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Review

Soil management, microorganisms and organic matter interactions: A review

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Plants obtain nutrients from two natural sources: organic matter and minerals. Organic matter includes any plant or animal material that returns to the soil and goes through the decomposition process. Different soil organisms feed on different organic substrates. Their biological activity depends on the organic matter supply. In addition to providing nutrients and habitat to organisms living in the soil, organic matter also binds soil particles into aggregates and improves the water holding capacity of soil. Most soils contain 2 to 10% organic matter. However, even in small amounts, organic matter is very important. Tillage is one of the major practices that reduce the organic matter level in the soil. Each time the soil is tilled, it is aerated. Soil enzymes act as biological catalysts of specific reactions that depend on a variety of factors, such as the presence or absence of inhibitors, tillage and fertilization, and can be considered as early indicators of biological changes. The incorporation of organic amendments to soil influences soil enzymatic activities because the added material may contain intra- and extracellular enzymes and may also stimulate microbial activity in the soil. Integrated animal and crop production enterprises that use manure as the primary nutrient source for crop production are not without problems. Nutrient loading on a farm with an animal enterprise may exceed crop nutrient needs.

Key words: Fertilization, microbial activity, soil management, sustainable agriculture, tillage.

INTRODUCTION

Soil is an integral compartment of the environment and the central organizer of the terrestrial ecosystem. Soil quality is the fundamental foundation of environmental quality largely governed by soil organic matter (SOM) content, which is dynamic and responds effectively to changes in soil management, tillage and plant production (Baker et al., 2007). Maintaining soil quality can reduce the problems of land degradation, decreasing soil fertility and rapidly declining production levels that occur in large parts of the world needing the basic principles of good farming practice. Minerals, organic components and microorganisms are three major solid components of the soil. They profoundly affect the physical, chemical, and biological properties and processes of terrestrial systems. To date, scientific accomplishments in individual disciplines of the chemistry of soil minerals, soil organic matter and soil microbiology are commendable. However, minerals, organic matter and microorganisms should not be considered as separate entities, but rather a united system constantly in close association and interactions with each other in soil environments. Interactions of these components have enormous impact on terrestrial processes critical to environmental quality and ecosystem health.

In view of the significance of soil mineral–organic matter–microorganism interactions, the International Society of Soil Science (ISSS) established the Working Group MO "Interactions of Soil Minerals with Organic Components and Microorganisms" in 1990. The objective of this Working Group is to promote research and education on the interactions of these major solid components of soil and the impact on the production of foodstuffs and fibers, the sustainability of the environment, and ecosystem health including human health on the global scale. Since its establishment, the Working Group has contributed substantially to advance the knowledge on physical/chemical/biological interfacial

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interactions in soil environments (Huang, 2004). Mineral colloids in general can directly or indirectly influence the activity of microorganisms in their immediate vicinity. Mineral colloids can also stimulate microbial activity by absorbing metabolites that would otherwise have an adverse effect on microbial growth. Montmorillonite is more effective than kaolinite and finely ground quartz. Furthermore, surfaces of mineral colloids can absorb other toxic substances to microorganisms such as antibiotics and pesticides.

Although soil organic matter can be partitioned conveniently into different fractions, these do not represent static end products. Instead, the amounts present reflect a dynamic equilibrium. The total amount and partitioning of organic matter in the soil is influenced by soil properties and by the quantity of annual inputs of plant and animal residues to the ecosystem. For example, in a given soil ecosystem, the rate of decomposition and accumulation of soil organic matter is determined by such soil properties as texture, pH, temperature, moisture, aeration, clay mineralogy and soil biological activities (Bot and Benites, 2005). A complication is that soil organic matter in turn influences or modifies many of these same soil properties. Organic matter existing on the soil surface as raw plant residues helps protect the soil from the effect of rainfall, wind and sun. Removal, incorporation or burning of residues exposes the soil to negative climatic impacts, and removal or burning deprives the soil organisms of their primary energy source. Organic matter within the soil serves several functions. From a practical agricultural standpoint, it is important for two main reasons: (i) as a "revolving nutrient fund"; and (ii) as an agent to improve soil structure, maintain tilt and minimize erosion. As a revolving nutrient fund, organic matter serves two main functions: (1) as soil organic matter is derived mainly from plant residues, it contains all of the essential plant nutrients. Therefore, accumulated organic matter is a storehouse of plant nutrients; (2) The stable organic fraction (humus) adsorbs and holds nutrients in a plant available form.

Organic matter releases nutrients in a plant-available form upon decomposition. In order to maintain this nutrient cycling system, the rate of organic matter addition from crop residues, manure and any other sources must equal the rate of decomposition, and take into account the rate of uptake by plants and losses by leaching and erosion (Bot and Benites, 2005).

