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Effect of Nutrient Management Regimes on Soil Biological Properties - A Review

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Abstract

Soil quality assessment is very important aspect in determining long term sustainability; however it is governed by different physico-chemical and bio-chemical parameters. These are interrelated among them and controlled by different management practices like tillage, water, organic and inorganic source of nutrients etc. Among the different soil parameters, it was considered that soil biochemical parameters provide rapid and accurate estimates on soil quality and its evaluation require understanding of biochemical and microbiological soil properties. Among the several biochemical and microbiological properties, soil organic carbon fractions, microbial biomass and soil enzymes activities may be considered as an important property which governed soil health or quality. Soil organic carbon fractions includes total organic carbon, soil organic carbon (oxidizable carbon), labile carbon etc., microbial biomass and enzymes activities include content of microbial biomass carbon, nitrogen, phosphorus and activities of different enzymes like dehydrogenase, acid and alkaline phosphatase, Urease, β-glucosidase, Aryl sulphatase etc. It is established and proved that, nutrient management practices (application of fertilizers and manures) marked significant effect on SOC fractions and soil enzymes activities. In most of cases, the application of organic sources of nutrients as well as integrated nutrient management resulted in significant improvement in the soil biochemical properties, however, microbial properties like microbial biomass carbon, nitrogen, phosphorus and enzymes activities are very sensitive to nutrient management options compared to soil organic carbon fractions.

1. Introduction

Under different management practices, soil organic carbon fractions, microbial biomass and soil enzymes activities may be taken as useful indicators/ parameters for soil quality/ health assessment. Soil biochemical properties provide rapid and accurate estimates on changes in soil quality and valid evaluation of soil quality requires better understanding of key biochemical and microbiological soil properties which depend on different soil management practices (Dinesh *et al.*, 2004). Soil management practices include tillage and water management, fertilizer application, application of manures, use of different agrochemicals etc. Hence, a brief review of the work related to the effect of nutrient management regimes on soil biochemical properties is described here.

2. Soil Organic Carbon Fractions

2.1 Total Organic Carbon (TOC)

Increasing concern about rise in temperature and global climate change, which is mainly caused by increasing atmospheric concentration of greenhouse gases, particularly CO_2, have enhanced the interest to know about organic carbon and soil carbon sequestration as a potential way to offset anthropogenic CO_2 emissions (Lenka and Lal, 2013). Strategies for increasing the SOC content and its pool are needed not only to mitigate CO_2 emissions but also to improve soil quality / health for economic and sustainable crop production (Kahlon *et al*., 2013). Management practices that supports greater amount of crop residue to be returned/ retained to the soil are expected to cause a net buildup of SOC stock (Kaur *et al*., 2008; Majumder *et al*., 2008). Soil sustainability can be measured by measuring changes in the lability of SOC because of its close association with the biologically active pool, which helps in short-term nutrient cycling (Mtambanengwe and Mapfumo, 2008). Depletion of SOC has a negative effect on soil properties

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which results in reduction of soil quality as well as crop yield (Pavan *et al*., 1985).

Total organic carbon (TOC) is composed of several fractions, some are more labile and readily lost from the soil and some are less labile and recalcitrant (Mandal *et al*., 2008). These consist of a large number of organic compounds which are broadly classified into different pools such as very labile pool, less labile pool, intermediate pool, recalcitrant and passive pool. The labile pool mainly comprises microbial biomass carbon, while the intermediate pool consists of plant and animal remains at different stages of decomposition and humification process. The passive pool is a complex material (humus) which is resistant to decomposition as it is associated with clay matrix. The relative proportion of these various fractions determines the quality of soil and its susceptibility to rapid mineralization and loss and is, therefore, a critical determinant of soil carbon dynamics (Ghosh *et al*., 2010). Soil management not only affects the TOC content but also the fractions of soil organic carbon and its proportions (Mandal *et al*., 2008).

