EFFECT OF DIFFERENT ORGANIC WASTES ON SOIL PROPERTIES AND PLANT GROWTH AND YIELD: A REVIEW

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The use of organic wastes in agriculture plays a great role in recycling essential plant nutrients, sustaining soil security as well as protecting the environment from unwanted hazards. This review article deals with the effect of different kinds of organic wastes on soil properties and plant growth and yield. Municipal solid waste is mainly used as a source of nitrogen and organic matter, improving soil properties and microbial activity that are closely related to soil fertility. Biowaste and food waste increase pH, nitrogen content, cation exchange capacity, water holding capacity, and microbial biomass in soil. Sewage sludge contains various amounts of organic matter and huge amounts of plant nutrients. Manure is a common waste which improves soil properties by adding nutrients and increases microbial and enzyme activity in soil. It also reduces toxicity of some heavy metals. These organic wastes have a great positive impact on soil physical, chemical, and biological properties as well as stimulate plant growth and thus increase the yield of crops.

municipal solid waste, soil nutrients, sewage sludge, food waste, manure

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INTRODUCTION

Waste is generated from consumer-based lifestyle (Hoornweg, Bhada-Tata, 2012), that are generated from all our daily activities in a large variety of wastes (European Information and Observation Network, 2013). Currently, 3 billion residents of world cities generate about 1.2 kg solid waste per capita per day (i.e. 1.3 billion t per year). By 2025, these numbers will likely increase to 4.3 billion urban residents generating about 1.42 kg municipal solid waste (MSW) per capita per day (i.e. 2.2 billion t per year). Waste generation rates will be more than double over the next twenty years in lower income countries. Waste management costs have been increased about five times in low-income countries and four times in lower-middle income countries (Hoornweg, Bhada-Tata, 2012). These ever-growing large amounts of wastes are associated with environmental and public health problems, and odour from the landfills. The reuse of wastes for agricultural puropse to improve soil properties and increase crop yield is a good solution for minimizing these problems. Nowadays, with the increasing demand to conserve natural resources and energy, recycling of wastes assumes major importance (Padmavathiamma et al., 2008). Recently, in agriculture, especially in organic agriculture, the use of organic fertilizers such as manure and compost have been important components of farming practices (Quintern et al., 2006). The organic waste of plant and animal origin provides a good source of nutrients to improve soil productivity (Tejada, Gonzalez, 2006; Tejada et al., 2007; Padmavathiamma et al., 2008).

With extensive tillage operations without the addition of organic matter (OM) the soil health is degrading. The OM content in soil can be increased by the addition of organic wastes (Achiba et al., 2010; Srivastava et al., 2016) such as MSW, food waste (FW), biowaste (BW), manure, sewage sludge (SS), etc. The quality of soil and improvement of soil health can be restored by incorporation of recycling organic wastes in the soil (Zhang et al., 2014). Debiase et al. (2016) reported that urban areas produce a huge amount of degradable organic wastes such as MSW and SS. These wastes contain several macro- and micro-nutrients that can be used as potential organic fertilizers for crop production. Goss et al. (2013) are of the same opinion. Several studies have been done related to organic amendments on improving soil physical, chemical, and biological properties, providing essential plant nutrients to stimulate plant growth and yield (Liu et al., 2009; Yu et al., 2012; Cavagnaro, 2014; Xie et al., 2014; Molina-Herrera, Romanya, 2015; Srivastava et al., 2015, 2016; Wang et al., 2015; Ling et al., 2016). Rodriguez-Vila et al. (2016) found that organic amendments sustain soil properties by increasing OM, nutrient content, microbial activity and thus increase crop growth and yield. Previous studies (Galende et al., 2014; Mackie et al., 2015; Pena et al., 2015; Puga et al., 2015) proved that organic amendments help recover degraded soils. In a former study, Weber et al. (2014) described that MSW and SS have a great positive influence on soil properties as well as increase crop yields. Research has revealed that the Chinese used organic manure in agriculture more than 2000 years ago and the Greeks and Romans also used organic wastes in crop production (Goss et al., 2013). Gopinath et al. (2009) reported that manure can maintain soil fertility in organic farming systems and Papafilippaki et al. (2015) stated that the addition of MSW and OM increased nutrient contents and thus improved soil fertility and crop yield. A beneficial effect of SS management in agricultural crop production is to amend the soil was confirmed by Zoghlami et al. (2016). Moreover, Tampio et al. (2016) studied five different kinds of waste and proved that they enhanced plant growth by improving soil properties. Organic products originating from industrial processes can also be used for reclaiming degraded soils (Tejada, Gonzalez, 2006; Tejada et al., 2007).

The objective of this review was to summarize the effects of different organic wastes on physical, chemical, ok?and biological properties of soil and also plant growth and yield.

Organic wastes

In this review paper, from the wide range of organic wastes, the followings are considered as important wastes:

Municipal solid waste (MSW). The term 'municipal solid waste' means waste from households and other waste that is similar to waste from households. Nowadays, composted MSW is being popular in agriculture as a soil conditioner and fertilizer. MSW recycling for agricultural use in form of composting is evidently a better way of MSW disposal than e.g. landfilling, which is linked with some important economic and environmental issues, such as cost for landfilling; legislation to protect environment; use of chemical fertilizers, and capacity for household waste recycling (Mbarki et al., 2008). MSW is mostly used in agriculture to supply nitrogen and OM into the soil (Walter et al., 2006; Hargreaves et al., 2008).