Fertilization is also one of the soil and crop management practices, which exert a great influence on soil quality (Chander et al., 1998). Farm-yard manure and compost are organic sources of nutrients that have been shown to increase soil organic matter and enhance soil quality. It is well known that organic amendments, such as plant residues, farm-yard manures and composts have a number of benefits in soil physical and chemical properties. Many reports have also revealed different aspects of biology of soils amended with organic matters, including the number of general microorganisms (Nishio and Kusano, 1980), biomass of bacteria and fungi, enzyme activities (Mohammadi, 2011) and biochemical properties (Lynch, 1983). Microbial communities perform necessary ecosystem services, including nutrient cycling, pathogen suppression, stabilization of soil aggregates, and degradation of xenobiotics. Soil microbial biomass, activity, and community structure have been shown to respond to agricultural management practices. Alternation to no tillage or increased cropping intensity increases microbial biomass C (MBC) in response to increase nutrient reserves and improved soil structure and water retention (Biederbeck et al., 2005).

EFFECTS OF TILLAGE ON SOIL AND PLANT TRAITS

Tillage is one of the major practices that reduce the organic matter level in the soil. Based on soil carbon losses with intensive agriculture, reversing the decreasing soil carbon trend with less tillage intensity benefits a sustainable agriculture and the global population by gaining better control of the global carbon balance. Field operation management, especially selecting and using tillage equipment, should be directed toward developing and maintaining an optimal proportion of soil components (water, air, organic matter and mineral components) for productive and sustainable agriculture. Tillage can either create or help to alleviate soil compaction. Tillage methods have significant effects on soil properties. Results of Mohammadi (2011) indicated statistically significant ($p<0.05$) differences in the enzyme activity in the soil between various methods of tillage. However, dehydrogenase activity was not affected by tillage methods. The activity of acid, alkaline phosphatase and protease tended to be higher in the no tillage treatment compared to the minimum tillage and conventional tillage treatments. Moreover, activity of urease and dehydrogenase were similar in no tillage and minimum tillage treatments (Figure 1). Findings of Jin et al. (2009) has already suggested the positive effects of conservation tillage practices on soil enzyme activities. The generally higher enzyme activities in no tillage mainly resulted from the larger water availability in the plots rather than the better soil fertilities.

Moreover, porosity, bulk density and water retention characteristics are physical properties characterizing soil structure and compaction phenomena. Findings of Mohammadi et al. (2010) showed that tillage systems had significant effects on soil bulk density ($P<0.05$). Minimum soil bulk density was observed under conventional tillage in 0 to 10 cm depth (Table 1). Conventional tillage practices increase soil pore spaces and decrease soil bulk density through clod forming and topsoil inverting, which are in agreement with Azim-zade et al. (2002). Tripathi et al. (2007) also demonstrated

