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Nano-Nutrients for Carbon Sequestration: A Short Communication

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Abstract

Global food production mainly depends upon the productive outcomes of the agricultural sector. Soils are the pool of nutrients required for plant growth. These nutrients directly enhance the crop yields and immune against the multiple biotic and abiotic stresses. These nutrient elements also supplement human food with these elements. It is a well-established fact that balanced nutrition results in the healthy growth of plants which can combat different stresses. Conservation agriculture is the key sustainable measure for increasing food security, alleviating poverty, biodiversity conservation, and safeguarding ecosystem services. Nano-fertilizers are also eco-friendly sources by maintaining a balance of C sequestration and N emissions in the environment. Nano- fertilizers, because of their unique properties, are now a promising approach to enhance soil, fertility, enhance plant growth, and improve soil C sequestration.

Keywords: Climate change; Nano-management; Conservation agriculture; Smart agriculture; Carbon sequestration

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1. Soil carbon sequestration and its potential

Carbon is the main element for producing the organic matter beside hydrogen and oxygen, which is the basic unit for any living organisms. Cultivated plants can catch carbon from atmospheric air through the photosynthesis process in the form of CO_2. This gas also can be produced by the respiration of living things and the decomposition of plants residues as

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well as the soil fauna and microbes. Soil organic carbon or soil organic matter (SOM), which resulted from any source of organic materials, is the main key component in soil controlling several properties of soil (i.e., physical, chemical, and biological properties). Several benefits of SOM have been reported long yearsago including soil quality improving, which leads to increase the crop productivity due to increased retention of water and nutrients (Ontl and Schulte 2012). The role of SOM is very clear under different climatic zones as presented in Fig. 1 (for the temperate climate in Germany) and Fig. 2 (for the arid climate in Egypt).

Due to continued increase in CO_2 and other greenhouse gases (GHGs) like N_2O, and CH_4, which result from human activities, the earth's climate is rapidly changing (Raza et al. 2021). Atmospheric CO_2 concentrations have risen from nearly 280 parts per million (ppm) prior to 1850, to 410.5 ppm in 2019, to 413.2 ppm in 2020 (WMO 2021). Therefore, soil C-sequestration is a process in which CO_2 is removed from the atmosphere and stored in the soil carbon pool (Ontl and Schulte 2012, Elbasiouny and Elbehiry, 2020a).

As reported by many researchers, organic C-sequestration in soil could be enhanced by the chemical, physicochemical and biological protection to SOC through recalcitrance of SOC, facilitating the organo-mineral interaction, and protecting SOC from microbes andmicrobial decomposition, respectively(Barré et al. 2014; Pramanik et al. 2020). The main recommended management practices for enhancing the C-sequestration include conservation agriculture (Lal 2015; Jayaraman and Dalal 2021; Ranjan et al. 2021), conservation tillage (Jayaraman et al. 2021), agroforestry (Hübner et al. 2021), adoption of diversified cropping systems (Ngangom et al. 2020), integrated nutrient management (Ghimire et al. 2017; Gogoi et al. 2021a, b), mulching (Ngangom et al. 2020), improved grazing (Sarkar et al. 2020; Mattila et al. 2022), and forest management (Pramanik et al. 2020; Ameray et al. 2021). Many approaches for managing soil C-sequestration could be found in Table 1.

2. Nano-nutrients and climate changes

The Cultivated plants need in their growth certain nutrients, which they should be available for plant uptake by their roots. Plant nutrients are essential for increased crop productivity and food supply to sufficient levels (Daniyan et al. 2017). To gain the proper amount of these nutrients by cultivated plants, soil fertility and its quality should to be sustained by improving soil physical and chemical characteristics (Li et al. 2017). For getting higher crop productivity, cultivated plants may need exogenous applying nutrients by mineral fertilization process, which it may cause environmental pollution (Abdulhameed et al. 2021). Nano-nutrients are considered a sustainable solution and alternatives can substitutethese (traditional) mineral fertilizers, which have high use efficiency and eco-friendly source for nutrients (El-Ramady et al. 2021a).These nano-nutrients have also the ability to increase ~~these~~ nutrients bioavailability and bioactivity because of their greater surface area, more reactivity, better nutrient solubility, reducing fertilizer nutrient loss rate, reducing adsorption and fixation, and extending the duration of nutrient release in soil (Kalia and Kaur 2019). These (there are forms of) nano-nutrientscould apply to cultivated plants in many formslike nano-enabled fertilizers, nano-based release nutrients, nano-chelated silicon fertilizers, nano-porous materials, nano-scale additive fertilizers, and nano-scale coating fertilizers (Guo et al. 2018; Basavegowda and Baek 2021).

