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COMPOSTING - A Thorough Analysis of Different Approaches and Effectiveness Over Chemical Fertilizers

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ABSTRACT
Unethical and uncontrolled use of chemical fertilizers for economic benefits is leading to the degradation of environment by adversely affecting the soil quality and is proving to be detrimental to human health because chemically grown crops are exposing the human internally to fatal diseases that affects nervous systems, cause Cancer and many more to count. Hence, there is a need of development of new modified improved fertilizer which can take over the chemical fertilizers for this, Composting technique is proving beneficial because it can also tackle the problem of organic waste disposal as 50% of total waste products generated in India is of organic in nature. These huge lumps of organic waste matters are decomposed in the aerobic condition having proper aeration and get converted into nutrients rich mass after few days and become compost which is then used as an amendment for soil. The Compost formed is mostly dark, crumbled and free from foul smell. Compost helps in modifying the quality of soil, it is cheaper compared to chemical fertilizer, it is easy to made, it can solve environmental pollution problems, also improve yields and nutrient contents of crops. This paper consists of following discussions like different approaches of composting, benefits of compost, factors affecting compost, challenges faced by Composting and future trends

Keywords:- Compost, chemical fertilizer, soil quality, environment, organic waste.

INTRODUCTION
According to the latest report India's population stood at around 1.4 billion based on the official statement of World-o-meter Elaboration of Latest UN Data. Annually, Urban India produces about 42 million of municipal solid waste(MSW) that accounts to 1.15 lacs metric tons per day. MSW is expressed in kg/capita/day and is multiplied by total population of the region to obtain the total rate of MSW generated. Out of total MSW produced 90% are disposed off unscientifically into available land fillings and get dumped outermost barren land of the cities in uncontrolled manner(Sarkar et al., 2016) . This type of unmanageable dumping is hazardous for the environment as it is causing pollution and emitting greenhouse gases leading to Global Warming. Major challenge is the disposal and utilisation of MSW in proper way which can be achieved by converting MSW into Compost for making green manure thus solving one of the problems of harmful effect of uses of Chemical fertilizers. Composting is a biochemical process taking place in aerobic condition where thermophilic microorganism i,e the bacteria helping

decomposition of organic waste around optimum temperature of 113°F to 160°F. Thermophilic bacteria are Thermus Thermophilus, Bacillus SPP and Hydrogenobacter SPP (www.google.com). There are three phases of composting first is mesophilic phase also known as moderate temperature phase which lasts for a day or two, second one is thermophilic phase also called as high temperature phase lasting for few days to several month and lastly, cooling or it can be said maturation phase (by Nancy Trautmann and Elaina Olynciw, cornell Waste Management Institute 1996, NY). C/N ration must be around 25:1 and 35:1 which is effective for microbial activity. N is obtained from green and wet materials and C is obtained from dry and brown waste materials.

Table1. Significance of different soil quality parameters.

S.No.	Parameters	Significance of the soil quality parameters.
1	pH level	Measures soil acidity or alkalinity. Optimum pH around 5.7 suitable for microbial growth.
2	Organic matter content	Determines the amount of decomposed plant and animal materials in the soil.
3	Nutrient levels	Evaluates the presence of essential elements like nitrogen, phosphorus, potassium, calcium, iron and silica.
4	Soil texture	Determines Evaluates the presence of essential elements like nitrogen, phosphorus, potassium, calcium, iron and silica. The proportion of sand, silt, and clay particles in the soil.
5	Soil structure	Assesses the arrangement of soil particles and their aggregation.
6	Water-holding capacity	Is the measure of the ability of the soil to retain and supply ample amount of water to the plants.
7	Cation Exchange Capacity (CEC)	Evaluates the soil's ability to hold and exchange nutrients.
8	Electrical Conductivity (EC)	Indicates the soil's salinity level.
9	Bulk density	Measures the mass of soil per unit volume.
10	Microbial activity	Assesses the presence and activity of microorganisms in the soil.
11	Heavy metal content	Determines the concentration of potentially harmful metals in the soil which are removed by bio remediation, chemical leaching, electro-kinesis method, physical separation etc.