Biowaste. It represents a diverse range of organic waste materials produced by a variety of sources. It includes commercial waste, garden waste, household waste, as well as MSW (Rigby, Smith, 2013). It is also called biodegradable waste (Puig-Ventosa et al., 2013; Rigby, Smith, 2013) or source separated waste (Sundberg et al., 2011). BW is an organic fraction (ca. 25–65%) of MSW (Lopez et al., 2010; Pognani et al., 2011; Lleo et al., 2013; Puig-Ventosa et al., 2013). Recently BW management has become a global challenge because it is associated with some important environmental issues. Therefore, an appropriate method to manage BW enabling its environmentally safe disposal or reuse is desirable (Gross et al., 2012).

Food waste. This category includes uneaten food and food preparation leftovers from residences, commercial establishments such as restaurants, institutional sources like school cafeterias, and industrial sources like factory lunchrooms. Usually, most of the foodwaste is disposed of in a landfill (Zhang et al., 2007). Now it is a public concern for recycling foodwaste as the environmentally sound as well as cost-effective use of the biomass (Zhang et al., 2007; Takata et al., 2012). Foodwaste also contains important nutrients and it would be more efficient to re-use them in agriculture. Composting is a well-known method to manage foodwaste for converting material like a hygienic, humus-rich, and stable product that acts as soil conditioner as well as growth promotor for crop plants (Lee et al., 2004; Stabnikova et al., 2005; Kim et al., 2006).

Sewage sludge (SS). It is an inevitable by-product of urban wastewater treatment which contains large amounts of nutrients, OM, and also some trace elements (Li et al., 2013). SS can be used as a fertilizer (Du et al., 2012) through composting or modifying and could be utilized as soil amendment to increase the content of soil OM, which plays a crucial role in improving the properties of soils (Li et al., 2013) and degraded soils reclamation (Pognani et al., 2011).

Farm manure or manure. Farm manure is a heterogeneous composted organic material, composed of a mixture of dung, crop residues, and/or household sweepings at varying stages of decomposition. It is an important organic resource for sustainable agricultural production in many countries. It promotes sustainability in agriculture by different ways: long-term positive effects on soil properties; recycling plant nutrients within a farm; possible substitution of readily available organic inputs for chemical fertilizers; improvement

Table 1. Organic matter, Zn and Cu content of clay and sandy soil after 6 months of experiment (M b a r k i et al., 2008)

Unit	Organic matter (%)	Zinc	Copper
		mg kg⁻¹ dry weight	
Clay soil (CS)	2.94±0.15c	38.6±4.9c	27±2.3c
CS + *MSW40	3.66±0.30d	43.5±4.7cd	28.7±1.4cd
CS + MSW80	4.92±0.29e	52.1±8.6e	33.9±3.4e
CS + MSW120	5.16±0.33e	49.2±9.5de	31.9±4.7de
Sandy Soil (SS)	0.95±0.14a	7.2±2.3a	4.2±1.7a
SS + MSW40	1.77±0.09b	7.4±4.2a	3.46±2.5a
SS + MSW80	2.21±0.25b	14.3±2.8ab	9.5±5.3b
SS + MSW120	2.35±0.58c	21.5±9.8b	7.5±4.4ab

*MSW = Municipal Solid Waste were added @ 0, 40, 80, 120 t ha^{-1} of compost.

Means of six replicated pots and standard errors (p = 0.05).

in crop yield and quality into the soil (M o t a v a l l i et al., 1994).

Effects of wastes on soil physical properties

Soil physical properties can be improved by the incorporation of optimum OM level waste. For example, in the saline-sodic soil of cold regions, soil physical properties were improved by the addition of MSW, which helped reduce bulk density, increase aggregate stability and permeability, and thus restore this type of soil (A n g i n et al., 2013). Similarly, soil organic carbon (SOC) also stimulates hydraulic conductivity by improving aggregate stability and porosity of agricultural soils (E i b i s c h et al., 2015) which can be managed by the MSW application (M a h m o o d a b a d i et al., 2013). The addition of manure showed similar trends in reducing bulk density, increasing porosity and SOC content and thus soil physical properties improvement (G o p i n a t h et al., 2009; L i u et al., 2009; A c h i b a et al., 2010). In line with this statement, Y a z d a n p a n a h et al. (2016) proved that the incorporation of MSW at 30 Mg ha^{-1} increases SOC content in soil. They also observed that water stable aggregates and total porosity were significantly increased and thus influenced the soil texture. In line with this study, M e e n a et al. (2016) observed that a combined use of MSW and a mineral fertilizer increases SOC. According to B l a n c h e t et al. (2016), with the addition of manure, SOC increased significantly (by 6.2%) compared to a mineral fertilizer application. Similar results were also found by S a b i r, Z i a - u r - R e h m a n (2015) and N e s t et al. (2016). It has been proved that organic additives reduce the compactness of soil by improving soil aeration and water penetration (K u n c o r o et al., 2014). Previously, the same was also confirmed by W a l t e r et al. (2006) and M b a r k i et al. (2008) with the application of MSW. Long-term application of MSW compost develops a good soil structure (G a r c i a - G i l et al., 2004). It improves water holding capacity and increases aggregate stability of soil through the formation of cationic bridges thereby improving the soil structure. H e r n a n d o et al. (1989) proved that the application of MSW at the rates of 30 and 60 Mg ha^{-1} increased the aggregate stability of soil. S c o t t i et al. (2016) investigated the impact of organic amendments on soil quality and found that with the incorporation of MSW and manure, after one year of study, SOC increased by 36% and 25%, respectively, compared to the control plot (Fig. 1).