A study carried out on the Guadalquivir River Valley (SW Spain) (silty loam soil) reported a higher content of TOC under organic fertilization as compared to conventional fertilization (Melero *et al*., 2006). Long term fertility experiments conducted in Barrackpur, Mohanpur, and Cuttack, showed that TOC content was largest in NPK + FYM (207 Mg ha^{-1}) and lowest in conventional cultivation (148 Mg ha^{-1}) with intermediate values in fallow (168 Mg ha^{-1}) and NPK treatments (164 Mg ha^{-1}) (Ghosh *et al*., 2010). In another study, it was observed that 100% organic sources of N could maintain higher TOC except in case of *Sesbania*, where it was at par with control (Verma *et al*., 2011). In a study on the effect of 40 years of farmyard manure, mineral and mixed fertilizations in a Fluvi-calcaric Cambisol from north-eastern Italy, Nardi *et al*. (2004) reported a larger influence of the organic treatment alone on total organic carbon than mineral fertilizer alone or mixed with farmyard manure. Long-term field experiment conducted at Indian Agricultural Research Institute Farm, New Delhi, indicated that greatest accumulation of total organic C was observed with 100% NPK + FYM treatment. Total organic C content in entire 0–45 cm soil profile followed the order: 150% NPK + FYM > 150% NPK > 100% NPK > 100% NP = 100% N = 50% NPK > control (Rudrappa *et al.,* 2006).

2.2 Soil Organic Carbon (SOC)

Soil organic carbon constitutes a fraction of TOC and is used for different soil fertility evaluation and recommendation. In most of the cases, the measurement and estimation of TOC is not done due to several reasons such as lack of instrument facility, lack of man power, etc. On routine basis, soil organic carbon content is measured by wet oxidation method of Walkley and Black (1934) (soil carbon is oxidized by a strong oxidizing agent in an acidic medium), which reflects a portion of TOC in the soil. Verma *et al*. (2013, 2014) also reported that proportion of SOC to TOC varied from 10.2–47.4 % and 25–38 % in different organic systems and nutrient management practices.

SOC content is highly dependent on changes in management practices. Banerjee *et al*. (2006) reported that crop productivity and root growth and biomass production in the fertilized as well as organically amended plots contributed to larger SOC, however, the largest SOC content was observed in soil amended with FYM in the puddled rice plots followed by green manures. In another experiment, integrated use of farmyard manure (100% NPK + FYM) evolved as the most efficient management system for accumulating larger amount of soil organic carbon (72.1 Mg ha^{-1}) (Rudrappa *et al.,* 2006). Long-term (1984-2007) field experiment concluded at the Changwu Ecological Station in China indicated that combined use of organic and inorganic fertilizers increased soil quality and SOC accumulation (Yi *et al*., 2009). It was found that there was progressive increase in SOC even after 150 years of manure application at the rate of 35 Mg ha^{-1} per year in the long-term experiments at Rothamsted, UK (Powlson *et al*., 1998). Bastia *et al*. (2013) reported that in three years of experiment, organic nutrient management options alone increased the SOC over that of the control in 0-15 cm and 15-30 cm soil depths which may be due to balanced organic nutrition and greater C input. Ortas and Lal (2014) also reported that the concentration of SOC was significantly high in plots receiving organic fertilizers than those getting inorganic fertilizers and the control due to the increased inputs of organic residues and high biomass production.

2.3 Soil Microbial Biomass

The microbial biomass accounts for only 1-3 % of soil organic carbon but it is the very important pools that govern the soil carbon dynamics (Jenkin, 1977). The soil microbial biomass plays a key role in the cycling and transforming process of carbon, nitrogen, phosphorus and sulphur etc., however, it also serves as the most important ‘‘warehouse’’ and ‘‘source’’ of these nutrient elements (Xu *et al*., 2008). Measurement of soil microbial biomass is very useful and important in soil organic matter dynamics and nutrient cycling studies. As the microbial biomass is one of the key definable fractions, measurements of its carbon (C), nitrogen (N), phosphorus (P), and sulfur (S) provide a basis for studies of soil organic matter formation and turnover (Brookes *et al*., 1990).