Moisture content must be around 40-60%. Composting can be done by anaerobic method where the by-products formed are methane gas, carbon dioxide and ammonia along with trace amounts of other gases and organic wastes. This technique is useful in composting of animal waste and sewage sludge waste(Gonawala&Jardosh, 2018). Compost can be formed within 10 days to three months as it varies according to the nature of organic matter used. Composting can be made faster by implementing new approaches like introduction of bio degraders, faster reaction rates, smaller composting area, fermentation of organic waste and by the growth of aerobic microorganisms (Elango et al., 2009). In all the three types of composting namely aerobic, anaerobic and mixed, both aerobic and mixed composting is alkaline, pleasantly earthly smell, dark brown in colour, high nutrient content, matured fast and C/N ratio is preferably 10-15, but in anaerobic smell is decaying matter, brownish green in colour and marshy in texture(Iqbal et al., 2010).

DIFFERENT APPROACHES OF COMPOSTING

In one of the experiment, three methods of composting keeping in mind the thermophilic phase under moisture content of 60% are first In Pit method in which a pit of 4 feet deep is made and 65kgs of waste from market + 14kgs of cow dung are mixed well under optimum temperature to maintain thermophilic condition. Second is In Earthen Pot method in which a 14 inches earthen pot is taken and filled with 10kgs vegetable waste + 3 kgs cow dung. Third is Pilling or Heaping (Windrows) method in which 40kgs of vegetable wastes are dried for 2 days and mixed with 2 kgs cow dung + diluted with 2 litres of water and mixed with finely chopped rice straw in the ratio of 1:5 and a heap is made up to height of 2 feet. In this method samples are preserved in glycerol at -70℃ for cell count. The compost is then dried in the oven preheated at the temperature of 105℃ continuously for 24 hours and finally grounded to fine crumbly powdery mass. In comparison to pits and earthen pots a long thermophilic phase is observed in heaps and piles method maintaining moisture content of 60%(Sarkar et al., 2016).

In one of the studies conducted in Tehran four different methods of composting by aeration method were studied. First is Pile Turning (PT) in which the pile is subjected to turning everyday regularly for the first two weeks and afterwards turning is done thrice a week. Second is Natural Ventilation Static Pile (NVS) connected with perforated PVC pipes of diameter 90 mm for proper aeration and PVC pipes are open to outer surface for convenient ambient and this pile is covered with compost. Third is Forced Aeration Static Pile (FAS) where same arrangements are made as NVS pile but an air blower of 0.6 dm^3 /min/kg is connected with the help of PVC pipe outlets. And last one is the combination of PT pile and NVS pile (CPN). Out of all these most efficient is CPN pile as it shows more specific consumption of energy, highest positive impact on CO_2 saving, better quality in terms of NO_3-N content and C/N ratio(Rasapoor et al., 2016).

In Uganda, Sweden an experiment is conducted on four different methods of composting that is Pit Covers (PC), Pit Open (PO), Above Ground Open (AO) and Above Ground Closed (AC) and observed in three different seasons like arid weather, precipitation season and monsoon season for checking frequency of compost formation using market crop waste (MCW). The process of composting is tested under many parameters like WSC (water soluble carbon), ammonia, nitrate, C/N, WSC/total N, WSC/organic N, total organic C, N, K and P. it is observed that all the compost reached the temperature of thermophilic phase rapidly and there is a sharp decrease in the concentration of total organic carbon(TOC), total nitrogen(TN), total phosphorous(TP), total potassium(TK), ammonia and water soluble carbon(WSC). There is increase in nitrate content and mature compost is obtained within 63 days of time. All these observations are made in AO Compost method but Pit compost method requires less investment and is suitable for small scale farmers(Tumuhairwe et al., 2009).

For composting of grains, Turned Windrow method and Static Pile method are used where cardboard is mixed to improve porosity and moisture is maintained by adding chicken feathers. For slaughter house waste, In-Vessel system and Aerated Static Pile methods are used along with bulking agents like wood chips and saw dust causing loss of ammonia and to prevent this, bark is also added as bulking agent.