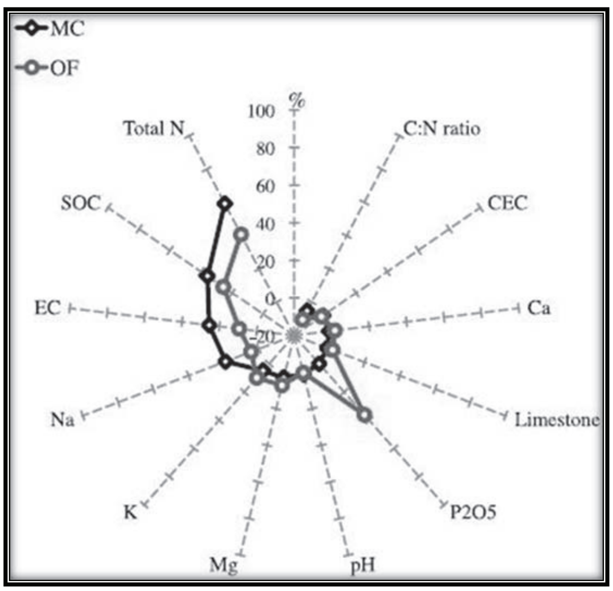

Fig. 1. Physical and chemical soil properties, at the end of the study (adapted from S c o t t i et al., 2016)
(Total N= total nitrogen; C:N ratio= Carbon and Nitrogen ratio; CEC= Cation exchange capacity; Ca= Calcium; P2O5= Available P; Mg= Magnesium; K= Potassium; Na= Sodium; EC= Electrical conductivity; SOC= Soil organic carbon)

The addition of MSW contributes to the OM content increase in soil (Table 1). Several authors (Hernández-Apaolaza et al., 2005; Walter et al., 2006; Madrid et al., 2007; Melero et al., 2007) proved that OM in soil is increased with the addition of compost of different wastes. For example, Table 1 shows that the highest values of OM were noted in clay soil treated with 120 t compost per ha. In sandy soils, the OM increased with increasing the level of MSW too. Numerous researches have proved that BW compost improves soil structure and OM content (Erhart et al., 2005; Hartl, Erhart, 2005; Rigby, Smith, 2013). For instance, in Germany, during a long-term investigation, Emmerling et al. (2010) observed that all parameters related to soil quality were improved by the BW compost application. In Pakistan, Mahmood et al. (1997) evaluated the effect of manure on the wheat-maize cropping system in a long-term (10 years) experiment and concluded that the application of manure improved soil properties by increasing soil OM. Shukla et al. (2008) reported that in India, the application of bioagents-amended manure improved soil porosity and reduced bulk density. Molina-Herrera, Romanya (2015) examined the synergistic and antagonistic interaction of organic amendments on soil and concluded that manure built up humus in soil and thus restored the soil. There was a remarkable amount of the OM content in soils treated with different doses of composted SS. The increased values of OM content in soils were positively correlated with the increasing SS application doses initially (control < 5% < 10% < 15% < 20%) (Fig. 2). Similarly, Fuentes et al. (2010) found that the SS application increased the OM content in soil. Casado-Vela et al. (2007) stated that lower values of the OM content in soils can be attributed to faster mineralization rates due to higher temperatures.

Haynes, Naidu (1998) reported that organic wastes were known to improve soil physical properties. For example, the authors confirmed that the application of organic manure helped improve OM content as well as water holding capacity, porosity, infiltration capacity, hydraulic conductivity, and water stable aggregation and reduce bulk density and surface crusting. Organic manure improves physical properties by increasing microbial activity in soil. Previously, Metzger, Yaron (1987) described that bulk density and water holding capacity of soil are greatly influenced by SOC of organic wastes. In line with this statement, Khaleel et al. (1981) described that with increasing SOC decreased the bulk density and increased water holding capacity of soil. Weil, Kroontje (1979) found that the addition of poultry manure resulted in higher infiltration rates in soil. Moreover, the incorporation of organic wastes also positively influenced other physical properties – increased aggregate stability, hydraulic conductivity, decreased surface crusting, runoff volumes. However, organic manures application should follow the recommendations, because they have some negative impacts on soil physical properties may occur including surface crusting, increased detachment by raindrops, decreased hydraulic conductivity, cease of water-repellent properties, etc. as reported by Haynes, Naidu (1998). Debosz et al. (2002) and Whalen et al. (2003) stated that manure and SS are well known to positively impact soil structural stability due to the presence of humic acid (Sander et al., 2004). The humic acid stmulates the aggregate stability by one or both of the following mechanisms: (*i*) making a bridge between soil clay platelets through the formation of adhesive films (Sander et al., 2004); and (*ii*) by inducing hydrophobic conditions and thus increasing aggregate resistance to slaking (Piccolo, Mbagwu, 1999). To support this statement, Mamedov et al. (2014) evaulated the effects of three different types of wastes with chemical amendments on aggregate stability of three types of soil before and after subjecting the soils to six rain storms. They found that the addition of organic wastes remarkably improved macro-porosity and the stability of macro-aggregate.