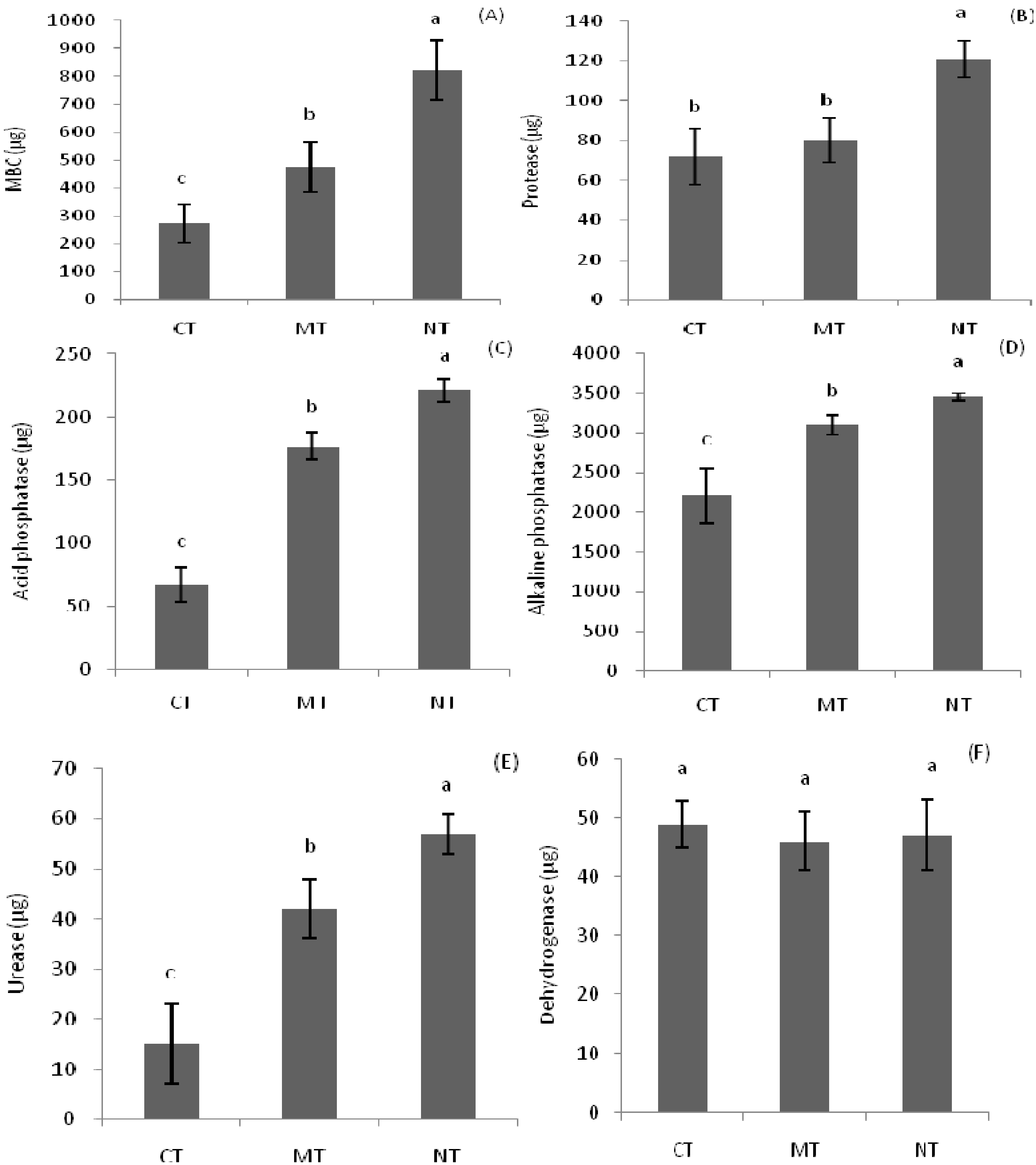

Figure 1. Effect of tillage practices on MBC (A), protease (B), acid phosphatase (C), alkaline phosphatase (D), urease (E), and dehydrogenase (F) activity in soil (Mohammadi, 2011).

Table 1. Effect of tillage methods on wheat traits and soil bulk density (means of two years).

Treatment	Grain yield (kg/ha)	1000-seed weight (g)	spikes per m^2	seeds per spike	spikelet per spike	spike length (cm)	Bulk density (g/m^3)		
							0 - 10 cm	10 - 20 cm	20 - 30 cm
Tillage									
Moldboard	1536.7[b]	42.34[b]	221.9[b]	12.22[b]	9.65[b]	6.19[b]	0.83[b]	0.96[c]	1.08[b]
Chisel	1841.8[a]	43.71[a]	228.6[a]	25.25[a]	10.53[a]	7.35[a]	1.12[a]	1.28[a]	1.30[a]
No tillage	1388.7[c]	41.15[b]	217.4[b]	17.18[c]	9.06[b]	5.63[c]	0.87[b]	1.18[a]	1.28[a]

Mean values in each column with the same letter(s) are not significantly different using Duncan tests at 5% of probability (Mohammadi et al. 2010).

minimum soil bulk density under conventional tillage system. Soil bulk density is increased at lower depths. At 10 to 30 cm from surface layer, there was no significant difference between no-tillage system and chisel plowing with respect to soil bulk density. Under no tillage system, only surface layer is disturbed by planter and deeper layers are not disturbed but are expressively compacted by agricultural machinery traffic, resulting in significant elevation in soil bulk density.

Findings of Mohammadi et al. (2010) showed that tillage methods significantly affected 1000-seed weight. Mean comparisons indicated that through chisel plow, 1000-seed weight and seed number were increased by 6 and 22% respectively, as compared with conventional tillage system. Number of spikelet per spike and spike length were significantly increased by chisel application (Table 1). Halvorson et al. (2002) showed that 1000-seed weight was lower under no tillage system compared to minimum tillage. Singer et al. (2004) resulted that tillage methods affected yield components of corn, soybean and wheat. They showed that the number of spikes per m^2 and seeds per spike were decreased through converting minimum tillage to no tillage system. Lithourgidis et al. (2006) indicated that the number of spikes per m^2 was not significantly affected by tillage methods. Applying conventional tillage system caused a reduction of 12% in grain yield as compared with chisel plowing (Mohammadi et al., 2010). Since conventional tillage system caused soil moisture reduction, therefore this tillage system is not recommended under dry framing conditions.

It has been observed that increasing cone index and soil compaction are the main reasons of yield reduction. Soil compaction leads to restriction of root growth. Consequently, water and nutrient uptake by roots will be confused and diminished. Schillinger (2005) demonstrated that using no tillage system caused lower production of wheat, barley and oat in comparison with conventional tillage system. Main reasons cited for lower yields under no-till system are reductions in plant density (Hemmat, 1996), increased weed infestation (Peltzer et al., 2009) and soil physical properties that limit crop growth (Haj Abbasi and Hemmat, 2000). The most probable cause of erratic stand establishment for no-till wheat treatment was poor soil-seed contact associated with the use of the drill for seeding into a layer of crop residue. Tarkalsona et al. (2006) reported that application of no tillage system in a long term period led to indicative improvement in wheat productivity in comparison with conventional tillage system. No tillage system needs specific planting tools that cannot be found easily in undeveloped countries, therefore using chisel plow is more favored by farmers.

In addition, the findings of Mohammadi et al. (2010) showed that no tillage system increased MBC compared to other tillage systems. Conventional tillage decreases soil organic matter and soil structure, and it is due to decreased soil microbial communities. Madejon et al. (2007) observed that conservation tillage increased MBC and microbial activities. Along with microbial biomass changes, one might also expect shifts in microbial community structure to occur due to the temporal increase in microbial niche, water retention or reduced physical disturbance with no-tillage. Conservation and reduced tillage have many benefits on reducing the cost of production; reduces fuel consumption, reduces machinery wear, optimizes soil moisture, and reduces overall production costs (NMSU reports that irrigated wheat yields in Clovis are comparable between conventional and conservation tillage, but production costs for conservation tillage were lower by as much as $50 per hectare) which are the most important reduced tillage in agro-ecosystems.

