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Review Article

COMPOSTING : A GREEN TECHNIQUE TO PREVENT ENVIRONMENTAL POLLUTION

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Abstract

In order to fulfill the increasing demands of the teaming millions for food security, the reckless use of synthetic fertilizers and frequent burning of agricultural wastes (stubble) has also increased. The repercussions of these anthropogenic activities are pollution of soil, water and air, which has simultaneously culminated into health issues. Although, agriculture alone contributes to 17–18% of Indian GDP but also, generates 350 million tonnes of waste every year. Crop waste (stubble) burning releases several noxious gases (CO_2, CH_4, NO and SO_2) and particulate matter that pollute the environment. Composting of agriculture waste and organic farming are eco-friendly, feasible, cost-effective, economical, green-techniques which ensures better yields and sustainable agriculture without harming the humans, livestock and the environment. This review discourages the use of chemical fertilizers and stubble burning and encourages composting of food and agriculture and agro-industrial waste as a green strategy towards sustainable agriculture and pollution free environment.

Key words: Agriculture, Fertilizers, Stubble, air pollution, Compost

Introduction

Household, municipal, agricultural and agro-based industrial waste management has been a challenge in the developed, developing and underdeveloped countries. Compared to rural areas, the urban areas having high population density have the problem of solid waste management. The global annual municipal waste generation is approximately 1.3 billion tonnes. It is expected that by 2025 this figure shall rise up to 2.2 billion tonnes per year (Karak *et al.*, 2012). The few conventional strategies like incineration, landfills, sanitary landfills, incineration plant contribute to various types of pollution (air, soil and water) that culminate in health hazards (Koul and Taak, 2018). However, interest in disposal strategies that take recycling (reduce-reuse-recycle) into account has increased in recent years (Kuo *et al.*, 2004).

Impact of chemical fertilizers on environment

Agricultural revolution in the late 1960s that increased the agricultural production worldwide and fulfilled the demands for food of the growing population caused not only an increase in the crop-production per unit area, but also enhanced the application of synthetic fertilizers in agricultural fields. In agricultural fields low soil fertility is one of the key factors hampering the crop production (Li and Wu, 2008). A huge number of chemicals fertilizers, pesticides, herbicides are used in agricultural fields in order to achieve more and more production per unit area. But, using high doses than the recommended of the inorganic fertilizers leads to various environmental and health problems (soil, water, air pollution), reduces food quality, soil degradation, micronutrient deficiency, toxicity to various useful living organisms and also affects the crop-production cost etc. No doubt, synthetic fertilizers are beneficial to the plants as they quickly fulfill their nutrient requirements than the organic fertilizer but they do have negative impact on both the environment and human health, which is not at all acceptable.

When applied in the fields these chemicals reach the water bodies by three main ways: drainage, leaching and surface flow. For instance, due to microbial activity, nitrogen is oxidized to nitrate; comparatively high percentages of applied N can be leached or eliminated from the root zone into the surface and groundwater. Plants use only up to 50% of the applied N fertilizer, 15-25% react with organic compounds in clay soil, 2 20% volatilize and the remaining 2-10% interact with surface and groundwater. Nitrate, the basic component of fertilizer and the most common source of dissolved nitrogen found in groundwater, is the key parameter of water contamination. The high concentration of nitrates in water can contribute to numerous health problems and surface water eutrophication. The main toxic effect of 50 mg NO_3 /L concentrations of nitrate in drinking water exceed the bowel value in adults, digestive and urinary systems, inflammation is observed. Secondary toxicity, high concentration of nitrates in drinking water cause disease in infants called methemoglobinemia (McLaughlin *et al.*, 1996; Sharma and Singhvi, 2017). Water eutrophication that is caused primarily by an increase in N and P compounds is the major ill-effect caused by excessive use of fertilizers. It results in over growth of plants and algae in aquatic ecosystems. Bacterial degradation of the biomass results in oxygen consumption thus creating a state of low oxygen.