2.3.1 Soil Microbial Biomass Carbon (SMBC)

Soil microbial biomass carbon (SMBC), which is the living and the most active part of SOC, has been suggested as a useful indicator for measuring changes in the SOC status even under short-term study (Verma *et al*., 2010). The microbial biomass consider as a small but labile reservoir of nutrients that helps in maintaining long-term agricultural sustainability (Melero *et al*., 2006). Soil microbial biomass carbon being regarded as the most active part of soil organic matters because it acts as the active warehouse or source and sink for soil nutrient transformation. It can also show the effective status of soil nutrients and the change of biological activity when the soil is affected by the external factors.(Xu *et al*., 2008). Changes in microbial biomass carbon can provide an early indication of short-term trends in total organic carbon of soils (Bergstrom *et al*., 1998) because of its comparatively rapid rate of turnover of 1-2 years. SMBC is fundamental in maintaining soil functions because it represents the main source of soil enzymes which regulates soil nutrient transformation process. It also controls the synthesis and breakdown of soil organic matter (Landgraf and Klose, 2002), the decomposition of organic residues, and is an early indicator of changes in soil management (Schinner *et al*., 1991) and of fertilizer practices (Kandeler *et al*., 1999).

Use of organic amendments and reduced tillage can play important role in increasing SOC and SMBC compared to conventional tillage without affecting crop yields (Tullberg *et al*., 2001). Melero *et al*. (2006) reported that SMBC was higher in organic plots than in conventional plots in a silty loam soil located in the Guadalquivir River Valley (SW Spain) due to greater supply of available C. Organic amendments such as FYM and green manures were superior to fertilizers and crop residue for enhancing SMBC and the effects are more pronounced in puddled soil as compared to non-puddled one (Banerjee *et al*., 2006). A study conducted in China showed that continuous tea plantation for many years resulted in relatively low soil fertility in acid soil, thereby, lowering SMBC, however, with the application of organic materials (straw mulching, organic manure, intercropping white clover) and fertilizers, the soil fertility was improved consequently increasing microbial growth and metabolism and adjusting soil C: N ratio (Xu *et al*., 2008). Wang *et al*. (2006) found that SMBC mainly ranged from 100 mg kg^{-1} to 500 mg kg^{-1} in subtropical red soil, hilly forest and drought land. In the agricultural soils, Verma *et al*. (2013) also reported that SMBC ranged from 105–998 mg kg^{-1} (mean of 384 mg kg^{-1}).

2.3.2 Soil Microbial Biomass Nitrogen (SMBN)

Application of nitrogenous fertilizers had a positive impact on soil microbial biomass because it helps in increasing crop yield, and subsequently through post-harvest residues helps in buildup of organic N and C into the soil (Coote and Ramsey, 1983). A study conducted under the long-term experiment with silage maize in Prague reported that SMBN ranged from 4.6 to 18.4 mg N kg^{-1} of soil (Černý *et al*., 2003). The highest content of SMBN was observed for manure application as compared to the control. Ocio *et al*. (1991), found 18% higher microbial biomass N compared to control in treatments with straw ploughing even in one year of application. In an investigation carried out by Basak *et al*. (2013), it was observed that application of value added manures alone significantly increased the SMBN in soil (highest being 62.8 mg kg^{-1} in treatment with vermicompost in case of maize and 70.1 mg kg^{-1} in wheat) over control (42.0 mg kg^{-1} and 44.1 mg kg^{-1} in maize and wheat respectively), but the value was lower in plots receiving combined application of manures and 50% NPK. It was reported that the value of the SMBN in soil under treatment receiving 100% RDF also increased significantly over control. Soils amended with organic manures improved the organic C in the soil, which could stimulate the microbial growth and activity and also influence SMBN (Manjaiah and Singh, 2001).