EFFECTS OF ORGANIC FERTILIZATION ON SOIL AND PLANT TRAITS

Manure management, the focus of this section, is the use of animal manures in a way that is appropriate to the capabilities and goals of the farm firm while enhancing soil and water quality, crop nutrition and farm profits. While it is possible to provide a general definition for manure management, the same cannot be said of the farms with this responsibility. The role of manure within a farm situation is diverse in form and occurrence in that the farms that generate manure vary from feedlots, dairy and beef farms, horse operations and poultry operations to open-range ranches. The form, nutrient content, and handling procedures associated with animal manure in these situations vary dramatically. The agronomic

Table 2. Effect of fertilization methods on MBC and soil enzyme activity (Mohammadi, 2011).

Treatment	MBC (µg)	Protease (µg)	Acid phosphatase (µg)	Alkaline phosphatase (µg)	Urease (µg)	Dehydrogenase (µg)
Basal fertilizer						
FYM (N1)	278.4^{c}	86.5^{c}	167.4^{b}	2987.3^{b}	49.6^{a}	60.1^{b}
Compost (N2)	312.6^{c}	94.6^{bc}	169.2^{b}	3001.4^{b}	44.4^{b}	62.9^{ab}
Chemical fertilizer (N3)	196.3^{d}	87.1^{c}	158.1^{c}	2678.6^{c}	28.8^{c}	21.2^{d}
FYM + Compost (N4)	409.5^{b}	110.3^{a}	226.6^{a}	3314.4^{a}	49.8^{a}	63.8^{a}
FYM + Compost + Chemical (N5)	691.2^{a}	96.2^{b}	169.2^{b}	2879.1^{bc}	29.4^{c}	53.7^{c}
Control (N6)	89.3^{e}	73.1^{d}	41.8^{d}	2658.7^{c}	27.9^{c}	20.8^{d}

Mean values in each column with the same letter(s) are not significantly different using LSD tests at 5% of probability (Mohammadi et al. 2011).

and environmental context in which this manure is introduced also varies in terms of assimilative capacity and vulnerability to degradation. The results of Mohammadi (2011) indicated statistically significant ($p<0.05$) difference in the level of MBC in the soil between various methods of fertilization. The addition of compost or farm-yard manure (FYM), significantly ($p<0.05$) increased the soil MBC in comparison to the chemical fertilizer and the control. Higher levels of MBC in compost treated soil could be due to greater amounts of biogenic materials like mineralizable nitrogen, water soluble carbon and carbohydrates. Integrated use of chemical fertilizers and organic fertilizers brings in more MBC in soil compared to their single application of them (Table 2). Similar observations were recorded by Leita et al. (1999). Fertilizers may meet up the demand of mineral nutrition required by the microbes, but not that of carbon, which is a major component of microbial cells. Integrated application of organic and inorganic materials provides a balanced supply of mineral nutrients as well as carbon. The findings of Hati et al. (2006) showed that application of farm-yard manure for three years in conjunction with the recommended rate of inorganic fertilizers to soybean in a soybean–mustard crop rotation improved soil physical conditions through better aggregation, increased saturated hydraulic conductivity, reduced mechanical resistance and bulk density, and enhanced root proliferation of soybean.

Furthermore, the findings of Mohammadi (2011) showed that the activities of soil enzymes were generally higher in the organic fertilizers treatments than in the unfertilized and chemical fertilizer treatments (Table 2). He found that the dehydrogenase, phosphatase and urease activities in the chemical fertilizers treatment were significantly lower than in the FYM and compost treatments. Alkaline and acid phosphatase generally increased with compost application. Increased phosphatase activity could be responsible for hydrolysis of organically bound phosphate into free ions, which were taken up by plants. Tarafdar and Marschner (1994) reported that plants can utilize organic P fractions from the soil by phosphatase activity enriched in the soil–root interface. Application of nitrogen fertilizers significantly decreased urease activity while addition of organic manure increased its activity. We concluded that because the nitrogen fertilizers used in the experiments contained NH^{4+} and that the reaction products of urease was NH^{4+}, microbial induction of urease activity had been inhibited. The effect of organic amendments on enzyme activities is probably a combined effect of a higher degree of stabilization of enzymes to humic substances and an increase in microbial biomass with increased soil carbon concentration. Compost application increased dehydrogenase activity. Stronger dehydrogenase activity in compost applied plots may be due to higher organic matter content.