Overuse of chemical fertilizer for promoting crop productivity releases various toxic greenhouse gases (Savci, 2012). Due to these gases ozone depletion occurs that leads to exposure of humans to harmful ultraviolet rays. The greenhouse gases such as CO_2, CH_4 and N_2O are emitted during the manufacture of nitrogen fertilizers. Soil bacteria convert nitrogen fertilizer into nitrous oxide, a greenhouse gas. So the higher use of nitrogen fertilizers leads to the air pollution by releasing of nitrogen oxides. Other gases like carbon dioxide, methane and chloro-fluoro hydrocarbon are responsible for ozone depletion. Nitrous oxide is the third most powerful greenhouse gas after methane and carbon dioxide and its potential for global warming is 310 times more than that of carbon dioxide. Nitrous oxides are specifically associated with global warming, resulting in loss of ozone, resulting in atmospheric "breaks" thereby exposing animals and humans to UV rays. The release of ammonia from fertilized soils, released in the atmosphere, is then oxidized to form sulfuric acids, nitric acid, which comes down as an acid rain and destroys the trees, houses, animals, etc. Finally, all of these toxic pollutants contribute to climate change worldwide.

Soil is a biologically active, porous medium that has formed in Earth's uppermost crust. Soil is one of life's principal substrates, acting as a water and nutrient source and delivering many other ecosystem services. The overuse of inorganic fertilizers leads to acidification of the soil. Soil acidification causes many issues, such as decrease in the content of organic matter, death of useful microorganisms, inhibition of plant production, changes in soil pH, rising pests and even greenhouse gas emission (Koul and Taak, 2018). Due to soil acidity the phosphate up take rate by plants declines which results in stunted growth of the plant. Soil reduces its ability to store nutrients after declining of humus content in the soil. Emission of greenhouse gases from excess use nitrogen fertilizer harms the climate. Inappropriate use of nitrogen to crop fields affects the balance between essential elements, *i.e.* N, P and K and results in crop-yield-penalty. Sandy soils are more vulnerable to soil acidification than clayey soils. Continuous application of chemical fertilizer can lead to a toxic accumulation of heavy metals such as U, Cd and As in the soil. Such toxic heavy metals not only pollute the soil but also accumulate in fruits, vegetables and food grains. The accumulation of heavy metals also causes health problems, like triple superphosphate which is a fertilizer and has trace elements like cadmium and arsenic that accumulates in plant and through food chains it reach to human and cause health problems (Koul and Taak, 2018). Application of synthetic fertilizers without adequate soil-testing results in soil degradation, nutrient unbalance, soil texture damage and crop-yield-penalty (Savci, 2012).

Composting as a strategy to prevent environmental pollution

The biodegradation of organic waste substances from different sources into humic-substances is one of the most effective environment-friendly strategies in many countries. Composting is a controlled and natural microbe-mediated decomposition process that involves transformation of biodegradable organic substances into stable humic-substances which can be used as a soil amendment to enhance the growth of plants (de Bertoldi *et al.*, 1983). In this process the ratio of carbon to other elements remains balanced, thus prevents temporary nutrient immobilization (Schorth, 2003). One of the many advantages of applying compost to the soil is the slow release availability of nutrients into the soil for the plants. The composting can be onsite-composting, aerated-windrow- composting, aerated-static pile-composting, vermi-composting and in-vessel-composting.

Compost has a remarkable capacity to enhance soil properties as it improves the soil-structure in soils that are clayey and increases water-holding capacity in soils with a high sand content. Rapid composting of agriculture or vegetable waste along with additives can produce an inexpensive soil-conditioner for high-value crops, including seasonally grown vegetables and flowers (Barthod *et al.*, 2018; Virginia, 1997; Raabe, 2001). Applying compost improves soil fertility and the efficiency for cation exchange, which even reduces the need for fertilizer by ~50%.

As composting is a microbe-mediated process (involving bacteria, actinomycetes and fungi), therefore it is crucial to provide the congenial conditions for maximal microbial activity (decompose raw organic materials). The materials which are amenable to composting are household vegetable wastes, agricultural wastes agro-based industrial wastes, leaf litters, animal manure etc. (Li *et al.*, 2013; Bernal *et al.*, 2009). The factors which determine the health of the compost are (i) chemical composition of the raw- materials or feedstock's (carbon, mineral content, pH), (ii) physical size and form of feedstock's and pile porosity and (iii) population of composting species (microorganisms, mesofauna and macrofauna) (Azim *et al.*, 2018).

