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Organic Fertilisers Enhance Soil Water and Nutrients Holding Capacity and Their Mechanism

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KEYWORDS

Climatic conditions, organic fertilizers, Nutrient holding capacity, Water holding capacity, Mechanism

ABSTRACT

Both macronutrients and micronutrients can be supplied to the soil through the use of organic fertilisers that have low carbon-to-nitrogen ratios. Along with the supply of nutrients, they have the potential to enhance the water holding capacity, texture, nutrient holding capacity and structure of the soil. In addition, they have the ability to retain nutrients. There are a number of mechanisms that may combine to enable organic fertilisers to have an impact on crop yields and soil quality. Some of these processes include improved nutrient synchrony, overall increases in fertility, and/or priming effects. Additional mechanisms may also be involved. During the process of applying organic fertiliser, it is necessary to take into consideration the rate, timing, and technique of application in order to minimize the loss of nitrogen and phosphorus. The use of organic fertilisers in significant amounts is required in order to fulfil the nutritional requirements of crops; thus, it is more advisable to apply resources that are readily available in the local area. Manure was shown to have the capacity to retain nutrients for a longer period of time, according to the findings of a case study that was conducted under rain-fed settings and involved the application of solo organic fertiliser, single inorganic fertiliser, and its mixes. For regions that are prone to drought, this is a promising discovery.

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1. Introduction

The most significant biophysical aspect that has an impact on crop output across the globe is the lack of fertility in the soil (Liliane and Charles, 2020). Taking into consideration the ever-increasing growth rate of the human population, which is anticipated to reach around 10 billion by the year 2050 (Do Land, 2022), it poses a significant risk to the safety of food supplies. In ages past, in order to satisfy the ever-increasing need for food among the populace, rural areas and marginal regions were transformed into agricultural land. Since this technique is responsible for the extinction and endangerment of a great number of plant and animal species, it is regarded with disapproval by a great number of stakeholders. In light of this, it would not be sensible to intrude on land reserves and other marginal areas for agricultural purposes that are now in existence. Therefore, it is of the utmost importance that we enhance the fertility of the soil and the health of the land that is accessible in order to not only boost food production but also guarantee the food security of the whole globe in light of the present and anticipated climate change. When it comes to soil fertility issues, the use of mineral fertiliser was formerly considered to be the most effective solution owing to the fact that it releases nutrients in a rapidly occurring manner (Beddington, 2010). On the other hand, mineral fertiliser does not have the capability of enhancing the physical qualities of the soil, which is why enhancement of fertility by fertilisers alone is not a sustainable method. It is possible that an over dependence on mineral fertiliser, without proper consideration of organic fertiliser, might result in increased soil erosion, pollution of surface and groundwater, higher emissions of greenhouse gases, and a reduction in biodiversity (Tilman et al., 2002). Mineral fertilizers are more costly than other types of fertilisers, and it is possible that many farmers do not have the financial means to purchase them (Tetteh et al., 2088). As a consequence of this, the use of organic resources has been brought to the attention of a varied group of stakeholders (Suge et al., 2011). Producing food via the use of organic fertilisers is a way that is more environmentally friendly. There is a never-ending body of research that reports on the efficiency and usefulness of organic nutrient sources in terms of preserving soil quality, increasing crop yields, and maintaining productivity (Yokamo et al., 2023; Meena et al., 2023). The chapter goes into further detail on the advantages that may be gained by using organic fertilisers on the soil.

1.1. Type of organic fertiliser being used

Organic sources of nutrients are those that are particularly drawn from the origins of plants and animals. This category includes organic fertilisers, plant residues, and animal wastes (Du et al., 2018). Biofertilizers are also included in this category. This is because organic fertilisers reduce the amount of pollution that is released into the environment. These fertilisers are more cost-effective and less harmful

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to the environment when they are readily available in their immediate vicinity (Gousterova et al., 2008). In addition to chicken manure, palm kernel cake, cocoa pod husks, sugarcane husk, slurry, blood meal, bone meal, household waste, composts, field crop residues, green manure and cow manure also comprise a variety of additional materials (Carr et al., 2020; Mureithi et al., 2005; Kumar et al., 2013). In the context of agricultural development, biofertilizers are products that include single microorganisms or mixes of microorganisms that, when applied to crops, help fix atmospheric nitrogen, solubilize nutrients, mobilize nutrients, or create growth-promoting compounds to aid in the development of the crop (Yang et al., 2021; Hemkemeyer et al., 2021; Mącik et al., 2021). Although these items do not provide nutrients on their own, they do improve the activities of soil microorganisms, which increase the amount of nutrients that are accessible to crops. Biofertilizers that fix nitrogen, biofertilizers that dissolve phosphorus, composting accelerators, and rhizobacteria that promote plant development are the several types of biofertilizers that are available.