Findings of Toyota and Kuninaga (2006) also clearly demonstrated that a different soil microbial community was established after the repeated applications of chemical fertilizers and farm-yard manure compared with the single application of chemical fertilizers. Application of compost caused a significant increase in dehydrogenase activity (Mohammadi, 2011). The higher organic matter levels in the compost treatments may provide a more favorable environment for the accumulation of enzymes in the soil matrix, since soil organic constituents are thought to be important in forming stable complexes with free enzymes. Soil factors, including redox potential (Eh) and pH can affect the rate of enzyme mediated reactions by influencing the redox status and ionization respectively, as well as solubility of enzymes, substrates and cofactors. In addition, some enzymes may predominate at specific p levels. Application of compost and FYM caused a

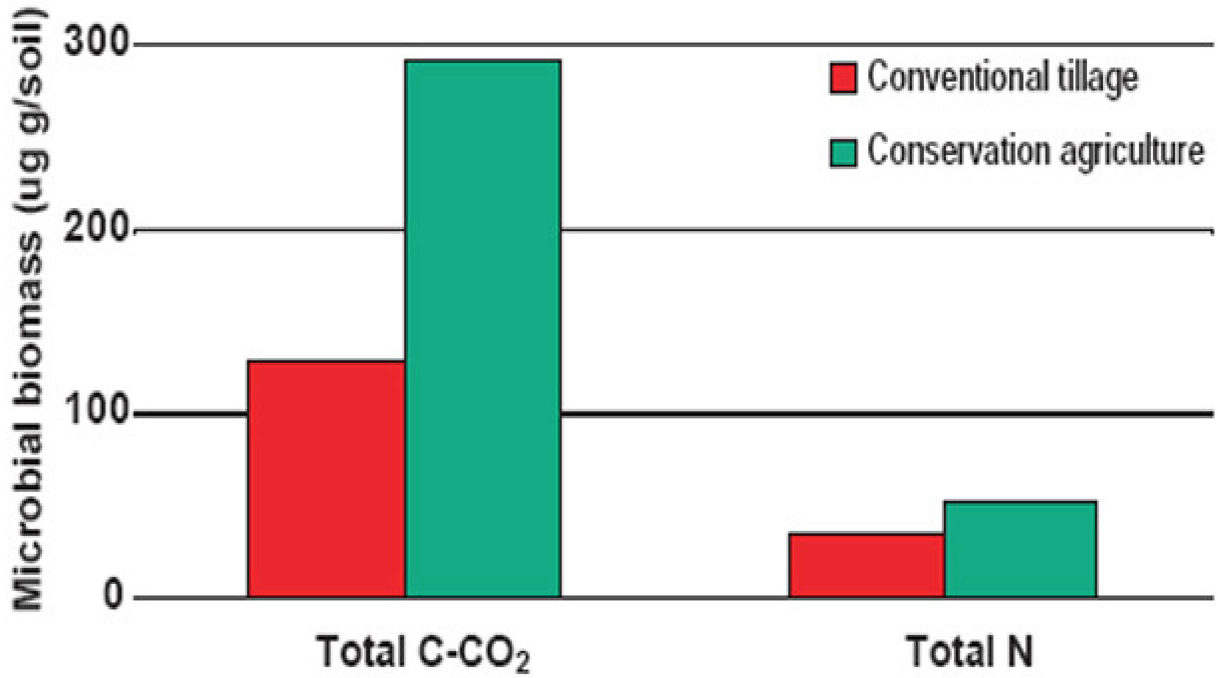

Figure 2. Microbial biomass under conventional tillage and conservation agriculture (Balota et al., 1996.).

faster and higher reduction of soil, and at the same time increased the soil pH. Report of Nayak et al. (2007) showed that soil pH was lowest in the inorganic fertilizers amended plots and highest in compost amended plots. Soil dehydrogenase activity exhibited a strong negative relationship with Eh and a positive relationship with Fe^{2+} content, suggesting aeration status is the major factor determining the activity (Mohammadi et al., 2011 b). Compared to cash-grain farming, agricultural production systems that integrate livestock and crop production enterprises can reduce costs of purchased inputs such as fertilizer, reduce economic risk through diversification of farm enterprises and increase economic return to rural communities by providing jobs in sales or meat processing. Integrating ruminant animals and the manure they produce into farming systems may also decrease soil erosion and surface runoff, by increasing the potential for including forages in the crop rotation. Integrated animal and crop production enterprises that use manure as the primary nutrient source for crop production are not without problems. Nutrient loading on a farm with an animal enterprise may exceed crop nutrient needs. This can occur because the amount of nutrients being removed in products from the diversified enterprise is often lower from livestock operations than from cash-grain operations. Problems with nutrient loading may be exacerbated by timing of manure nutrient availability, which is often not synchronized with potential crop utilization.