2.3.3 Soil Microbial Biomass Phosphorus (SMBP)

Soil microbial biomass phosphorus (SMBP) is a source of bioavailable P to terrestrial ecosystems (Sparling *et al*., 1985) and the turnover of SMBP is largely governed by the short life span of microorganisms (Sun *et al*., 2013). Therefore, SMBP is one of the active components in soils (George *et al*., 2006) and is an important source of bioavailable P in ecosystems (Chen *et al*., 2000).

Application of organic amendments (FYM and poultry litter) significantly increased microbial biomass P concentrations (96-220 %) compared to the unamended soil in Qutbal and Balkassar with a greater increase with poultry litter which might be due to its higher TOC concentration (Malik *et al*., 2013). SMBP content varied with the sampling points also and it was reported that SMBP varied from 10.9 to 19.4 µg g^{-1} under tree canopy and from 4.6 to 11 µg g^{-1} between the rows (Balota and Auler, 2011). They further indicated that SMBP was also increased due to increase in soil P content. Similar observation was also reported by Conte *et al*. (2002). The increase in SMBP may be due to simultaneous addition of phosphatic fertilizer and carbon addition from the previous groundcover residues (Conte *et al*., 2002). A significant relationship between pH and SMBP occurred in the six vegetation zones on the eastern slope of Gongga Mountain, Tibet, which suggested that low pH values resulted in greater SMBP (Sun *et al*., 2013). Some studies have confirmed that microbes can produce acids that decrease pH and release P from rocks (Rodriguez *et al*., 2004; Sharma *et al*., 2005).

2.4 Glomalin Content in Soil

Soil management as well as tillage operation, besides affecting soil physico-chemical properties and soil structure, also reduces biological activity due to the breakdown of macro aggregates which provide an important microhabitat for microbes (Dick, 1992). Soil organic carbon plays an important role in aggregation (Kemper and Rosenau, 1986). Relatively labile carbon is protected in soil aggregates (Jastrow and Miller, 1997; Six *et al*., 1998). The SOM is physically protected from microbial decomposition under the aggregates may be partially responsible for the increase its content with reduced tillage (Six *et al*., 2000).

The increased fixation of CO_2 by plants may have a direct effect on the mycorrhizal fungi which are root symbionts that utilize plant-fixed carbon for growth. Mycorrhizal fungi which belongs to the order Glomales (Zygomycota), are ubiquitous symbionts for the numerous higher land plants and have several effects on plant physiology (van der Heijden *et al*., 1998), have an indirect effects on soil carbon storage also, hence they are also very important in soil aggregate stabilization (Tisdall and Oades, 1982; Jastrow and Miller, 1997). These fungi can contribute to stability of soil aggregate by their extra radical fungal hyphae (Rillig and Mummey, 2006); these extend several centimeters from the root surface into soil or indirectly by modifying the biochemical and morphological properties of host plants (Borie *et al*., 2008). A recent discovery of copious production of a glycoprotein, glomalin, by hyphae (Wright *et al*., 1996) and its role in aggregate stability (Wright and Upadhyaya, 1996) has implications for enhanced soil carbon sequestration. Glomalin is a proteinaceous substance in soil and linked with soil carbon storage through its effect on soil aggregate stabilization (Rillig *et al*., 2002).

Glomalin is present in soils in significant amount (for example, >60 mg cm^{-3}, or over 100 mg g^{-1}), hence it must have to be considered for plant–soil interactions studies (Rillig *et al*., 2001). The addition of organic sources of nutrients such as cattle manure, compost, and crop stubble significantly stimulates mycorrhizal development and glomalin content (Joner, 2000). Lee and Yun (2011) also reported that the average concentrations of glomalin in the organic farming system were significantly higher than that in the conventional farming system.