Climate change is a global problem, which may include extreme weather events, rising in temperatures, flooding, changing in precipitation patterns, droughts, extreme heat stress, and sea level rise (Elbasiouny and Elbehiry, 2020b, El-Ramady et al. 2021b). Climate and its elemental factors (temperature, precipitation, pressure, wind, etc.) totally control the growth and production of crops beside the essential nutrients. It is found that the nutrient availability can impact on the physiological response to increased CO_2 and temperature (Liu et al. 2020). The using of nano-nutrients in enriching cultivated crops has a promising progress like nano-Cu, nano-Fe, nano-Se, and others. Recently, several publications have been issued concerning the impacts of changing in climate on the nutrition of cultivated plants like Liu et al. (2020), Krüger et al. (2021), Kumar et al. (2022), but a few on the plant nano-nutrition like El-Ramady et al. (2018), Sharma et al. (2019), Mishra and Khare (2021), Mahapatra et al. (2022), which confirmed that there is a need for the technology of nano-agro-nutrients. Climate change can mainly affect plant nutrition, which in turn will impact food security through basically of elevated [CO_2] and higher temperatures on cultivated plants (Leisner 2020), as well as the influence of climate change on plant-herbivore interactions (Kuczyk et al. 2021; Zytynska 2021). Climate change may lead to the nutritional imbalance in cultivated plants under rising atmospheric CO_2 (Kundu et al. 2022), so there is a need for producing crops in the future, which have a climate-resilient plant immune system (Kim et al. 2021).

TABLE 1. Recent published literatures about management approaches for soil C-sequestration

The country	Main title of the study	Reference
Global	Responses of soil organic carbon to conservation practices including climate-smart agriculture as well as cover crop, conservation tillage, and biochar application in tropical and subtropical regions	Das et al. (2022)
China	Apple wood derived biochar promotes soil organic C-sequestration and reduces net global warming potential in apple orchard	Han et al. (2022)
Canada	Impacts of climate changes through sequestration of C in soils, from agricultural management practices (moving from conventional tillage to no-till, eliminating summer fallow in crop rotations, and growing crops with higher albedos) in the Canadian Prairies	Liu et al. (2022)
Ireland	Tillage management during pasture renewal as a strategy for enhanced C-sequestration and storage in Irish grassland soils	Madigan et al. (2022)
Finland	Different approach for soil carbon sequestration as a survey on 105 carbon-farming plans	Mattila et al. (2022)
Global	Soil nitrogen and climate drive the positive effect of biological soil crusts (Mosses, lichens, and algae crusts) on soil organic C-sequestration in drylands	Xu et al. (2022)
Australia	Future climate impacts of reforestation on forest growth and implications for C-sequestration and the need for CO_2 fertilization	Wang et al. (2022)
China	Impacts of long-term soil surface mulching on soil organic C-fractions and the carbon management index in a semiarid agroecosystem	Zhang et al. (2022)
India	Enhancing soil ecosystem services by sustainable integrated nutrient management under the wetland cultivation of rice-cropping system	Gogoi et al. (2021b)
Global	Soil organic C-sequestration rates in vineyard agroecosystems under different soil management practices including biochar amendments, returning pruning residues to the soil, organic amendments, no-tillage, cover cropping, and their combinations	Payen et al. (2021a)
Western European	Predicting the abatement rates of soil organic C-sequestration management in vineyards using cover cropping, organic amendments, and no-tillage treatments and their combinations	Payen et al. (2021b)
Global	Different strategies for reducing inorganic C-losses under soil acidification and it impacts on C-sequestration and climate change mitigation by using of manure, biochar, and crop residues	Raza et al. (2021)
China	Land planting systems (daylily, peanuts, oil tea planting with bare floor or inter-row coverage of straw, white clover or peanuts) and its management of soil C-sequestration and sloping croplands	Tao et al. (2021)
China	Extensive management system on soil C- sequestration under bamboo plantations in China including fertilizer application, understory removal, and deep tillage	Yang et al. (2021)