Numerous studies have focused on optimizing the use of animal manure to supply crop N needs and on N losses from manure to groundwater, but few have addressed the problem of excessive P accumulation. The application of green manures to soil is considered a good management practice in any agricultural production system because it can increase cropping system sustainability by reducing soil erosion and ameliorating soil physical properties by increasing soil organic matter and fertility levels by increasing nutrient retention and by reducing global warming potential. Soil micro-organisms are of great importance for plant nutrition as they interact directly in the biogeochemical cycles of the nutrients. Increased production of green manure or crop biomass aboveground and belowground increases the food source for the microbial population in the soil. Agricultural production systems in which residues are left on the soil surface and roots left in the soil such as through direct seeding and the use of cover crops, therefore stimulate the development and activity of soil micro-organisms (Bot and Benites, 2005). In one 19-year experiment in Brazil, such practices resulted in a 129% increase in microbial carbon biomass and a 48% increase in microbial N biomass (Figure 2)

Green manure application had a significant effect on leaf and grain nitrogen content (Mohammadi et al., 2011a). Incorporating vetch and barley biomass into the soil before chickpea cultivation, increased leaf and grain nitrogen contents by 18 and 7%, respectively. Nitrogen fixation by vetch increasing soil organic matter, and optimizing conditions for *Rhizobium* bacteria are the main reasons for increased nitrogen uptake. Soil micro-organisms degrade organic matter through the production of diverse extracellular enzymes and for this reason after the application of green manures to soil, soil enzymatic activities increased. These results are in agreement with those of Kautz et al. (2004) who found an increase in enzymatic activities after the addition of different green manures to soil. Soil enzymes act as biological catalysts of specific reactions that depend on a variety of factors, such as the presence or absence of inhibitors, amendment type, crop type, etc. and can be considered as early indicators of biological changes. The incorporation of organic amendments to soil influences soil enzymatic activities because the added material may contain intra- and extracellular enzymes and may also stimulate microbial activity in the soil. Dehydrogenase activity has been proposed as a measure of overall microbial activity (Masciandaro et al., 2001), since it is an intracellular enzyme related to oxidative phosphorylation processes. Garcia et al. (1993) found that dehydrogenase activity is a good index of the soil microbial biomass in semiarid Mediterranean areas. The greater dehydrogenase activity observed at the high dose of green manures suggests that these did not include toxic compounds to microorganisms.

However, under field conditions, the decomposition of green manures is complex, and is controlled by numerous factors such as availability of carbon and nitrogen, the biochemical nature of the plant residue, contact between soil, compost and soil and climatic factors, etc. According to Tejada and Gonzalez (2006), the carbon to nitrogen (C/N) ratio of the organic wastes will largely determine the balance between mineralization and immobilization. The C/N ratio was the best predicting parameter for the potential amount of N that can mineralize from a crop residue. In this respect, Maiksteniene and Arlauskiene (2004) found a higher mineralization of clover and lucerne green manures after the application of soil (C/N ratio 12 and 10, respectively) vetch and oat mixture (C/N ratio 31) and straw wheat (C/N ratio 55). For this reason, the increase in the soil microbial biomass- C as well as in the soil enzymatic activities was very different depending on the type of green manure applied to the soil. This difference in the C/N ratio of the different green manures is manifested in the different evolution of the soil C/N ratio. As a result, the mineralization of the organic matter applied to the soil will be carried out under good conditions of the mineralization versus the immobilization processes; aspect that is manifested in the highest values in soil microbial biomass and the soil enzymatic activities.

The results of Blaise et al. (2005) indicate that it is advantageous to apply FYM as it improves fiber yield by way of improved ginning outturn. Improvement in uniformity ratio with the application of FYM results in better fiber quality. Furthermore, FYM also supplies nutrients and maintains a healthy positive nutrient balance besides being a source of soil organic matter further emphasizing the need for integrated and balanced nutrient management in cotton in the non-irrigated vertisols of India.

ORGANIC MATTER

Soil organic matter consists of living parts of plants (principally roots), dead forms of organic material (principally dead plant parts), and soil organisms (micro-organisms and soil animals) in various stages of decomposition. It has great impact upon the chemical, physical and biological properties of the soil. Soil organic matter is any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process. At any given time, it consists of a range of materials from the intact original tissues of plants and animals to the substantially decomposed mixture of materials known as humus (Figure 3).

Total soil organic matter content is the soil property most closely associated with soil structure stability. Soil organic matter accumulates over the long term to a steady-state level, which is determined by the amount of biological contributions over time, soil water content and temperature (regulating decomposition) and other factors such as texture. As primary producers in terrestrial ecosystems, plants ultimately can be credited with nearly all of the organic matter added to soil. Direct contributions occur from seasonal shedding of leaves and roots and root exudates as well as the whole plant upon death. The organic compounds added and the microbial activity and products that result greatly enhance soil structure and improve structural stability. Qualitative differences in soil organic matter and the mechanisms of stabilization involved may account for unexplained differences in aggregate stability associated with plant species. Often much of the short-term increase in organic carbon has been found in the sand-size fraction, which includes fragments of plant tissue (Wilkinson, 2000). Living organisms are made up of thousands of different compounds. Thus, when organisms die, there are thousands of compounds in the soil to be decomposed. As these compounds decompose, the organic matter in soil is gradually transformed until it is no longer recognizable as part of the original plant. Micro-organisms can access N in the soil more easily than plants. This means that where there is not enough N for all the soil organisms, the plants will probably be N deficient. When soils are low in organic matter content, application of organic matter will increase the amount of N (and other nutrients) available to plants through enhanced microbial activity.