The performance (conversion efficiency) of the composting microorganisms is subject to the availability of air, carbon source, water (moisture) and the pH of the medium. The optimized conditions for efficient aerobic composting are: (i) C/N ratio of feedstock between 25:1 and 35:1, (ii) moisture content 45-60% by weight, (iii) available oxygen percentage > 5%, (iv) feedstock particle >1 inch, (v) pH between 5.5 and 8.5, (vi) The C/N ratio of the biomass : it is a crucial parameter for microbial activity. The C:N ratio of composting microorganisms ranges from 5:1 to 10:1. If C/N ratio of the feed stock is > 20:1 (poor in N), the microbes will immobilize the soil nitrogen in order to compensate their demand for nitrogen and thus make the soil deficient in nitrogen. When C/N ratio is < 20:1, then N_2 shall escape as NH_3 gas and causing odor into the atmosphere. The increasing order of the ease with which the raw-materials undergo composting is lignin < cellulose = chitin < hemicelluloses < carbohydrates (Richard, 1996; Tuomela *et al.*, 2000; Hubbe *et al.*, 2010).

Organic waste such as cow-dung, food-waste, vegetable waste, paddy straw, sugarcane trash (agricultural waste), agro-industrial waste etc. are amenable to coposting. The table 1 summarizes the reports on composting using various materials. The lignocellulosic material can be biodegraded by various fungi such as *Phanerochaete chrysosporium*, *Polyporus ostriformis*, *Pleurotus ostreatus* and *Trichoderma harzianum* table 2. Low moisture content affects the microbial activity and so the composting process. The moisture content controls the temperature and a low value generates more heat in the compost piles. However, higher moisture content (> 60%) indicates saturation of pore spaces with water and this creates anaerobic conditions and may even lead to foul odour. For aerobic composting, 5 percent oxygen is essential. The pH preference range of fungal decomposers is 5.5 to 8.0 while that of bacterial decomposers is 6.0 to 7.5. In poor, densely populated areas lacking water carriage sewerage systems the disposal of human excrement and the preparation of manures through composting are

Table 2: List of some microorganisms that mediate composting.

Bacteria	Actinomycetes	Fungi
Alcaligenes faecalis	*Actinobifida chromogena*	*Aspergillus fumigates*
Bacillus brevis	*Microbispora bispora*	*Humicola grisea*
B. circulans complex	*Micropolyspora faeni*	*H. insolens*
B. coagulans type A	*Nocardia sp*	*H. lanuginose*
B. coagulans type B	*Malbranchea pulchella*	*Psuedocardia thermophilia*
B. licheniformis	*Streptomyces rectus*	*Myriococcum themophilum*
B. megaterium	*S. thermofuscus*	*Paecilomyces variotti*
B. pumilus	*S. thermoviolaceus*	*Papulaspora thermophila*
B. sphaericus	*S. thermovulgaris*	*Scytalidium thermophilim*

Table 1: Reports on composting using various materials.

Composting Material	Composting duration	References
Pig carcasses + pig litter	Not available	Imbeah *et al.*, 1998
Winery waste : two residues (sludge and grape stalks) mixed in two proportions (1:1 and 1:2)	200-210 days	Bertran *et al.*, 2004
Food wastes and Bulking agents (pine wood shavings + wheat residue pellets + straw + cardboard + cattle feed)	Not available	Adhikari *et al.*, 2008
Cornstalks + saw-dust + spent mushroom substrate) to compost kitchen waste in the presence of oxygen	Not available	Yang *et al.*, 2013
Olive leaves + husk + sheep manure	90 days	Alfano *et al.*, 2008
Sheep manure + poultry manure + cow manure + olive mill waste + horse waste	200 days	Makni *et al.*, 2010
Olive mill solid waste + wheat straw + bean straw + chicken manure + waste wool + gypsum + ammonium sulphate + urea	33 days	Parati *et al.*, 2011
Olive pulp + olive leaves + wood chips + rice by-products	548 days	Komilis *et al.*, 2009
Domestic sewage sludge + winery waste + olive mill waste	Not available	Fernández *et al.*, 2010