A study at IIT Guwahati used two methods of composting that is Windrow (M1) and Vermicompost (M2) on primary stabilized compost maturation by rotary drum on a demonstration scale of 3.5 $m^3$and evaluated changes in physico-chemical and biological parameters of wastes collected from the institute. The rotary drum is connected to 7.5 kW motor to turn the drum clockwise at 2 rpm for proper mixing and agitation and to expose the material to air, to add oxygen and remove extra heat and gases produced. The size of waste products were maintained to 1-2 cm with the help of shredder connected to 3.5 kW motor. M1 consists of 40kgs of primary stabilized compost and arranged in trapezoidal piles and M2 consists of bedding materials having wheat straw, saw dust, mature compost and inoculated with Eisenia fetida (100g) at rate of 3kg/m^2 + 5kgs of primary stabilized compost and the findings were observed around three season that is winter, spring and summer. It was obtained that M2 composting technique is more efficient in providing best quality of finely grained matured compost within 20 days. It was also observed that at inlet and middle zone higher temperature of 60-70℃ is achieved leading to high degradation rate and TOC, C/N, CO_2 evolution and coliform decreases drastically and a quality compost is formed having 2.6% total nitrogen and total phosphorous around 6 g/kg(Kalamdhad et al., 2009).

A study in China of two stage composting combined with Maifanite (MF) and Silage (SG) to check the improvements in composting of green waste (GW). MF is granitoid silicate produced by weathering and denunciation of acidic and alkaline intrusive rocks(Chen et al., 2016). It is highly porous in texture and is having large specific surface area thus it supports aerobic degradation of organic waste and is excellent absorbent. It reduces loss of N also act as catalyst and source of nutrients for micro-organisms necessary of composting. SG is obtained by the process of fermentation of forage crops, shrubs and agricultural waste that are raw under aerobic condition thus enhances aeration and water permeability of soil to many folds. Combination of MF and SG lowers the pH, decreases ammonia and DOC, increases CEC, microbial count and enzyme activity. By preparing a mixture of 8.5% MF and 45% SG, produced best quality compost within 21 days(Zhang & Sun, 2018).

For increasing the efficiency of composting of municipal solid waste and dry grass (MSWG) a new method of composting using inoculation method is studied. Four types of inoculation were made that is control, initial stage, two stage and multi stage in which multi stage is more efficient. Due to inoculation of MSWG with microbes Fulvic acid is produced which provides stability and maturity to the inoculated compost and helps in overall growth of plants because fulvic acid composed of carboxylic group (Amir et al, 2005). Inoculated compost enhances biodegradation of aliphatic proteins and polysaccharide(Xi et al., 2012).

To obtained best quality of compost, sugarcane bagasse (0, 15, 20% ratios) and exhausted grape marc (0, 10, 20%ratios) are mixed together with green waste and it is observed that within 21 days best quality compost with 15% sugarcane bagasse and 20 % exhausted grape marc is produced with enhance WHC of soil, coarseness index, pH , electrical conductivity, organic C and N, improved microbial and enzyme activity, phytotoxicity, particle size distribution, nutrient, polysaccharide and lignin content(Zhang & Sun, 2016).

To control the loss of nitrogen and achieve maturity of vegetable waste compost, three in situ methods were investigated namely struvite based addition (K_2HPO_4, MgO) (MP), woody peat addition (WP), and intermittent aeration (IA) with temperature maintained over 70℃ required for inactivation of harmful pathogens. The composting system is a 200 L pilot-scale and out of all these two methods MP and IA reduces N loss by 27.5% and 16.1% respectively without affecting temperature, availability of nutrients and maturation phase. WP method failed to maintain thermophilic phase because it is influenced by physicochemical characteristics of the material. All these methods helped in achieving maturity within 20 days and provide good nutrient. Struvite based method is remarkable atreducing N loss by chemisorption mechanism(R. Chang et al., 2019).

Composting can be done using waste collected at household and known as home composting mainly having food waste and major challenged faced by home composting is the unpleasant odour which can be eliminated by implementing Effective Microorganisms (EM). But home composting with and without EM gave similar results except odour control, enhance humification and greater fat reduction (73%) compared to home compost without EM(Fan et al., 2018).

It was found that there is a significant effect of physical characteristics of bulking agents on the composting process for these three bulking agents are compared, rice husk, rice bran and saw dust. A composition of 100% rice husk and another mixture of 50% rice husk + 50% saw dust showed high germination rate. Saw dust increases water absorption capacity, composting rate became shorter, increase in acidification time and decrease in pH. But the use of rice bran as bulking agent is totally rejected(J. I. Chang & Chen, 2010).