Effects of wastes on soil chemical properties

Organic wastes such as MSW, manure, BW, FW, and SS are good sources of plant nutrients and influence chemical properties of soil. Castro et al. (2009) reported that organic amendments increase macronutrients in soil and Fuentes et al. (2010) found that the SS application increased electric conductivity (EC) and nutrient availability of soil, such as available N and P contents was increased in soil. In a 50-year long-term study, Blanchet et al. (2016) found that manure application improved chemical properties of soil and provided a significant amount of P and K and similar results were also obtained by Sabir et al. (2015). Achiba et al. (2010) also observed that it contributed to increasing the N content in soil. Gopinath et al. (2009) conducted a two-year study and observed that

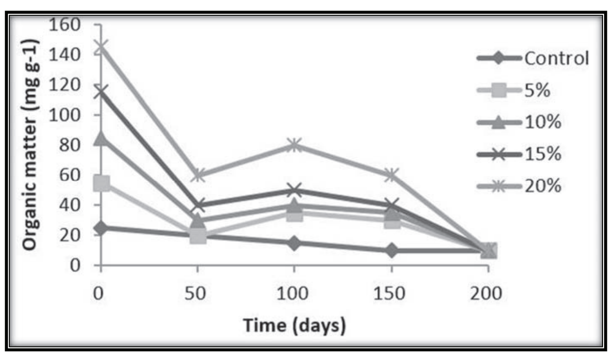

Fig. 2. Evolution of organic matter in soil treated with different levels of sewage sludge with time (adapted from Li et al., 2013)

manure significantly contributed to increasing soil pH if compared to chemical fertilizers. S c o t t i et al. (2016) examined the impact of MSW and manure on soil quality and found that in the soil treated with MSW and manure, after one year of study, total nitrogen was increased by 60 and 40%, respectively, compared to the untreated soil. They also observed that EC and exchangeable Na were increased under MSW by 25% and 19%, respectively, over the control treatment. Moreover, with the addition of manure, available P content was by 36% higher than in the untreated soil. On the other hand, other chemical parameters of soil like CEC, pH, limestone, exchangeable Ca, Mg, and K contents were not influenced by both types of amendments (Fig. 1). The availability of N in soil varies with the time after application of MSW compost. It has been estimated at 10% in the first year after the application of MSW compost with some reports of N release in the second year following the application. It was also reported that 21% (B h a t t a c h a r y y a et al., 2003b) to 22% (H a r g r e a v e s et al., 2008) of the total N was recovered. Some previous studies (B h a t t a c h a r y y a et al., 2003b; M o n t e m u r r o et al., 2006; W a l t e r et al., 2006; Z h a n g et al., 2006; H a r g r e a v e s et al., 2008) showed that the addition of MSW compost in soil increased N, P, and K contents from 1.7 to 1.76 g kg^{-1} for N, 6.2 to 7.3 g kg^{-1} for P, and 0.11 to 0.13 g kg^{-1} for K, respectively, after a two-year application of MSW compost in wetland rice field (B h a t t a c h a r y y a et al., 2003b). Similar results were also found by W a l t e r et al. (2006) in a five-year-long experiment and by M o n t e m u r r o et al. (2006) in a three-year trial. M b a r k i et al. (2008) reported that N and P contents in plant shoots were highly dependent on the dose of MSW compost. Indeed, the N and P contents in shoots of *Medicago sativa* were by 1.2–1.7 times and the growth yield was by 1.2 times higher than without amended treatments, comparing cuts at 60 and 150 days. For all treatments (40, 80, and 120 Mg ha^{-1} MSW compost), shoot biomass and contents of N, P, and K increased 3–5 fold from the first harvesting (at 60 days) to the fourth harvesting (at 150 days).