perfectly complementary. Two critical needs, sanitation and nutrient conservation, can thereby be satisfied with hand labor. Such conditions in India led to the development in the 1920s of the Indore Process (Howard, 1940), which is still widely used (Bond and Straub, 1973). Although this can be taken as the first modern process, there are earlier records of systematized composting (Boussingault, 1845).

Composting process

Under natural conditions, the initial step of composting involves mechanical breakdown of raw-materials. The soil micro and macrofauna such as mites, springtails, sow-bugs, beetles, ants, nematodes and earthworms mediate this step through grinding or chopping. Composting is done by the action of microorganisms found naturally in the soils. As the conditions become congenial, the organic material gets colonized by soil bacteria, fungi, actinomycetes and protozoa and the composting process starts. Such mesophilic species function best in the temperature range of 50-113^{0}F.

The active composting phase

As the compost pile temperature rises, thermophiles (micro-organisms that can tolerate >113^{0}F) takeover. Temperature of the compost pile rises quickly to 130-150^{0}F within 24-72 h of pile-up. The temperature remains the same for several weeks (active-composting phase). The high temperature of the active "thermophilic" process destroys the pathogens (*Bacillus subtillus*, *Staphylococcus aureus*, *Escherichia coli*, *Clostridium botulinum*) and the phytotoxic compounds (Wichuk *et al.*, 2011). Here the demand for oxygen rises up which must be replenished through compost pile turning or passive/forced aeration Fig. 1.

Curing phase

When the active composting phase ends the temperature of the compost-pile declines to around 100^{0}F. At a low remperature the mesophilic microorganisms colonizes. At this stage the composting undergoes curing process. The oxygen consumption rate rises and compost-pile does not require turning up. The organic materials continue to decompose and get converted to biologically inert humic compounds (completed compost). Curing is a vital stage of composting which is often overlooked. If in the initial stages of composting adequate aeration and moisture is not present then the unfinished or immature compost pile requires a long curing phase. It is very important to remember that the immature composts contains high pH values, organic acid content, C:N ratios and salt content that is detrimental for the plant growth. As such there is no specific curing time. Ordinary