Composting of flower wastes can be done by agitated pile method by response surface methodology for this purpose a mixture is prepared using floral waste, cattle dung and saw dust 65 kg, 25 kg and 10 kg respectively, proved to be optimum combination for composting having pH 7.1, electrical conductivity 3.31 mS cm^{-1}, total organic carbon 32.98% and C/N ration 14 (Sharma et al., 2018).

The combination of earthworm casts (EWC) and Zeolite (Clinoptilolite)(CL) improved the quality and maturation of two stages composting of green waste (GW). This combination improved composting process condition and quality of compost products also improved at thermophilic phase, also there is marked improvement in humification, numbers of microbes, enhanced enzyme activity and nitrification, hemicelluloses and degradation of cellulose, physic-chemical characteristics and remarkable improvement nutrient content of the final compost. Maturity mostly achieved at 90-270 days in traditional composting but by using the combination of EWC 0.30% and CL 25% the maturity is achieved within 21 days that too best quality compost. This compost showed high aeration, water permeability, optimum pH, degradation, enzyme activity and high nutrient content (Zhang & Sun, 2015).

FACTORS AFFECTING COMPOSTING

C/N Ratio: One of the critical factors in composting is the carbon to nitrogen ration expressed as C/N. For this the effective composition ratio of carbon and nitrogen must be 25:1 to produce ideal compost. The amount of carbon should not increase beyond this limit otherwise it will affect the composting process by delaying the decomposition process. Also increased amount of nitrogen affects the composting by increasing foul smell and by increasing temperature of the compost pile.

Moisture: Level of moisture should be around 40-60 % so as to enable microorganism do their activity of breaking down of organic waste. The optimal moisture content for composting manure is between 40-60%. Excess of moisture make the compost aerobic in nature causing unpleasant smell and deficiency of moisture is responsible for slowing down of composting process.

Temperature: For killing pathogenic bacteria and unwanted seeds of weeds, the temperature required must be above 45℃ where decomposition stops and below this temperature decomposition will not start. A compost thermometer is used to monitor this temperature. Classification of microorganism needed for composting according to the temperature of their existence. 20-40℃ temperature range is for mesophilic microorganism responsible for the initiation of decomposition and 40-70℃ temperature range is for thermophilic microorganisms(Ayilara et al., 2020).

Aeration: This can be done by proper and regular turning of the compost pile so as to maintain level of oxygen required by the microbes for undergoing decomposition of organic waste. Aeration also helps in maintaining optimum temperature and moisture level necessary for achieving maturation.

Pile size: Too large and too small pile size is not acceptable because size of pile will affect the process of composting. Too small pile will not produce sufficient heat for decomposition and break down of organic matter is hindered. If the pile is too large it will hinderthe supply of oxygen and centre of pile will be deprived of oxygen.

Additives: For improving C/N ration and provide good aeration additives are mixed with the waste materials. For ex saw dust, straw, wood chips and bark dried plant wastes etc. They are also known as bulking agents. Microbial inoculants are also mixed to increase the rate of composting.

By keeping in mind all these factors composting can be modified and one may obtain best quality compost full of nutrients which can help in improving soil quality and provide enhance crop yield by promoting healthy plant growth.

BENEFITS OF COMPOSTING

Nutrient-rich soil amendment: Compost mainly consists of range of nutrients like nitrogen, potassium and phosphorous, essentially required for overall growth of plants and crops. Hence compost can be used as nutrient rich amendment for soil.

Table 2. Parameters of compost and its optimum value with testing methods

S.No.	Compost Quality Parameters	Optimum Value	Testing Methods
1	Water Holding Capacity	--	Field capacityor moisture retention test.