In the Philippines, C u e v a s (2009) conducted a pot experiment and reported that the addition of BW compost at 16–46% significantly increased pH (from 4.2 to 6.8), water-holding capacity (by 20%), and also changed CEC (from 15 to 41 $cmol^{+}$ kg^{-1}) if compared to unamended grassland soil. In Korea, L e e et al. (2004) observed that pH, EC, total-N, OM, and available P were generally increased at six weeks after the application of foodwaste compost (Table 1). N e s t et al. (2016) reported that after a long-term (40–50 years) experiment with manure application, extractable P was increased 2–4 times if compared to a mineral P fertilizer application. The authors proved the application of manure to be more effective in increasing soil pH and P availability than the mineral fertilizer. Moreover, S a b i r et al. (2015) reported that CEC and buffering capacity were increased with the addition of manure to soil. In contrast, Fe and Ca contents were not influenced by manure application. In China, Y a n et al. (2016) studied for nine years a tomato double cropping system with the application of manure and N application in a greenhouse on the transformation and transport of soil P. The authors confirmed that a high dose of manure remarkably increased available P in soil. M e e n a et al. (2016) conducted a field experiment in India, they examined the combined use of MSW compost, gypsum enriched

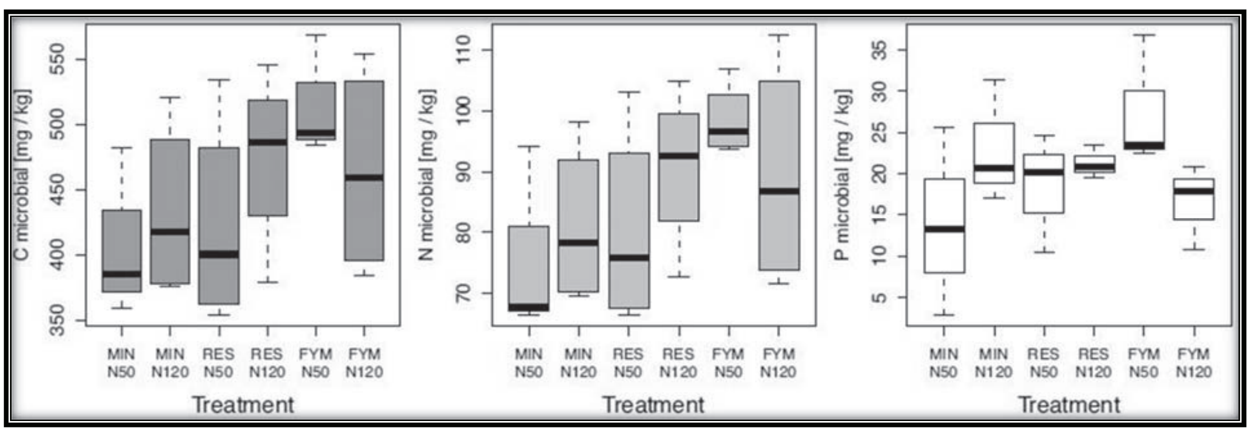

Fig. 3. Boxplots of carbon (C), nitrogen (N), and phosphorus (P) content in microbial biomass in the plough layer (0–20 cm) for the different treatments. Boxes are median and 25th and 75th percentiles; whiskers are non-outlier ranges (adapted from B l a n c h e t et al., 2016) (MIN=mineral fertilizers alone; RES=crop residues incorporation with reduced mineral fertilization; FYM=cattle farmyard manure; N50 and N120= Nitrogen application rate 50 kg and 120 kg/ha)

compost, rice straw compost, and chemical fertilizers for improving biological and chemical properties of saline soil in a mustard–pearl millet cropping system. They found that the MSW application with mineral fertilizer increases noticeably the availability of N, P, and K in soil over control plot after mustard and pearl millet harvest. W a n g et al. (2015) found that organic wastes stimulate the availability of NO_3-N in soil as reported by S r i v a s t a v a et al. (2015). M o l i n a - H e r r e r a, R o m a n y a (2015) evaluated the synergistic and antagonistic interactions between unstabilized manure and stabilized manure of contrasted stability, nutrient availability, and soil OM in the regulation of C mineralization. According to J a n et al. (2011), manure reduced the toxicity effect of some heavy metals in soil and plants. S i n g h et al. (2007) found that manure mitigated chromium toxicity in spinach, K h u r a n a, K a n s a l (2014) reported that cadmium was reduced in a maize field after the application of farm manure. In Nigeria, M g b e z e, A b u (2010) reported that the addition of farm manure increased pH in soil from 9.4 to 10.39.

Effects of wastes on soil biological properties

There is evidence that organic amendments influence remarkably the biological properties of soil. Accordingly, M e e n a et al. (2016) observed that a combined use of MSW and chemical fertilizers increased microbial activities, which was also observed by C a s t r o et al. (2009). Similarly, W a n g et al. (2015) observed that microbial activities can be increased by the addition of organic wastes. The authors confirmed that after harvesting the mustard and pearl millet the microbial biomass C was increased by 50 and 56% compared to an untreated plot. S a b i r et al. (2015) stated that soil biological activity was enhanced by the application of manure. Similarly, B l a n c h e t et al. (2016) found that the addition of manure increased microbial C, N, and P (Fig. 3). Enzymatic activities are increased due to the application of organic wastes. S c o t t i et al. (2016) compared the effect of MSW compost and manure on soil quality. They reported that phosphomonoesterase (+ 260% and + 219%), β-glucosidase (+ 180% and + 74%), and fluorescein diacetate hydrolase (+ 160% and + 101%) enzymes were increased for MSW and manure, respectively. Whereas, urease enzyme was increased only in plots treated with MSW compost (Fig. 4).

