destruction of natural vegetation cover, and erosion of indigenous organic soil materials (Hillel, 2004). Such practises tend to cause enhanced compaction, less porosity, lesser ability to retain water and become more vulnerable to wind and water erosion which is all detrimental to crop yields.

The recent researches have given prominence to organic amendments as an effective and practical method of improving soil physical makeup and fertility. The action of organic materials occurs in several ways: they facilitate the formation of aggregates, reinforce the connexions between particles, make the soil more porous and aerated, more elastic, and better able to retain the water (Eswaran et al., 2000; Al-Nuaimi, 2015). Some of the common organic amendments are farm yard manure, plant residues, animal residues, compost, and biochar, which all have distinct effects based on the type of soil, rate of application and the mode of incorporation.

In addition to direct beneficial effects on the soil structure, organic additives increase the sustainability of agricultural production and the environment in the long term. They prevent soil degradation, improve nutrient cycling, and enhance soil resistant to changes in climate (Lal, 2006; Liu et al., 2020). The field experiments have reported quantifiable changes in the structural stability, aggregation, porosity, and water retention of the soil after the introduction of organic amendments in Iraq, Jordan, Egypt and other countries of the region and hence their significance in sustainable farming in arid and semi-arid soils.

This review aims at examining Arab and international research on the effect of organic amendments on the physical structure of soil. The paper pays attention to primary materials of organic origin employed, their activities, and quantitative impact on the physical characteristics of soil. It as well gives practical suggestions on the application of organic amendments to enhance the productivity of soil and maintain agricultural systems within the Arab region.

2. Physical Properties of Soil and their association with organic matter.

The physical properties of soil define this ability of soil to realise the growth of plant, to store and conduct water and nutrients, and to resist compaction and erosion. The key properties that apply to this review are as follows.

1. The texture and particle size distribution of the whole sample is

Soil texture The proportions of sand, silt and clay in a soil that are relative to each other determine greatly the extent of water and nutrient retention, aeration and the responsiveness of soil to management practises. Organic amendments combine with particles of the soil to create permanent aggregates, which hold the fine and coarse particles. This clumping lowers the bulk density, enhances the structural stability and also enhances the ability of the soil to resist disintegration (Hillel, 2004)

2. Structural Stability

Structural stability is said to be the capacity of soil aggregates to resist degradation due to the influence of water, wind and mechanical forces like tillage and traffic. Organic matter also increases the stability of the structure as it contains natural binding agents (polysaccharides, hemicelluloses, and other carbonaceous compounds formed by plant residues and microorganisms) to bind the structure. These materials are used as glues keeping mineral particles together and preventing the slaking and dispersion of aggregates (Eswaran et al., 2000)

3. **Porosity and Aeration**

The ratio of the volume of the soil made up of pores and not the solid particles is referred to as porosity. It is necessary in terms of the translocation and exchange of air and water in the root zone. The organic amendments have a tendency to enhance the total porosity and also the distribution of the macro and micropores.Increased porosity enhances root aeration, promotes water infiltration and drainage hence minimising the danger of waterlogging as well as drought stress (Lal, 2006).

4. **Elasticity, Shrink-Swell Behaviour and Compaction.**

During the drying and wetting cycles, soils containing high levels of organic matter are more prone to be elastic and less likely to crack and exhibit extreme levels of shrink-swell. Organic materials are able to absorb water and give it off slowly and thus the change of volume is moderated and the deep cracks and surface crusts are minimised. This enhanced elasticity also increases resistance of the soil to compaction by farm tractor (Brady and Weil, 2010)

5. **Water-Holding Capacity**

Organic material may hold vast amounts of water in the structure and the related micropores. This water is released gradually to root out of plants adding to the effective water-holding capacity of soil and sustaining crops when there is a dry season. Better distribution of water in the soil profile also minimises the run off and deep percolation losses, which enhances the efficiency of the irrigation and rainfall utilisation.

6. **Providing Support and Plant Development.**

Organic amendments also enhance a more favourable environment in enhancing root proliferation by increasing the aggregate stability, porosity as well as water holding capacity simultaneously. Increased root development will improve nutrients and water uptake which contributes to increased yields and development of crops in standard conditions of stress. In the bigger time scale, these enhancements lead to long term sustainable soil productivity and less degradation of land.

3. Organic Amendments types and their impacts on physical structure of soils.

3.1 Organic Materials which occur in nature.

This category comprises of farmyard manure, plant residues and animal residues.

Farmyard Manure The farm yard manure enhances the binding strength of the soil particles particularly the sandy and clay soils. It improves the stability of the aggregate, the capacity to retain water and the provision of nutrients that fuels biological activity.It has been demonstrated that manure would reduce crusting and compaction in both light and heavy soils and would improve the conditions of the seedbed

Plant Residues: Plant residues, crop straw, leaves, stems etc. build up over time in the soil as they decompose to add to the organic matter in the soil. Having them enhances porosity and root aeration especially in sandy soils. In the long term, plant remains improve the aggregation and slow down the process of surface sealing and hardening as a result of drying.