2	C/N Ratio	25/1 or 30/1(Gonawala&Jardosh, 2018)	Dry combustion method
3	Nitrogen Content	--	Kjeldahl method
4	Phosphorous Content	--	Olsen P method
5	Potassium Content	--	Flame Photometer (violet color flame)
6	Moisture Content	40-60%	Gravimetric method

Reduces waste: Uncontrolled waste generated from households, industries, municipal corporation due to excess population is controlled by Composting methods. Composting helps in tackling the problem of Green House Gas emission. Improves environmental sustainability and helps to deal with the problem of disposal of waste. In a case study conducted in state of Qatar solving the problem of food waste generation greenhouse gases bringing about Global Warming, 1 tonne of food waste is converted into compost by using anaerobic digestion combined composting thus reducing the environmental burden as compared to windrow technic of producing compost from food waste(Al-Rumaihi et al., 2020).

Improves soil structure: Composting makes the plant healthier, help the roots to penetrate soil easily, absorb nutrients and water from soil because composting ameliorate the structure of soil.

Enhances soil biodiversity: Composting makes soil fertile by allowing a healthy habitat for the growth of microorganisms like bacteria and fungus, hence increases soil biodiversity. Soil fertility is further enhanced by microorganism as they help in breaking down of organic waste and convert them into useful nutrient rich mass.

Reduces need for chemical fertilizers: As it is well known fact that artificial fertilizers are hazardous for health as well as detriment the fertility of soil. Compost creates bio-fertilizer which is easy to make, beneficial for plants and environment, low cost, great impact on crops and plants hence compost is a best replacement of chemical fertilizers.

CHALLENGES FACED BY COMPOSTING PROCESS

Time-consuming: To produce usable compost, it takes several days and even years to achieve the desired results. Those who are looking for quick and easy way to make compost get disappointed by this time taking process which is the biggest drawback.

Odour: One of the major disadvantages is the foul smell coming out of compost which occur due to improper management of compost pile. Hence compost making require open spacious place away from populated area which is generally not possible.

Attracts pests: Insects, pest, flies and rodents get attracted towards compost due to unmanageable practices of composting and this problem is difficult to tackle.

Requires space: Composting requires large area which is not possible in case of small apartment and limited outdoor area.

Requires maintenance: Regular turning, addition of bulking agents, temperature checking, aeration and supply of microbes are very time taking during composting process because these should be done in regular basis which is not possible for people having busy schedule and limited time.

Heavy metal contents: it was found that factor which may limit the possibility of using fly ash as a compost substrate is the presence of higher concentrations of heavy metals, especially Chromium (Malarski et al., 2023). It was determined that the maximum addition of fly ash to the compost mass was 154 kg d.m.ash/(ton d.m.straw+sludge) (Malarski et al., 2023).

FUTURE TRENDS IN COMPOSTING

Increased focus on circular economy: As composting is a technic of reuse and regeneration of waste materials into new beneficial products which is environmentally friendly approach. As awareness of the importance of a circular economy grows, composting will play an increasingly important role in taking composting more seriously. Hence composting will get investment, infrastructure support, technical aids and prove a boon to research in the field of agriculture, environment and science.

Use of advanced technologies: New age technologies like IoT, Industry 4.0 and 5.0, blockchain and Artificial intelligence are applied to composting methods for improving overall method, efficiency, reduce the capital, reduce wastage etc. The technologies make composting easy process and help to produce best quality compost having remarkable improvements compared to traditional process of composting

Application of compost in agriculture: Large scale use of chemical for increasing crop production is leading to deterioration of climate, environment and human health.Thus, a replacement of chemical fertilizer is the need of the hour which is happening by composting of organic waste. Composting also decrease green house as emission and is environment friendly.

Composting in urban areas: More and more people are migrating towards urban regions for search of better lifestyle and earn handsome income and thus generation of waste is also increasing many folds and to tackle this problem composting of waste to convert it into something useful matter is highly gaining popularity. This practice of composting will make urban agriculture practices more sustainable.

Utilisation of undeveloped land: In Taiwan a large population is living in barracks having a huge land cover which is left undeveloped and can be utilised for the production of compost. This helps the military to avoid huge waste management problem and helps in lowering the cost of waste disposal (Tai & He, 2007).

CONCLUSION

This paper includes all the aspects of composting. All these discussions proved that composting is the necessity of the future as well as present agriculture practices for the environment, for the people, for universe and for whole human population. There are many future possibilities of improvement in composting technologies. And still there is area of improvement to this process of converting green waste into something better for soil health and plant growth.

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