Hydrophobic coatings (presumably waxes from plant roots or associated microorganisms) can cause water repellency of sand-textured aggregates and lead to the development of localized dry-spot formation in turf. Water repellency can reduce the rate of clay-aggregate wetting and therefore increase aggregate stability and contribute to development of preferential flow paths of water infiltration. Grassland soil aggregates exhibit greater potential water repellency than aggregates of arable (maize) land. The grassland vs. cultivated comparison, then, may reflect breakage of hydrophobic coatings

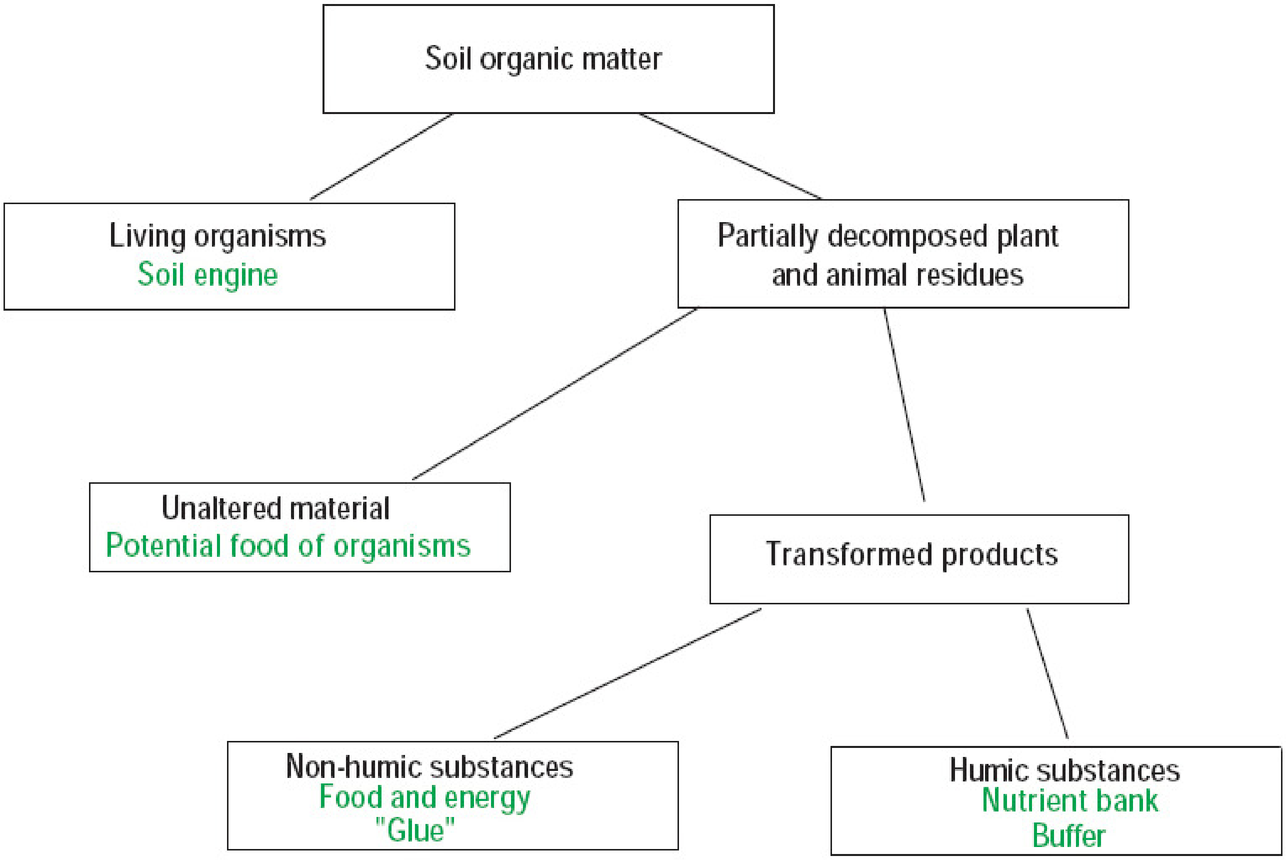

Figure 3. Components of soil organic matter and their functions (Bot and Benites, 2005).

(exposing uncoated soil) and/or microbial oxidation of the coatings in the cultivated land. Another possibility is a species difference in deposition of hydrophobic coatings on soil particles. Strong correlations occur between soil carbohydrate content, or some fraction thereof, and soil structural indices (Wilkinson, 2000). Periodate-sensitive materials (polysaccharide and/or polyuronides) have been shown to be stabilizing agents for aggregates in many cases as well as pyrophosphate sensitive materials probably bound to minerals by polyvalent cations. Carbohydrates have been found to constitute 8 to 16% of soil organic matter in some virgin soils, the amount generally increasing with clay content. Soil in agricultural land use generally contains greater carbohydrate content than fallow and species variability is evident. Some of the soil carbohydrate is contributed by structural components of plants (cellulose), but soil also gain carbohydrates in the form of soluble compounds released from plant roots (Wilkinson, 2000).