Y a z d a n p a n a h et al. (2016) investigated the relationship between the soil properties and hydraulic conductivity in response to different rates (0, 10, and 30 Mg ha^{-1}) of MSW and alfalfa residue under field conditions. The study revealed that microbial respiration in the soils was increased with the addition of MSW if compared to an unfertilized field. This result agrees with the observation of Y a z d a n p a n a h et al. (2013) who found that organic amendments enhanced microbial activity in soils. The study also revealed that microbial respiration was increased in both soils up to the highest dose of organic fertilizers and it was higher in clay loam soil. MSW can contribute by increasing the microbial activity (G a r c i a - G i l et al., 2004). For instance, incorporation of MSW compost at the rates of 2.5, 10, 20, and 40 t ha^{-1} increased soil microbial biomass C and soil respiration (B h a t t a c h a r y y a et al., 2003a). In a long-term experiment, additions of MSW compost at 20 and 80 t ha^{-1} increased microbial biomass C by 10% and 46% over the control, and the process continued for 8 years after the application (G a r c i a - G i l et al., 2000). M o l i n a - H e r r e r a, R o m a n y a (2015) evaluated the synergistic and antagonistic interactions between unstabilized manure and stabilized manure of contrasted stability, nutrient availability, and soil OM in the regulation of C mineralization. The results showed that with manure incorporation the soil microbial activity raised 4–7 times if compared to the control treatment. With the addition of SS, soil biological parameters such as microbial communities and enzymatic activities (dehydrogenase, phosphatase, protease, and cellulase) are stimulated as reported by Z o g h l a m i et al. (2016). The addition of manure has been proved to improve the population of ammonifying and nitrifying bacteria in soil (S h u k l a et al., 2008). BW compost is known to improve soil biological properties. For example, microbial populations (bacteria and fungi) increased by 16% in a soil treated with BW compost (C u e v a s, 2009; E m m e r l i n g et al., 2010) so as the enzyme activities (E m m e r l i n g et al., 2010). R a s u l et al. (2008) reported that the addition of compost increased microbial biomass C with increasing amounts of C

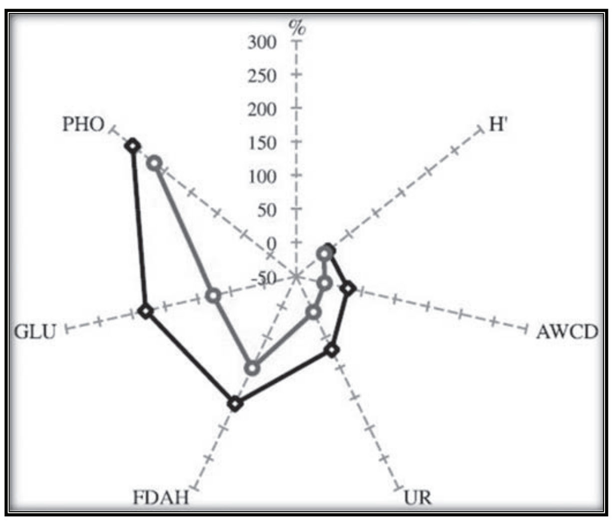

Fig. 4. Biological properties of soil with municipal solid waste (red line) and other compost addition at the end of the study (adapted from S c o t t i et al., 2016)
(AWCD= BIOLOG EcoPlate™; UR= urease; FDAH= fluorescein diacetate hydrolase; GLU= β-glucosidase; PHO= phosphomonoesterase)

Table 2. Effect of FYM on growth, yield and harvest index of wheat under moisture stress condition (adapted from Jan et al., 2011)

FYM (Mg ha^{-1})	Plant height (cm)	Grains $spike^{-1}$	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
0	65 c	14 c	850 c	2720 d	23 c
10	66 c	15 c	937 c	2892 c	24 c
20	69 b	18 b	1247 b	3087 b	28 b
30	75 a	21 a	1470 a	3272 a	30 a
$LSD_{0.05}$	2.66	5.35	129	136.8	1.28

added. Lee et al. (2004) found that the addition of 2700 kg foodwaste compost per 10 acres improved the soil chemical properties and stimulated the soil microbial activity. A three-year investigation on two Mediterranean agricultural soils proved that FW compost increased soil respiration, fluorescein diacetate hydrolysis, phosphatase and arylsulphatase activities at both sites (Iovieno et al., 2009).

Effects of wastes on plant growth and yield

Organic wastes not only influence soil properties, but also play a great role in the growth and development of plants and thus improve agricultural productivity. This observation corresponds with Lakhdar et al. (2011) reporting that the application of MSW at 40 t ha^{-1} in growing *Mesembryanthemum edule* enhanced nutrient (N, P, and K) uptake, which led to the increase of plant biomass and relative growth rate (+ 93% on average) as compared to the control. These results are supported by Papafilippaki et al. (2015) who concluded that mature MSW compost stimulated the yield of spiny chicory and increased bioavailability of trace elements (Cu, Zn, Fe, Mn, Cr, Ni, Pb, Cd) in soils. Mbarki et al. (2008) reported that shoot and root growth response to the MSW applications was very low by cutting at 60 days, and it increased with the duration of the experiment. Ryegrass yields reportedly increased with the addition of MSW (Hargreaves et al., 2008). Furthermore, the addition of MSW compost at approximately 45 and 90 Mg ha^{-1} increased the yield of timothy and red clover forage crops (Zheljazkov et al., 2006). The plant uptake of P was increased by the addition of MSW compost in different crops such as strawberries, tomato, spinach, ryegrass, potatoes, and Swiss chard (Zheljazkov, Warman, 2004; Shanmugam, 2005). Moreover, the S uptake of forage crops (timothy and red clover) was also increased when MSW compost was applied in soil compared to control (Zheljazkov et al., 2006).

