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Soil Microbial Indices Contributing to Soil Carbon Sequestration

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Soil is a sensitive and living resource that only produces approximately 10 cm of fertile soil in 2000 years (IASS Vimeo Channel. Let's Talk about Soil. 2013. Agricultural sustainability, environmental quality and ultimately, plant, animal and human health, are determined by soil quality. Soil quality can be described as the integration of the physical, chemical and biological properties of the soil for productivity and environmental quality. The numbers, types, and activities of soil microorganisms are important to the productivity of soil through their regulatory effect on soil carbon (C) and nitrogen (N) levels. Soil microorganisms play integral roles in nutrient cycling, soil stabilization, and organic matter decomposition. As such, soil microbiological and biochemical properties must be taken into account in soil resource inventories to properly manage agricultural systems. Microbial and biochemical soil properties are the early and sensitive indicators of changes in soil quality as they manifest themselves over shorter timescales and are central to the ecological function of a soil. Soil enzyme activities in particular are increasingly used as indicators of soil quality because of their relationship to decomposition and nutrient cycling, ease of measurement, and rapid response to changes in soil management.

Soil organic carbon fractions (organic carbon, soluble carbon and microbial carbon (C_{mic})) originates from long term accumulation of plant residues, their photosynthates released as root exudates, microbial byproducts and their senescent biomass etc. These various C fractions play a key role in the structure formation and stabilization of soil. In addition, due to their vital role played in the plant nutrient availability /mobilization, it is an important indicator of soil quality and health and a valid biomarker to indicate changes in total microbial activity due to changes in soil management, under different agronomic practices and climates. Input of external C sources like crop residues influences soil C.

With increasing global interest in climate change, there has been increasing interest in the potential for carbon (C) sequestration in agricultural soil. Soil is not only the basis of crop production but is also the key facilitator of C sequestration in terrestrial ecosystems. As the largest C pool in the terrestrial ecosystem, soil has high ecological value. The accumulation of SOC is considered to be the best choice for long-term C sequestration in the terrestrial ecosystem. Reducing CO_2 concentration to mitigate global climate change by carbon (C) sequestration has been a promising method (Zhu LQ et al., 2015). Considerable attention has been given to the dynamics of soil organic C (SOC) stocks and its function in long-term C accumulation and sequestration of atmospheric CO_2 for mitigating climate change, maintaining crop productivity sustainability, and increasing soil fertility. Once a soil ecosystem is destroyed, the rate of decomposition of organic carbon in the soil will be accelerated, greenhouse gas emissions will increase, and the greenhouse effect will be intensified, resulting in global warming (Zhu et al., 2016; Forte et al., 2017; Krauss et al., 2017).

Soil organic matter (OM) has important effects not only on soil enzymes activities but first of all on microorganism's activities. Soil OM has been considered as an indicator of soil quality (similarly like dehydrogenases,) because of its character of nutrient sink and source that can enhance soil physical and chemical properties, and also promote biological activity (Salazar et al., 2011). It is evident that soil enzymatic activity is strongly connected with soil OM content. The higher OM level can provide enough substrate to support higher microbial biomass, hence higher enzyme production. The soluble C fraction is an important pool with respect to soil organic matter turnover in agricultural soils, since it acts as a readily-decomposable substrate for soil microorganisms and as a short-term reservoir of plant nutrients (Gregorich et al., 1994). It has been suggested that the biomass C/TOC ratio reflects the potential for soil's organic matter mineralization after the addition of organic materials (Pascual et al., 1997).

Soil respiration is the CO_2 emission process and is the C flux between the atmosphere and terrestrial ecosystem; furthermore, cropland soil respiration (Rs) also plays an important role in CO_2 transportation. Soil respiration is one type of enzymatic reaction and, within a certain temperature range, there is higher temperature and higher enzymatic activity and vice versa. Approximately 85% to 90% of SOC was decomposed by soil bacteria and soil fungi. The degradation of soil organic matter by microbial activities, by the process of respiration causes a release of CO_2. Thus, soil respiration reflects the total potential of microbial activity and is considered a reliable bio-indicator of soil quality. The high soil basal respiration is a function of the contents of soil organic matter and nutrients, which enhance the microbial activity (Emmerling et al., 2000), and better microbial biomass cycling. The potential soil metabolic capacity of the microbial community was determined by microbial respiration and selected enzyme activities. Basal and substrate induced respiration (SIR) are valid indicators of general soil microbial activity and active microbial biomass (Michelsen et al., 2004).