1.2. Organic fertilisers provide a number of advantages for the soil

1.2.1. Balanced nutrition

Organic fertilisers provide all of the important crop nutrients in balanced forms, including micronutrients. These nutrients include nitrogen, potassium, sulphur, magnesium, boron, chlorine, copper, molybdenum, and zinc. When it comes to any particular inorganic fertiliser, this is not always the case. The process of decomposition results in the release of all of these nutrients into the soil (Dhaliwal et al., 2021). This is because the biomass of organic leftovers is comprised of all of these nutrients. By itself, organic fertilisers contain extremely little levels of these nutrients; hence, they need to be applied in large quantities in order to fulfil the nutritional requirements of crops (Shaji et al., 2021; Selim, 2020). This is one of the drawbacks of using organic fertilisers. Additionally, while applying organic fertilisers, it is necessary to take into consideration the fact that only a small portion of the nutrients contained in organic fertilisers may be released throughout each season. As a general rule of thumb, only around fifty percent of the nutrients that are included in organic fertilisers are capable of being mineralized during the first season of application (Yadav et al., 2022). In most cases, the concentration of nitrogen is the primary nutrient that is considered when determining the quantity of organic fertiliser that should be applied. For instance, around 2% nitrogen is present in thirty percent decomposed cow manure.

1.2.2. The enhancement of the ability to retain nutrients

In addition to providing a balanced supply of nutrients, organic fertilisers also provide organic matter to the soil when they are applied over an extended period of time. Organic matter is comprised of organic acids, which are responsible for elevating the surface charge and the quantity of $H+$ ions present in the soil. This, in turn, causes the cation exchange capacity of the soil to increase, which, in turn, increases the soil's capacity to store nutrients. The capacity of the soil to store more cations at exchange sites is increased as a consequence of this, which in turn leads to an improvement in the soil's ability to keep various nutrients. Organic matter also enhances the buffer capacity of the soil and increases the soil's ability to tolerate a change in pH, which in turn impacts the amount of nutrients that are lost or gained by the soil. Organic fertilisers stimulate the activity of microorganisms in the soil, which results in higher rates of nutrient mineralization within the soil, which is beneficial to the crops. The activities of aerobic and anaerobic bacteria and arbuscular mycorrhizae fungus are stimulated by them. These fungi and bacteria work together to produce networks of root extension, which allows for widespread nutrient availability to crops. The lysis and breakdown of soil microorganisms results in the release of nutrients that were previously stored in their biomass. These nutrients are then made accessible to crops and the soil

1.2.3. Increasing the capacity to store drinking water

The water holding capacity of the soil is controlled by the organic matter content, bulk density, structure and texture of the soil (Lal, 2020). A soil's moisture content may be determined by a number of parameters, two of the most significant of which are the specific surface area of the soil and the thickness of the water films that cover the pores. According to Jashothan (2021), the integration of organic matter into the soil leads to an improvement in soil aggregation as well as an increase in the surface area of the soil. This is accomplished by the application of organic fertiliser. More space is made available to the soil as a result of this, allowing water films to ring the soil particles. According to Herawati et al. (2021), this is the reason why the soil is able to hold onto a bigger amount of water despite the force of gravity, which causes water to be extracted from the soil.

Despite the fact that soil organic matter is responsible for binding soil particles, it also encourages the activity of soil microfauna. The movement of these organisms creates micropores and macropores in the soil, which in turn creates more space for water to penetrate. Therefore, the introduction of organic fertilisers has the potential to boost the capacity of the soil to retain water (Panagea et al., 2021). Because of climate change, if it is probable that unexpected droughts may occur in the near future, the best alternative to enhance the water holding capacity of the soil is to apply organic fertiliser. This is because organic fertiliser is produced from organic matter. Furthermore, the physical presence of organic materials on the soil functions as mulch, which helps to increase the amount of moisture that is retained in the soil and reduces the quantity of water that is lost due to evaporation (Karamina and Fikrinda, 2020). In addition to this, it slows down the pace at which runoff water travels and makes it possible for rainwater or irrigation water to penetrate the soil at a rate that is more favourable, which in turn minimises the amount of soil and nutrient loss.