Animal Residues: Animal litter (e.g., poultry litter, sheep and cattle manure) augment the contents of soil organic carbon and nutrients. They enhance the stability of soil aggregates, increase the water-holding capacity and promote the growth of roots. They are relatively high in nutrient content and therefore frequently lead to quick gains in soil structure and fertility.

3.2 Prepared Amendments Organic, industrially.

This category incorporates compost and biochar, which have more stable organic fractions, and with more long-term impacts.

- **Compost:** Compost is a mixture of decomposed organic substances which has been subjected to regulated biological decomposition. Compost when used on soil either enhances the formation of aggregates or increases structural stability, particularly in the fine-textured soils. It increases elasticity, decreases the degree of shrink-swell and increases the water-holding capacity. The structural advantages of compost are usually long term than fresh plant remains.
- **Biochar:** Biochar is a carbon-based product that is a result of biomass pyrolysis where oxygen is added in limited amounts. It is marked by the high internal porosity and the great specific surface area. Biochar also enhances internal porosity, aeration of soils and moderation of bulk density in the heavy soil. It also increases the ability of the soil to hold on to moisture as well as to have proper drainage and thus encourages the growth of roots in compacted soils or those that are poorly structured.

3.3 Table 1 is a summary of the qualitative impacts of various organic amendments on significant soil physical properties, as per the reviewed studies

4. Expanded Review of Arab and International Studies

Type of organic amendment	Aggregate bonding	Structural stability	Porosity	Elasticity	Water-holding capacity	Additional notes
Farmyard manure	High	High	Medium to high	Medium	High	Rapid and effective improvement in sandy and clayey soils
Plant residues	Medium	Medium	High	Low to medium	Medium	Particularly effective in sandy soils; effects develop gradually
Animal residues	High	High	Medium	Medium	High	Increases soil fertility and water-holding capacity
Compost	Very high	Very high	High	High	Medium to high	Produces long-term improvements in heavy soils
Biochar	High	Very high	Very high	High	Medium	Long-term support of soil structure; improves air permeability

4.1 Arab Studies

Iraq (Al-Nuaimi, 2015)

In Iraq, the addition of 10 percent farmyard manure to the sandy and clayey soils enhanced the structural stability by about 20-25 percent and aggregate bonding and better particle-size distribution. Manure use minimised soil erosion and, at least, improved water retention, which becomes especially significant when there are semi-arid conditions. Nevertheless, the paper concentrated on short-term effects and failed to consider the long-term effects pointing out to the necessity of follow-up studies

Jordan (Al-Zuhairi, 2014)

In Jordan a study was done on the use of plant residues as soil amendments. Plant residues addition resulted in the increase of total porosity (approximately 12 percent) and enhanced water infiltration (15 percent). The impacts were more felt in the sandy soils as compared to the clayey soils. The findings explained the need to choose proper organic materials based on soil texture. Nonetheless, no specific data of elasticity or long-term structural stability were presented in the study

Egypt (Al-Ani, 2009)

The use of farmyard manure in Egypt enhanced water-holding capacity in soil by approximately 18 percent and aggregate stability of soil during wind and water erosion. Improved root development and improved soil moisture uptake was also reported in the study. However, it did not make comparisons between manure and other organic fertilisers like compost or biochar.

Egypt (Abdallah, 2012)

A study conducted in Egypt showed that the application of compost enhanced the particle-size distribution and structural stability especially on the fine-textured soils. Compost minimised the shrink-swell and surface cracking which enhanced seedling emergence and minimised erosion.

4.2 Synthesis of Arab Findings

In Iraq, Jordan, and Egypt, physical structure of soils was always enhanced by the use of organic amendments:

- In Iraq, 10% produced an improvement of 20-25 percent in structural stability and porosity in Iraq
- in Jordan were found to improve aggregate bonding and the cracking in soils with clayey soils.
- In Egypt, Compost and manure enhanced the Elasticity, water retention, and shrink-swell cycles in Egypt.

These results underscore the potential of organic amendments as a key tool for restoring degraded soils in the Arab region and for supporting climate-resilient, water-efficient agriculture.

Synthesis of Arab Findings

In Iraq, Jordan and Egypt, the use of organic amendments always enhanced the physical structure of soil:

Compost and Biochar (Lehmann and Joseph, 2015; Six et al., 2002) International researches have discovered that biochar helps in holding soil aggregates and enhancing internal porosity of heavy soils leading to enhanced aeration and decreased bulk density.Compost, on the other hand, is particularly useful in the improvement of aggregate bonding and elasticity, and the strength of soil structure against mechanical and climatic stress. The two materials also have long-term benefits since they have relatively stable organic fractions.