Soil microbial biomasses influence the conversion of SOM, and are critical for the cycle of nutrients and energy in the ecosystem. Therefore, studying MBC and MBN is of great significance to explicit soil nutrient flow, soil C cycle, and the balance of soil C pools. The MBC and MBC/SOC ratio can provide an early effective warning of the deterioration of soil quality. Especially, the ratio of MBC/MBN could reliably indicate the tendency of SOC variation. The soil organic carbon (SOC) is linked to soil microbial biomass carbon (SMBC), while soil microbial biomass nitrogen (MBN) is related with mineralization of soil nitrogen (N). The soil microbial biomass nitrogen (MBN) is more sensitive to variations in soil microorganisms relative to total organic nitrogen.

Microbial enzymes are involved in soil nutrient cycling, and are used to evaluate soil quality. Among soil microbes, fungi are critical components in the soil system and are regarded as the primary decomposers in soils, as they secrete various enzymes that break down lignocelluloses. Plenty of data reported on fungal communities in different natural soil habitats (Marin et al., 2017), but less is so far known about fungal communities in agricultural soils.

Dehydrogenases play a significant role in the biological oxidation of soil organic matter (OM) by transferring hydrogen from organic substrates to inorganic acceptors. Thus, DHA serves as an indicator of the microbiological redox-systems and could be considered a good and adequate measure of microbial oxidative activities in soil. Therefore, DHA reflects metabolic ability of the soil and its activity is considered to be proportional to the biomass of the microorganisms in soil. The amount of microbial biomass in soil affects the amount of enzymes in soil, which in turn affects the decomposition rates of the respective components of soil organic substances including the components of microbial bodies. Most organic components of soil are decomposed into inorganic substances due to the action of soil enzymes mainly secreted by microorganisms. The dehydrogenase enzyme (DHA) activity indicates soil biological activity, which is attributed to intact live cells. Soil organic matter oxidation in microbial respiration is mediated by dehydrogenase due to the transfer of protons and electrons from substrates to acceptor. It is significantly influenced by availability of organic matter, soil temperature and soil moisture. The increased DHA are reported in conservation agriculture with legume crops in rotation than CT. Unlike other enzymes which can occur in an extracellular state, dehydrogenases only occur within living cells, and are considered one of promising indicators of microbial activity. However, numerous soil factors including organic C, soil pH, N fertilizer, crop management and soil texture affect microbial activity.

Depth of the soil profile is one of the most known and popular environmental factors reducing soil enzyme level. The highest microorganisms abundance is in the surface layer of the soil profile (till to the depth of 30 cm), at the deepest part of the soil, the number of microbial cells is limited, and consequently also DHA level displays a diminishing trend. Generally it is possible to state, that both diversity, abundance as distribution of microorganisms are more even under oxic (surface layers) conditions, relative to anoxic (deeper layers) conditions (Fierer et al., 2003).

AM fungi are root symbionts present in many terrestrial ecosystems and are known to form beneficial associations with nearly all agricultural crops, though symbiotic associations, especially in high phosphorus or high nitrogen environments. AM fungi can provide benefits to crop plants through multiple mechanisms including pathogen resistance and nutrient acquisition. AM fungi can also increase soil ecosystem function. Following colonization of the crop root, AM fungi typically create an extensive extra-radical hyphal (ERH) network to explore the soil and transfer nutrients. Both AM fungus spore and ERH cell walls contain a recalcitrant soil glycoprotein known as glomalin, which may contribute 4–8% of soil organic carbon in natural ecosystems and 2–4% of soil organic carbon in agricultural systems, and also contributes to formation of water stable soil aggregates (Piotrowski et al., 2004).

Referances

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