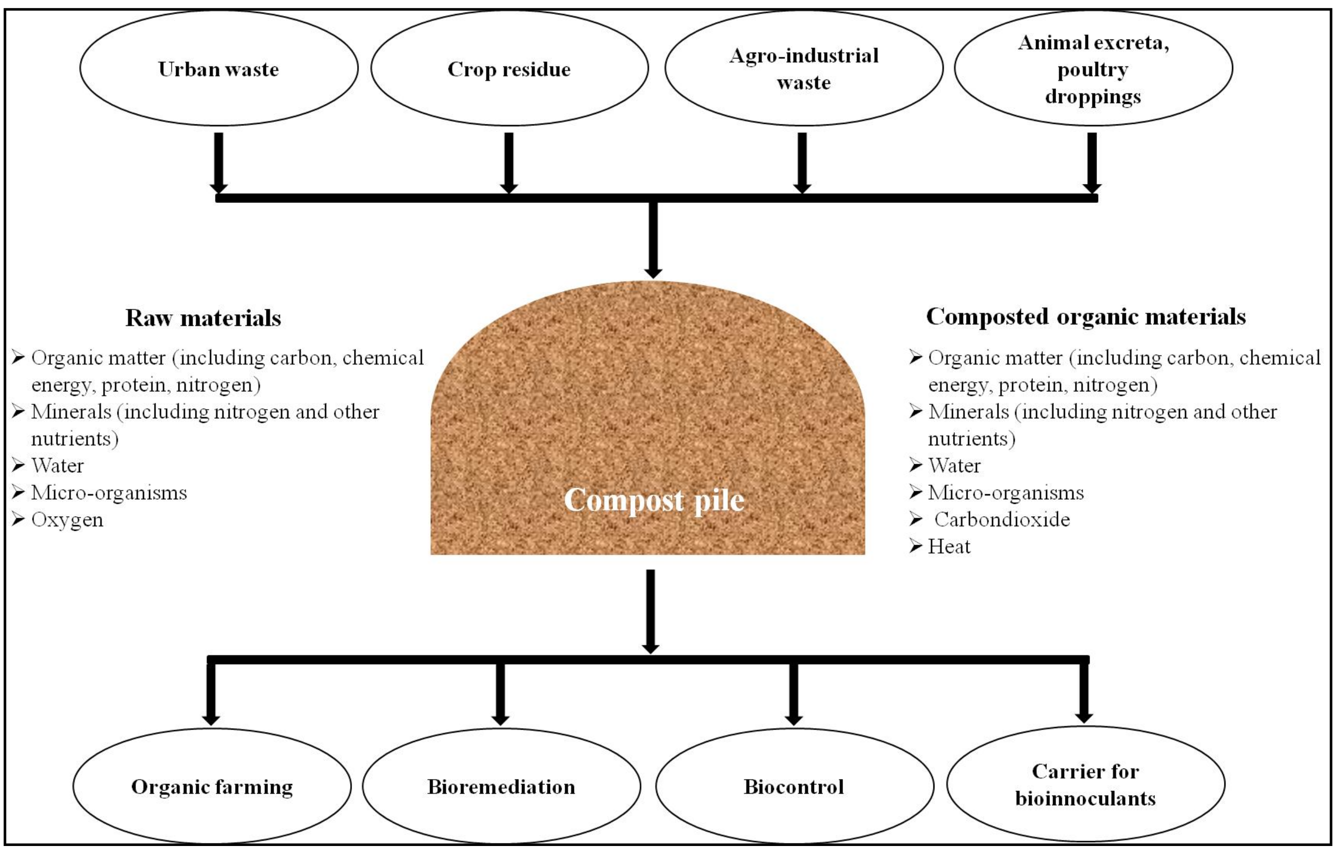

Fig. 1: Composting: a green technique.

commercial composting activities require one to four months and the gardener piles can cure for six to twelve months.

When does compost get ready?

The production of finished compost does not have a set date. It depends on composting process feedstock's used, aeration, moisture content, pH, C/N ratio of the feedstock, microbial consortia etc (Antil *et al.,* 2014). It may take 3 months or even 2years. Composting is said to be complete if the raw feedstock's does not decompose any more and is chemically and biologically stable (finished biological activity). The extent of humification decides the maturity of the compost (Agnew and Leonard, 2003; Anwar *et al.,* 2015). Moreover, the compost stability is easier to calculate than maturity, so majority of composters calculate either temperature or oxygen intake. Another observation towards 'stable compost' is that the central temperature of the pile remains ambient and oxygen concentrations remains > 10-15 percent for many days. It is necessary to know how to analyze the compost's maturity or stability, as stability is related to several chemical and biological properties and eventually the efficacy of the compost.

Profits from applying compost to soil

Compost is a special organic source of matter that improves the mechanical, physical and biological nature of soils. It increases water retention in sandy soil and promotes soil structure in clayey soils by improving surface relative quality. The application of compost to soil increases its fertility, cation-exchange-capacity, productivity and minimizes the fertilizer demands by 50%. The composted soils synergizes the microbical activity and becomes more resistant to pathogens (both soil and foliar). The improved microbial activity enhances the breakdown of pesticides and other synthetic agents. Modifications to composting reduce the heavy metals bioavailability an important quality to remediate polluted soils.

Conclusions

It is true that composting has a great scope in the plant growth and environment clean up. As aforementioned, composting is a simple, feasible, cost-effective, less-expensive, less- cumbersome and productive technique. It can be opted as an alternative business by the small-scale farmers, agro based industries, food-processing industries and budding entrepreneurs as an alternate source of income. The farmers can become self-sufficient in soil amendment (compost) and can ensure higher yields through this eco-friendly technique.

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Conflict of interest

The authors declare no conflict of interest.

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