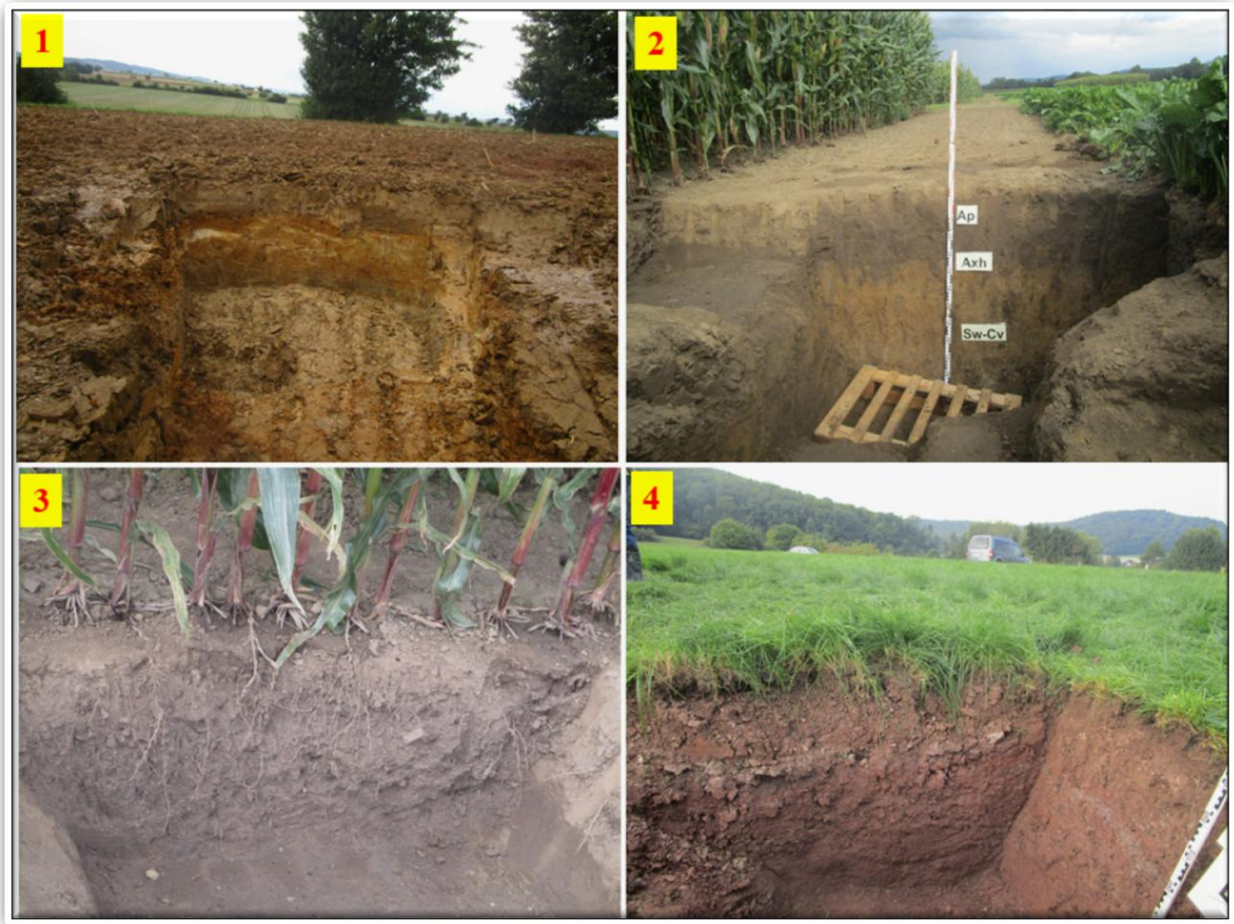

Fig. 1. Four different soil profiles from Göttingen in Germany were presented during the Annual Meeting of the German Society of soil Science, which hold during September 2017. The impact of soil organic matter including the plant roots could be distinguished in all soil profiles. All photos by El-Ramady