Andriamananjara et al. (2016) reported that P availability increased in acid and weathered soils with the application of organic amendments. They confirmed that manure with triple superphosphate (TSP) application to irrigated rice soils increased rice grain yields by 4.2 Mg ha^{-1} over the control. The study also revealed that the total P uptake in grain and straw was increased with the total P application. The positive effects of waste on plant growth were also proved by Tampio et al. (2016). The authors evaluated the agronomic characteristics of five urban waste types and registered by 5–30% higher ryegrass yields. During a three-year field experiment with two different MSW composts were used by Weber et

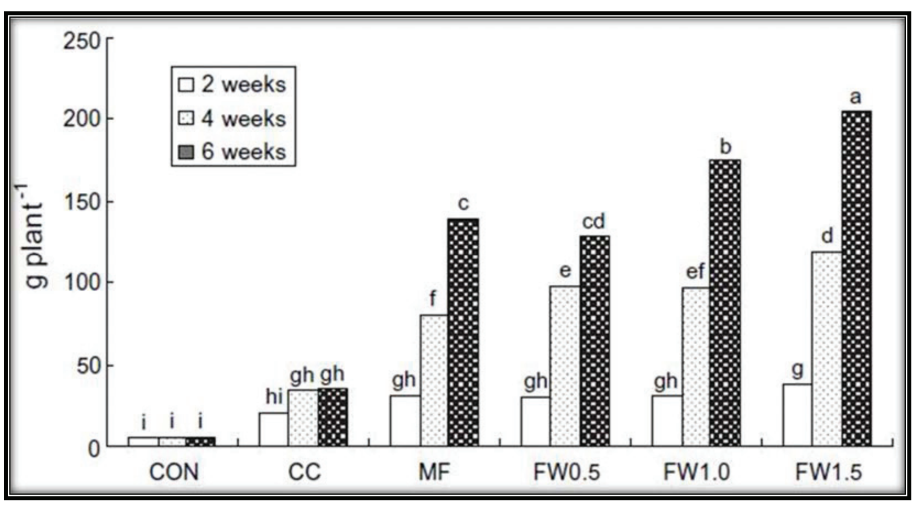

Fig. 5. Fresh weight of lettuce in pots as affected by commercial compost (CC), mineral fertilizer (MF), and food waste compost (FWC) (Lee et al. 2004) FWC 0.5, 1.0, 1.5 = FWC with MS® (Miraculous Soil Microorganisms) at 900 kg, 1800 kg, and 2700 kg per 10 acres (4ha) Means with the same letter(s) are not significantly different at $p<0.05$ when compared by LSD. Treatment means are the average of three replicates.

al. (2014) in their effects on soil properties, nitrogen availability to plants, and its uptake efficiency. The study revealed that the plots with compost application gave yields equal to the plots fertilized with chemical fertilizers. Debiase et al. (2016) reported that incorporated organic wastes gave 32% higher yields than an unfertilized field. Moreover, the authors confirmed that SS application ensured 12% higher yield compared to MSW addition of a wheat field. These amendments not only increase crop yields, but also minimize the risk of nitrogen leaching from the soil. Castro et al. (2009) also found the similar results with the addition of SS in all crop seasons. The addition of manure improved the growth of *Chenopodium album* L. and reduced the heavy metal content in contaminated soil (Sabir et al., 2015).

According to Rehman et al. (2016), plant height and root length were increased with the addition of farm manure over the control. The plant height, root length, and dry weight of shoot were increased by 18, 19.5, and 5.3%, respectively. Matichenkov, Bocharnikova (2016) conducted a greenhouse test and described that the root and shoot biomass of barley was increased by 20 and 16% with the application of disinfected untreated SS, whereas with disinfected and detoxified SS it was increased even by as much as 80 and 61%. Under a greenhouse condition, Ouni et al. (2014) examined the negative impact of soil salinity on *Polypogon monspeliensis* (L.) Desf. and *Hordeum vulgare* L. They used MSW compost for their study and shoot biomass reportedly increased in both species by up to 47% and the number of leaves per plant and root length. In a pot experiment, Gwenzi et al. (2016) examined the effects of SS and its biochar on soil chemical properties, maize nutrient, and heavy metal uptake, growth and biomass partitioning on a tropical clayey soil. The study revealed that plant growth and yield of maize including nutrient uptake increased significantly over the control pot. Fuentes et al. (2010) found that SS application helped the seedlings survive and stimulated plant growth. Lee et al. (2004) found that the application of FW compost at 2700 kg per 10 acres led to significantly higher fresh weight of lettuce than in control and commercial compost treated soils (Fig. 5). In Pakistan, Jan et al. (2011) reported that manure application improved plant growth and increased yield of wheat under moisture stress condition (Table 2). These results were supported by Mahmood et al. (1997), Blair et al. (2006), and Kundu et al. (2007). In India, Shukla et al. (2008) reported that the application of manure along with bioagents to sugarcane ratoon crop removed the highest amount of N (165.7 kg ha^{-1}), P (24.01 kg ha^{-1}), and K (200.5 kg ha^{-1}) from the soil. They also noted that manure increased ratoon cane (70.2 Mg ha^{-1}) and sugar (7.93 Mg ha^{-1}) yields if compared to the control. Mohsin et al. (2012) studied the effect of manure along with chemical fertilizers on spring maize and found that the application of 50% N from manure along with 50% N from mineral fertilizers produced longer cobs (18.57 cm), maximum cob weight (216.4 g), maximum 1000-grain weight (279.1 g), higher grain yield (5793 kg ha^{-1}), and maximum biological yield (14 880 kg ha^{-1}).