3. Soil Enzyme Activities

Soil organic matter transformation is associated with the activity of microorganisms and soil enzymes (Melero *et al*., 2006). Soil enzymes have been considered as potential indicators for soil quality because, it has a significant role in soil biology and its rapid response to soil management options (Dick, 1997). Soil enzyme activities also respond to different management practices such as fertilizers, amendments, vegetation cover, pesticides and agrochemicals (Gianfreda and Bollag, 1996) and to conservation practices (Bergstrom *et al*., 1998). There have been a number of studies advocating the inclusion of soil enzyme activities as the indices of soil quality (Gil-Sotres *et al*., 2005). It was reported that soil enzyme activities are significantly correlated with SOC content because SOC acts as a precursor for the enzyme synthesis (Wang *et al.,* 2013). Soil enzymes produced by microbes have a important role in the biochemical transformation of organic matter and nutrient cycling and its release patterns (Waldrop *et al*., 2004). It is not only considered as an important indicator of soil health and quality, but it also reflects the real picture of soil microbial activity and diversity (Basak *et al.,* 2013).

Under the soil enzymes study, it was found that acid phosphatase and urease play an important role in mineralization and release of soil P and N because they help in catalyzing the hydrolysis and transformations of various organic P and N, respectively (Acosta-Martínez *et al*., 2007). Acid phosphatase, glucosidase, arylsulfatase, and urease activities increased when fertilizers are applied in organic and inorganic form (Eivazi *et al*., 2003). The ratios among the soil enzymes and microbial biomass were significantly increased after addition of manures in historic Sanborn field (Missouri) soil under different crop management practices since 1888 (Eivazi *et al*., 2003). The addition of organic manures enhanced humus content and protective sites within the soil, which leads to increased level of enzyme activities. However, repeated addition of organic fertilizers can also reduce the enzyme activity (Marcote *et al*., 2001).

3.1 Dehydrogenase Activity

Dehydrogenase activity reflects oxidative activity of soil micro-flora, hence considered as a good indicator of microbiological activity and diversity (Nannipieri *et al*., 1990). It is considered that this enzyme does not accumulate as extracellular in the soil but exists as an integral part of intact cells. The enzyme oxidizes soil organic matter through transfer of protons and electrons from substrates to acceptors. These are part of respiration pathways of soil microorganisms and are closely related to the soil type and soil air-water conditions (Kandeler *et al*., 1996). Hence, studies on soil dehydrogenase activities is very important as it may give indications of the soil capacity to support biochemical processes which are very much essential for maintaining soil fertility and productivity (Makoi and Ndakidemi, 2008). It is often used to detect the changes in soil management practices (Reddy and Faza, 1989). Manjaiah and Singh (2001) reported that optimum and balanced fertilizer application resulted in significant increase in dehydrogenase activity whereas, in case of highly fertilized treatment (150% NPK), significant reduction in dehydrogenase activity was found. In a study conducted by Basak *et al*. (2013), it was reported that significantly high enzyme activities were observed due to application of organic manures and fertilizers. Dehydrogenase activity was higher under integrated nutrient management, the highest being 18.87 mg TPF g^{-1} h^{-1} in treatment with 50% NPK + 5 t ha^{-1} vermicompost for maize and 17.97 mg TPF g^{-1} h^{-1} for wheat as compared to 100% NPK and control.