1.2.4. Enhancing the structure and texture of organic matter

Improved soil structure may be attributed to the soil-binding characteristics of organic matter as well as improvements in soil aggregation. Additionally, the incorporation of organic matter increases the aeration and texture of the soil. Improved soil structure and texture make it easier for air, water, and roots to circulate through the soil, which in turn supports the establishment of healthy crops.

1.3. Mechanism of action

There have been several studies that have shown that the use of organic fertiliser results in increased crop yields when compared to the application of mineral fertiliser, which provides the same amount of nutrients (Ye et al., 2022). In order to explain the increased crop yields that result from the application of organic fertiliser, a number of different processes have been postulated (Cen et al., 2020). There are several benefits associated with this, some of which include enhanced nutritional synchronicity, priming effect, and overall fertility increases.

When organic fertilisers are given, they provide bacteria with energy from the carbon that they contain, which drives decomposition processes. This causes the soil nitrogen to become immobilized over time, which allows them to construct their body tissues. When crops have reached their full maturity, the peak of nutrient delivery corresponds with the period at which crop nutrient demand is at its maximum (Allam et al., 2022; Wei et al., 2020). This allows for the nutrients to be used effectively while minimizing the amount of nutrients that are wasted to the environment. Using a mix of organic and mineral nutrition sources has been proven to result in synergy and increased synchronization of nutrient release and nutrient demand and absorption by plants, which ultimately leads to greater yields. This is the basic process that is used to promote fertility. As was mentioned before, one of these advantages is the enhancement of the soil's structure, as well as its capacity to store water and nutrients. In addition to this, it contributes micronutrients, which are often not the primary focus of the application of inorganic fertiliser (Bergstrand, 2022).

Priming is a word that describes robust, short-term changes in the turnover of soil nutrients that are brought about by the incorporation of organic components that are quickly decomposable. Depending on whether nutrients are swiftly mineralized or immobilized, changes may be either good or negative according to the situation. According to this process, the total amount of nutrients that are accessible in the soil after harvest as well as the nutrients that are present in crops that have been harvested from the field are more than the total amount of nutrients that were present in the soil initially as well as the nutrients that are present in organic materials. Therefore, the extra unaccounted-for nutrient is the consequence of organic fertiliser causing a more faster mineralization rate and the dissolution of nutrients that were previously inaccessible or locked into solution. The increase of microbial population, variety, and activity that is brought about by the incorporation of organic material is what makes this particular approach beneficial. Despite the fact that these methods were provided by a variety of writers, they all lead to the fact that organic fertilisers are helpful to the soil and, as a result, to crops.

In spite of the fact that organic fertilisers are beneficial to the soil, the application of organic resources is restricted due to the enormous quantities that are necessary to satisfy the need for nutrients. For this reason, it is necessary to make use of the organic resources that are readily accessible in the local area. When it comes to organic fertiliser resources, feedlot manure is the most readily accessible commodity in regions where animal husbandry is prevalent. Increasing the amount of residue produced on farms may be accomplished via the retention of agricultural residues and the rotation of cash crops and cover crops. An integrated nutrient management method, in which organic and inorganic fertilisers are administered in the appropriate amounts, is yet another alternative that has been shown to be successful. Synergy in terms of crop yields is achieved via the use of this technique, which helps to harness the processes that are responsible for the impacts of organic fertiliser application on soil and plants.

1.4.Role of organic fertiliser in climatically smart agriculture

During times when climate change is imminent and its impact on agriculture is likely to undermine food security, it is of the highest significance that farmers and other stakeholders make use of methods and resources that are capable of adapting agricultural systems to the changing environment. This is because it increases the likelihood that food security will be compromised. According to Agrimonti et al. (2021), greenhouse gases, which include carbon dioxide, methane, and nitrogen dioxide, are released into the atmosphere as a consequence of both natural and human activity. It is these activities that are the key contributors to the shift in climate. According to Aryal et al.'s research from 2020, it is likely that it might lead to substantial droughts or catastrophic floods, both of which have the potential to have a devastating impact on agriculture and food supply. Under these circumstances, organic fertilisers are an excellent option because of the replenishing effects that they have on the chemical and physical qualities of the soil. Aside from the advantages of organic fertilisers, which were addressed before and have the potential to adapt the soil to drought conditions, soils in places that are prone to flooding should be well-drained and loose in order to prepare for the effects of climate change. The use of organic fertilisers would increase the aggregation and structure of soil particles in soils that are compact and have poor drainage. This would allow the soil to have more space for water to penetrate without allowing it to remain on the surface for an excessive amount of time, which might lead to flooding. Through the incorporation of organic matter, the amount of greenhouse gases that are released into the atmosphere as a result of agricultural practices is decreased (Bhattacharyya et al., 2020). The use of organic fertilisers results in the sequestration of carbon into the soil, which allows for this to be accomplished. In the absence of the carbon being integrated into the soil, it would have been released into the atmosphere as either carbon dioxide or carbon monoxide (Zougmoré et al., 2020). Therefore, the application of organic fertilisers to the soil helps to decrease greenhouse gas emissions, which in turn leads to global warming and, as a consequence, climate change. Additionally, the application of organic fertilisers helps the soil adapt to changes in the climate that are occurring now and will occur in the future (Mazhar et al., 2020).