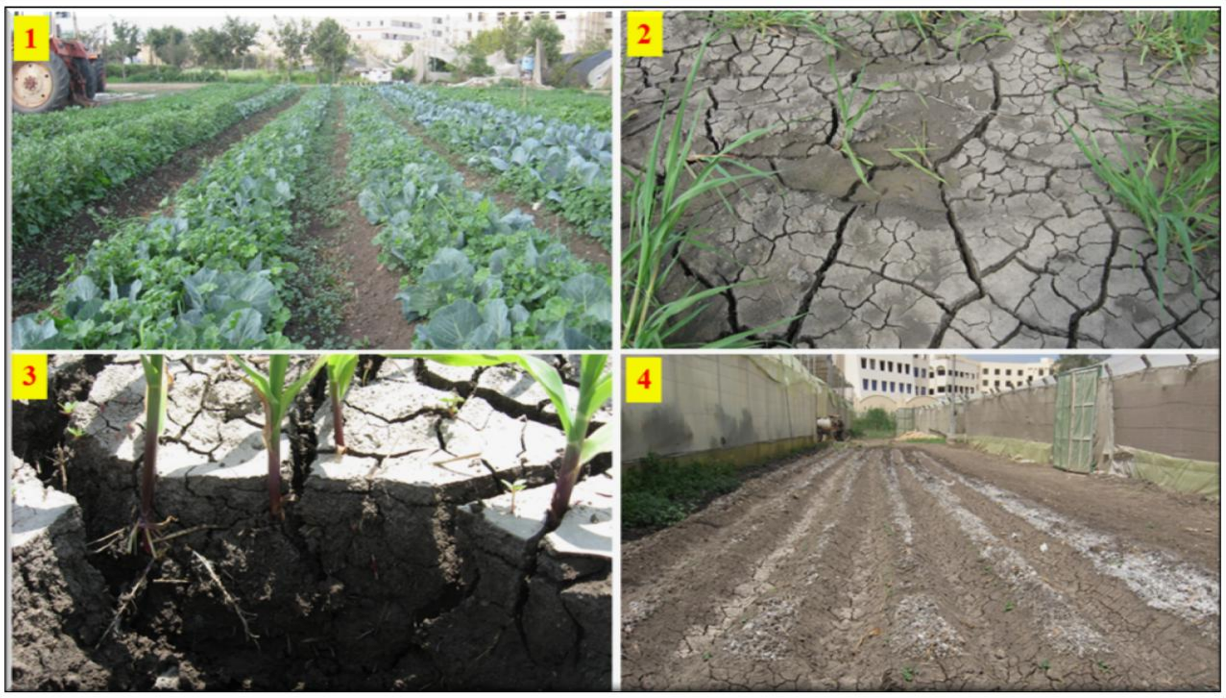

Fig. 2. Different photos for some cultivated soils from the farm of Kafr El-Sheikh University in Egypt, which represent the good cultivated soil with some vegetables (Photo 1), uncultivated alkaline soil, which the accumulation of salts on the surface of soil due to high temperature (Photos 2 and 4), for the arid climate in Egypt. and the effects of high temperature during August (around 50 °C) on cultivated maize in heavy clay alkaline soil (Photo 4). All photos by El-Ramady during summer of 2015

3. Nano-nutrients for C-sequestration in agricultural soils

Modern innovations like nano-enhanced products (such as nano-fertilizers and nano-pesticides) with a nano-based smart delivery method providing nutrientat the target sites, time, and rate to improveproductivity can be used to use state-of-the-art in understanding the processes leading to SOC sequestration (Jinus et al., 2021). Nanotechnology has a greatpotential for improving terrestrial C pools for better soil health and a cleaner environment. Because of their distinct characteristics, nanomaterials (NMs) have been shown to improve C stabilization and itspossible soil sequestration. Soil C is influenced by a wide range of edaphic, environmental, and management factors, the most important of which are soil aggregation and structure (Pramanik et al., 2020). Mani and Mondal (2026) reported that the nanoparticles (NPs) have a proclivity to aggregate and interact with organic colloids (such as dissolved organic matter (DOM), humic materials, polysaccharides, and peptidoglycan), and it is thought that NPs, due to their high surface-to-volume ratios, might be extremely successful in Csequestration. TheNPs are the most significant adsorbents in soil, and they can regulate nutrients transport, control OM fixation, and stimulate thenew mineral phase's precipitation. (Reword) The NPsin situ ~~in~~ intact soil structures areof critical importance in the future.

In addition, NPs have direct impacts on plants, such as enhanced the activity of plant enzyme, improvedseed germination, higher plant tolerance to negative circumstances, enhanced C sequestration and Nfixation, and enhanced photosynthetic and respiratory activities. As a result, the plant biomass and nutritional condition are greatly improved, resulting in higher crop returns (Kalia and Kaur et al., 2019). In this context, biochar is known that it can retain C for a longer time compared to organic waste due to its higher stable structure, and long-term stability, thus, GHGs emission is decreased during manufacturing and after soil application. Biochar application is C sequestration approach (Elbasiouny et al., 2021). Recently, nano-biochar is also a promising approach in this context, it is a more enhanced biochar where it can absorb nutrients and enhance soil fertility, thus C sequestration and green and sustainable agriculture (Khan et al., 2021).

Conflicts of interest

This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication

All authors declare their consent for publication.

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Conflicts of Interest

The author declares no conflict of interest.

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