3.2 Acid Phosphatase Activity

Esters and anhydrides of phosphoric acid are hydrolyzed by a group of enzymes called phosphatases (Schmidt and Lawoski, 1961) and are considered as good indicator of soil fertility. In soil ecosystems, these enzymes are supposed to play very crucial roles in P transformations (Speir and Ross, 1978) as shown through evidence of their significant correlation with P stress and plant growth. Different morphological and enzymatic adaptations are developed by plants to tolerate the limited P availability (Makoi and Ndakidemi, 2008). It was observed that transcription activity of acid phosphatases, increases with high P stress (Miller *et al*., 2001; Li *et al*., 2002). If there is signal of soil P deficiency than secretion of phosphatase increased from plant roots which help in phosphate solubilization and remobilization and help plants to cope with P-stressed conditions (Mudge *et al*., 2002; Versaw and Harrison, 2002). Phosphatase activity is correlated with the availability of P (Acosta-Martínez *et al.,* 2007) and P addition reduced its activities (Allison and Vitousek, 2005). Various studies have shown the correlation of organic matter with the activity of acid and alkaline phosphatases (Jordan and Kremer, 1994; Aon and Colaneri, 2001). Crop management practices, types of crops and varieties governed the amount of acid phosphatase exuded by plant roots (Wright and Reddy, 2001; Ndakidemi, 2006), hence it is, anticipated that management practices that causes P deficiency or stress may govern the secretion of these enzymes in the soil (Ndakidemi, 2006). Garcia-Ruiz *et al*. (2008) reported that soil acid phosphatase activity was significantly higher in the organic olive oil orchards than in the conventionally managed ones demonstrating greater biological activity (i.e. assayed soil enzymes) in organically managed soils than the conventionally managed soils. The application of manure affected the functioning of the microbial community and had a positive effect on acid phosphatase activity (Truu *et al*., 2008).

3.3 Urease Activity

Urease enzyme is responsible for the hydrolysis of urea fertilizer applied to the soil and results in a rapid N loss to the atmosphere through NH_3 volatilization (Simpson *et al*., 1984; Andrews *et al*., 1989). In general, urea is the main nitrogenous fertilizers for many crops, hence, urease activity in soil has received a lot of attention (Byrnes and Amberger, 1989; Van Cleemput and Wang, 1991). Soil urease originates mainly from plants (Polacco, 1977) and micro organisms and presents as both intra- and extra-cellular enzymes (Burns, 1986; Mobley and Hausinger, 1989). Burns (1986) has shown that urease enzymes associated with soil organo-mineral complexes are more stable than those present in soil solution and also resistant to denaturing agents (high temperatures and proteolytic attack) (Nannipieri *et al*., 1978). It was observed that urease extracted from plants or micro-organisms is rapidly degraded by proteolytic enzymes (Pettit *et al*., 1976; Zantua and Bremner, 1977) suggesting that these extracellular urease is stabilized on organic and mineral soil colloids by process of immobilization and carries out a significant ureolytic activity. Its activities is governed by several factors as cropping history and pattern, soil organic carbon, soil depth, addition of external inputs to soil, soil temperature and moisture etc. (Tabatabai, 1977; Bremner and Mulvaney, 1978).

Melero *et al*. (2006) reported that urease activity was greater under organic than under conventional fertilization. Addition of organic manure increased urease activity while application of nitrogen fertilizers significantly decreased its activity (Mohammadi, 2011). It was notice that urease level decreased after continuous application of nitrogenous fertilizers compared to native soils or soils which receives organic fertilizers (Burket and Dick, 1998). It might be due to the acidifying nature of nitrogenous fertilizers (Dodor and Tabatabai, 2003) and also availability of nitrogen for microbes is increased that triggers to less production of urease (Marcote *et al*., 2001). Contradicting the above findings, Basak *et al*. (2013) reported that urease activity was higher under 100% NPK (7.76 μg urea g^{-1} h^{-1}) compared to other treatments. They also reported that application of value added organic manures along with 50% RDF caused significantly higher urease activity in soil than treatment receiving only value added manures except treatment with vermicompost. On the other hand, Saha *et al*. (2008) reported higher urease activity in non-amended controls followed by NP and NPK + FYM, however, urease activity was inhibited in the organic amended soils. Since urease plays an important role in hydrolyzing urea fertilizer, uncovering other unknown factors that may influence the activity of this enzyme in the ecosystem is very important.