Organic matter accumulation in soils depends on three processes:

(1) Plant production, which provides most of the inputs,
(2) The capacity of soil to stabilize and store organic matter, which depends on soil depth, the amount and types of the clay and other minerals available to form stable organo-mineral compounds,
(3) The rate of mineralization through biological oxidation which is, in turn, determined by a suite of hierarchically-organized factors, namely, climate, certain soil properties (clay type and amount, pH) and biological activities (especially of the larger organisms).

Most soils will benefit from the addition of organic matter, except those rare soils that are already high in organic matter such as peaty soils. Soils with good levels of organic matter are generally easily worked (they have a good 'tilth'). If you squeeze a handful of soil into a ball in your hand and it remains in a hard lump, then it has a poor tilth and hard clods will result when it is ploughed. If it crumbles, then it is well granulated; organic matter promotes granulation. Cultivated soils with good tilth are less subject to wind and water erosion. Organic matter will improve the soil by:

(1) Helping to improve soil structure; this will also improve water penetration and drainage, as well as improving aeration. Adding organic matter is particularly valuable for poorly structured clay soils by adding the valuable nutrients to the soil.
(2) Helping to retain moisture in well drained soils (sandy soil); every percentage point of soil organic matter is

considered capable of holding the equivalent of 25 mm of rainfall.
(3) Acting as a buffer against sudden temperature or chemical changes, which may affect plant growth.
(4) Encouraging the activity of beneficial soil organisms such as earthworms.
It may be difficult to increase the percentage of organic matter in a soil, but it is important to try to maintain that percentage. The average mineral soil contains around 2 to 5% organic matter. Organic content will drop if you remove plants from a soil and do not return organic material to the soil. Organic matter can be added in the following ways (Mason, 2003):

(1) Cultivate the roots of crop plants back into the soil when the plant has grown and add compost regularly
(2) Apply organic mulches regularly to the surface of the soil
(3) Feed plants with manure (preferably well rotted) and other organic fertilizers.

The cover crop is then ploughed in, replenishing the lost organic content from the previous season. Nutrients can be added to soil by digging in kitchen scraps, animal manures, cover crops, natural minerals such as rock dusts, and synthetic chemical fertilizers. Nutrients are also obtained from irrigation water, rainfall, from the atmosphere (micro organisms converting atmospheric nitrogen) and from the natural weathering of rock and soil itself. The source is unimportant to the plant; nitrogen from animal manure is exactly the same as nitrogen from sulfate of ammonia, and phosphorus from rock dusts is exactly the same as phosphorus from superphosphate. The choice of which source of nutrients to use should depend on the effect that it will have on the soil. Artificial fertilizers are easier to apply and manage than animal manures and organic fertilizers, but can create major soil problems, in particular soil acidification. These fertilizers release nutrients quickly so nutrients are easily washed through the soil where they can pollute rivers and creeks. Organic fertilizers generally don't cause these problems, and have the added advantage of improving soil structure, and promoting beneficial soil life. As such, they represent a favorable option for proponents of sustainable agriculture (Mason, 2003).

Conservation agriculture encompasses a range of such good practices through combining no tillage or minimum tillage with a protective crop cover and crop rotations. It maintains surface residues, roots and soil organic matter, helps control weeds, and enhances soil aggregation and intact large pores, in turn allowing water infiltration and reducing runoff and erosion. Farming systems have tended to mine the soil for nutrients and to reduce soil organic matter levels through repetitive harvesting of crops and inadequate efforts to replenish nutrients and restore soil quality. This decline continues until management practices are improved or until a fallow period allows a gradual recovery through natural ecological processes. Only carefully selected diversified cropping systems or well-managed mixed crop-livestock systems are able to maintain a balance in nutrient and organic matter supply and removal.

CONCLUSION

This manuscript provides information on soil microbial biomass and activities as influenced by fertilization and tillage in plant production. Microbial biomass and soil enzyme activity is sensitive in discriminating between organic fertilizers and inorganic fertilizer application on a short-term basis. Soil microbial biomass and enzymatic properties were also closely related with the C inputs. Consistent distinctions in enzyme activities were observed between different tillage practices. These differences were most pronounced between no tillage on the one hand and conventional and reduced tillage on the other hand. The grain yield was impacted by soil fertility amendments and tillage methods. Organic manure increased yield by altering soil physical properties, increasing soil fertility, increasing beneficial microbial populations and activity. The application of green manures to the soil produced an improvement in the soil biological properties as well as in the nutrition, production and quality of the obtained maize. Nevertheless, these improvements depend on the chemical composition of the green manures applied to the soil. The difference in the C/N ratio of the different green manures is manifested in the different evolution of the soil biological properties and yield. Nutrient exchanges between organic matter, water and soil are essential to soil fertility and need to be maintained for sustainable production purposes. Where the soil is exploited for crop production without restoring the organic matter and nutrient contents and maintaining a good structure, the nutrient cycles are broken, soil fertility declines and the balance in the agro-ecosystem is destroyed. There are four principal issues which need to be addressed in future. These are as follows:
(1) Residues management concerning recycling and environmental protection.
(2) Soil organic matter management in different cropping areas for improving soil health.
(3) Integrated nutrient management (inorganic, organic and bio-fertilizer) for sustenance of soil fertility and
(4) Conservation tillage methods in sloped and marginal areas.

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