Classical studies of Soil Organic Matter (Brady and Weil, 2010; Hillel, 2004) The classical references in soil physics and soil science show that organic matter enhances the key physical characteristics including the stability of the aggregate, structural integrity, porosity, and holding water. It is through these works that the mechanism through which organic amendments alter the soil structure is given its theoretical background

Systematic reviews (Zhang et al., 2019; Kant et al., 2014; Zhang et al., 2019) It has been demonstrated through meta-analyses that organic amendments are very effective in enhancing the physical characteristics of soils and the yield of crops of various climates and soil composition. Increases in bulk density, porosity, aggregate stability and accessibility to water were repeatedly linked to high yields and greater drought resilience.

5. International Studies

Organic Amendments Effects on Soil Physical Structure

1. Structural stability

Organic amendments enhance soil stability of aggregates which minimises erosion by rainfall, irrigation, and wind. Labile organic contents in farmyard manure and animal residues increase the strength of inter-particle bonding whereas compost and biochar offer a more stable structural support and resistance to compaction and aggregate destruction (Brady and Weil, 2010, and Lehmann and Joseph, 2015).

2. Aggregate bonding

Organic matter serves to cement clay, silt, and sand. It enhances the aggregate bonds and avoids dispersing fine particles by creating organo-mineral complexes and microbial polysaccharides.It has been demonstrated in Iraq and other nations that aggregate bonding has improved significantly due to manure and animal residues (Al-Nuaimi, 2015; Al-Hasan, 2010).

3. **Porosity:**

Organic amendments tend to enhance all porosity and enhancement in the ratio of macro- to micropores. Plant residues especially are useful in augmenting the macroporosity and augmenting the water infiltration of coarse-textured soils (Al-Zuhairi, 2014), and compost as well as biochar enhances internal porosity in heavy soils, thereby augmenting both aeration and water retention.

4. **Elasticity, shrink-swell and compaction.**

Biochar and compost enhance the ability of soil to swell and shrink and decrease the intensity of the swell-shrink cycle. This results into reduced cracking on the surface and increased resistance to wetting and drying. Even though these aspects have not been examined in detail in most Arab studies, international studies have shown that these properties are very critical in ensuring the structural integrity particularly in clay-rich soils.

5. **Water-holding capacity**

Organic modifications enhance the ability to hold water of soils through the provision of sorptive surfaces and development of water-absorbing micropores. In Egypt and Iraq, researchers indicate that manure and animal residues applied on the soil lead to significant increases in water retention (Al-Ani, 2009; Al-Nuaimi, 2015). The improved water retention improves crops during dry seasons and improves irrigation effectiveness.

Practical Recommendations

Resting on the reviewed evidence, it is possible to suggest the following practical recommendations:

1. Type of match amendment to soil texture: In sandy soils the farmyard manure and the remains of plants can be used especially to enhance the porosity and water retention. In clay based and heavy soils compost and biochar are better to improve the structural stability and to decrease the shrink-swell behaviour.
2. Write balanced and regular applications: Optimization of application rates should be done to enhance structure without overindulging salinity, nutrient imbalances or environmental pollution. The application on a regular basis and in moderate doses is often more efficient and sustainable than the infrequent heavy doses
3. Co-locate with other sustainable practices: Conservation tillage, crop rotation, residue retention and vegetative cover should all be used together in organic amendments to maximise benefits and reduce erosion and compaction
4. Monitor long-term changes: A number of research studies in the region are short term. The persistence of structural improvements requires long-term experiments to assess the effects of the interventions and to improve recommendations in new climatic and management conditions.

All in all, the augmented body of knowledge is a compelling indicator that organic amendments enhance soil physical structure through various processes such as augmented aggregate bonding, higher level of structural stability, incremented porosity, enhanced elasticity, and augmented holding capacity of water. These benefits are dependent on the nature of the amendment, rate of application and the condition of the soils.

6. Conclusion

Organic amendments help improve the aggregate stability, porosity, elasticity and water-holding ability, thus improving the physical environment of root development and microbial activity.

1. The successes of organic amendments are based on the nature of the amendments used, its application rate, and the nature of the soil.Compost and biochar are likely to have longer-

lasting structural advantages and manure and plant or animal residues are likely to have short-lived but less durable benefits.

2. The sustainable exploitation of organic amendments help in the increase and stability of crop production, a decrease in soil erosion, and the increase of agricultural systems to climate variations.
3. In the Arab world, where most of that soil is plagued by structural degradation and water scarcity, the concept of strategic application of organic amendments, when combined with other land conservation methods, is a viable way of ensuring more sustainable land management.

The review highlights the need to have locally adapted guidelines in the choice and implementation of the organic amendments with long-term field studies quantifying their structural and agronomic advantages in varying environmental conditions.

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