3.4 β-glucosidase Activity

β-glucosidase is considered as one of the most important glycosidases in the soil because it helps in carbohydrates hydrolysis having β-d-glucoside-bonds, such as cellobiose. As a result, these enzymes have a significant role in mineralization of cellulose, which is considered as the main organic carbon compound in nature (Landgraf and Klose, 2002). Various β-glucosides present in plant debris needs β-glucosidase in catalyzing the hydrolysis and biodegradation of the organic compound during the decomposition process (Martinez and Tabatabai, 1997), which leads to formation of glucose an important carbon and energy source to soil microbes (Esen, 1993). Hence, it is very useful as a soil quality indicator, and provides a reflection of past biological activity and soil capacity for organic matter stabilization (Ndiaye *et al*., 2000). Generally, it can provide early indication of changes in organic carbon much before than other routine methods which measured accurately (Wick *et al*., 1998). The hydrolysis products of β-glucosidase such as carbohydrates are believed to be important energy sources for microorganisms (Hazarika and Parkinson, 2011). Bandick and Dick (1999), investigating different soil enzyme activities and found that β-glucosidase was the most consistent enzyme in showing separation of treatment effects. Consequently, a better understanding of β-glucosidase enzyme activities and the factors that influence them in the ecosystem may significantly contribute to soil health studies. β-glucosidase activity was significantly higher in the organic olive oil orchards than in the conventionally managed ones reflecting greater biological activity (*i.e.,* assayed soil enzymes) in organically managed soils than the conventionally managed soils (Garcia-Ruiz *et al*., 2008).

3.5 Aryl Sulphatase Activity

Plant takes sulphur in inorganic sulphate (SO_4^-) form and its availability depends on its mineralization or mobilization (Williams, 1975; Fitzgerald, 1976) in the soil from aromatic sulphate esters (R-O-SO_3^-). Sulphur present in soil in the bounded form as organic compounds, resulting their limited availability to plants. Its availability in soil depends on the hydrolysis of aromatic organic sulphate esters or oxidation of soluble organic matter absorbed by the micro-organisms to get carbon and energy for their growth and development in which inorganic SO_4-S are released as a by-product (Dodgson *et al*., 1982). All these transformations are governed and regulated by the aryl suphatase enzyme (Fitzgerald and Stickland, 1987). Aryl sulphatases are very abundant in nature (Dodgson *et al*., 1982) as well as in soils (Gupta *et al*., 1993; Ganeshamurthy *et al*., 1995) and are responsible for the hydrolysis of soil organic sulphur (sulphate esters) (Kertesz and Mirleau, 2004). Its secretion in the environment is controlled by the limitation of sulphur and availabality (McGill and Colle, 1981). Its availability and content in soil is often correlated with microbial biomass and rate of sulphur mineralization and immobilization (Klose and Tabatabai, 1999; Vong *et al*., 2003).

Studies have shown that various environmental factors affect the release of sulphur from soluble and insoluble sulphate esters in the soil (Burns, 1982) such as soil pH (Acosta-Martinez and Tabatabai, 2000), quality and quantity of organic matter or organic carbon (Sarathchandra and Perrott, 1981; Dalal, 1982), organic sulphur content (Dogson and Rose, 1976) etc. It was reported that, aryl sulphatase activity was significantly higher in the organic olive oil orchards as compared to conventionally managed ones, implies that greater biological/ microbial activity (*i.e.,* assayed soil enzymes) in organically managed soils (Garcia-Ruiz *et al*., 2008).

4. Conclusion

Soil organic matter, which is mainly composed of carbon is the key element and governs or regulates most of the soil properties. The organic carbon dynamics in soil are reported to be related to soil biochemical properties and soil enzyme activities. There was a significant effect of nutrient management practices on SOC fractions and soil enzymes activities. In most of cases, the application of organic sources of nutrients as well as integrated nutrient management resulted in significant improvement in the soil biochemical properties than soils treated with inorganic fertilizers. Hence addition of organic manures either alone or in combination with fertilizers had positive effect on soil biochemical properties. Microbial properties like microbial biomass carbon, nitrogen, phosphorus and enzymes activities are very sensitive to nutrient management practices compared to soil organic carbon fractions.

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