Table 3. Problems resulting from slurry high dry matter and carbon content (adapted from, Novák and Bönischová-Franklová, 1980)

Problem
Storage
Crust formation and sedimentation of solids
High energy consumption for pumping and mixing
Emission of N_2O, CH_4 and odor
Spreading
NH_3 losses
High technical effort for even and low emission application
Suffering from plants due to scorching by slurry
Fertilization
Less effective than mineral fertilizer
Effect less predictable than from mineral fertilizer
N immobilization in the soil
Denitrification and subsequent N_2O emissions

Limitations of organic wastes application

However, the application of organic wastes for agricultural purposes has also some disadvantages. Some important issues are discussed below.

According to Scotti et al. (2016), due to decomposition of wastes the soil salinity was increased, because of direct solubilization of ions that released soluble mineral nutrients in soil In line with this statement, Zoghlami et al. (2016) observed that the SS application increased soil salinity and also phytotoxic heavy metals (namely Cd and Cr) contents in soil. Nest et al. (2016) reported that the addition of manure to soil triggered significant P leaching. In the case of MSW and SS addition to soil, various kinds of harmful components, especially heavy metals are entered into soil as well as into plants (Debiase et al., 2016). Similar results were also found by Papafilippaki et al. (2015) who observed the heavy metal risks with the addition of MSW to soil. In addition, the application of MSW decreased EC value in the long-run (Hargreaves et al., 2008). Achiba et al. (2009, 2010) found similar types of heavy metals accumulation with the application of MSW. Sometimes the addition of MSW was responsible for decreasing enzyme activities. For example, protease activities were decreased with the addition of MSW compost (Garcia-Gil et al., 2000; Crecchio et al., 2004). Furthermore, Garcia-Gil et al. (2000) noted that the addition of MSW compost in the same amount inhibited the activity of urease and protease. The application of manure to agricultural land is also connected with some problems, mainly of technological nature (Novak, Bonischova-Franklova, 1980) as related handling or storage as presented in the Table 3. Before the field application, the animal slurry must be homogenized in condition. With a high dry matter content of a slurry, NH_3 emissions increased after the application to soil (Amon et al., 2006). According to Balladares et al. (2013), in the Philippines, the addition of 2.5 kg m^{-2} BW compost significantly improved all growth parameters of *Aster ericoides* L. which showed 100% survival, bolting, and flowering under these conditions. In a pot experiment of Norway, Haraldsen et al. (2012) observed that the application of BW gave the same N, P, and K uptake as the fertilizer Fullgjødsel at both 80 and 160 kg N ha^{-1} under greenhouse condition.

Although the SS provides some essential plant nutrients, it also contains some harmful components such as heavy metals, organic pollutants, pathogenic microbes, and thus reduce soil function, environment health, even the food chain. The addition of lime-stabilized sludge in acidic soil may contribute to salinity by the addition of Ca^{+2} which hampers crop growth and development. During the application of SS, the soil type is another important influencing factor for bearing capacity for pollutants (Du et al., 2012).

CONCLUSION

The composting of organic wastes is the most common technology of recycling and disposing them easily in a safe way. The present review has presented that organic wastes can improve soil physical and chemical properties, increase soil biological activity, and sustain soil health. Organic wastes increase the OM content of soil, thus its water holding capacity, porosity, infiltration capacity, hydraulic conductivity, and water stable aggregation and reduce bulk density and surface crusting. They also provide essential plant nutrients and maintain soil fertility and thus stimulate crop growth and yield. By increasing microbial activity, the organic manures enhance enzyme activities, microbial respiration and thus increase nutrient availability for agricultural crops. Moreover, they also reduce toxicity of some heavy metals such as Cd and Cr. It may be concluded that organic wastes from different sources can be used for improving soil health (properties) and stimulating plant growth and yield. On the other hand, organic wastes have also some detrimental impacts on soil. With the high manure application dose, surface crusting and decrease in soil hydraulic conductivity may occur. In addition, Na^+ release aggravates soil salinity; sometimes harmful heavy metals may be released. Therefore, it is necessary to determine the proper application doses of these organic by-products to avoid the negative impacts on soil, environment as well as human health.

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