1.5.Qualities that make an organic fertiliser a good choice

It is challenging to provide a general recommendation for an organic material due to the fact that organic materials come in a wide variety of types and include a wide variety of various nutrients. In the event that organic material is applied, the lignin, polyphenol, and nitrogen concentrations of the material are significant restrictions on the mineralization of its nutrients. In order to assess whether the application of an organic material would result in the mineralization or immobilisation of nitrogen, it is essential to conduct an analysis of the carbon to nitrogen ratio of the biological material. If the C:N ratio was 25 or higher, it would be beneficial for soil microorganisms to decompose and mineralize the soil, whereas a C:N ratio that was more than that would be beneficial for immobilizing nitrogen. Therefore, the ratio of carbon to nitrogen will be lower, which means that nutrients will be made accessible to the soil more quickly. Typically, organic materials that include a high percentage of lignin (more than 15%) and polyphenol (greater than 5%) have high carbon-to-nitrogen ratios and are resistant to microbial breakdown; as a result, they disintegrate slowly. To a greater extent, the substance would degrade and mineralize more quickly if it included a nitrogen level of 2.5% or more.

1.6.Techniques for applying organic fertilisers in order to get all of their benefits

When it comes to fertiliser, the manner in which an organic substance is administered is another factor that determines how effective it is. The application of organic fertiliser to the surface increases the loss of nitrogen by ammonia volatilization, as well as the loss of nitrogen and phosphorus through runoff and erosion. The band spreading approach, the trailing hose method, the burying method, the quick soil integration method, and the inclusion of nitrogen inhibitors are all examples of ways that may be used to apply organic materials in a responsible manner in order to prevent waste and nutritional losses.

The application of slurries or liquid organic fertilisers might be carried out in these narrow bands by use of trailing hoses that are suspended from a boom and run along or just above the surface of the soil. It is also possible to bury organic amendments at a depth of around 5 to 30 centimeters, depending on the establishment of the crop. It is possible to practice burying at a deeper depth before crops are grown, but burying at a shorter depth is more appropriate for agricultural fields that have already been developed. The loss of nitrogen via ammonia volatilization and the loss of material through erosion were both significantly brought down by this approach. In order to lessen the amount of nitrogen and phosphorus that are lost due to volatilization and runoff, manure might be quickly integrated into the soil by the use of hand instruments or through soil tillage (prior to planting). In situations where there is a strong possibility for denitrification, nitrification inhibitors might be added to organic fertilisers in order to slow down the pace at which ammonium is transformed into nitrates. Nitrates are an appropriate substrate that serves as a precursor to the denitrification process. In order to minimize the amount of nutrients that are lost, it is essential to apply organic fertilisers at the appropriate rates and during the cooler periods of the day.

2. Conclusion

Low-carbon-to-nitrogen organic fertilisers provide macronutrients and micronutrients to the soil. In addition to delivering nutrients, they increase soil structure, texture, water retention, and nutrient retention. Organic fertilisers may affect crop yields and soil quality via nutrient synchrony, fertility, and priming. Additional mechanisms may be implicated. The rate, timing, and method of organic fertiliser application must be considered to minimize nitrogen and phosphorus loss. To meet crop nutritional needs, organic fertilisers must be used in large numbers, hence local resources are best. A rain-fed case study found that manure retains nutrients longer than solo organic, solitary inorganic, and their mixtures. This finding is promising for drought-prone areas.

3. Conflict of interest

Authors declared no conflict of interest each other.

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5. Contributions

All the authors contributed equally in the current manuscript.

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