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Enriched Composting: A Cost-Effective Technology For Better Soil Health and Crop Productivity

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Abstract

Declined soil quality and crop productivity in post green revolution era has led the agricultural research for development of advanced scientific composting techniques which has significant positive effect on soil ecosystem services. Research on enrichment of compost with different additives like organic, mineral and biological in nature and their impact on soil ecosystem services have proved that enriched composts have significant positive impact on soil physic-chemical and biological properties, soil organic matter and nutrient status of the soils. In addition to their positive impacts on soil physic-chemical and biological properties, composts increase the crop productivity and quality. Consequently, application of compost, especially enriched composts equalize the seasonal fluctuation in soil temperature, air, water and nutrient availability and thus the crop yields. Thus, for sustainable agricultural system composting can be an effective plant nutrient management strategy.

Keywords: Bio-inoculants, Crop productivity, Ecosystem Services, Enriched Compost, Soil Health.

Being a sole food provider to the animal kingdom of the planet, agriculture employs a key role in economic development of agrarian economy like India. Agriculture based industries are the largest industry across the globe as it covers~ 40% of total available land. When it comes to the average per capita energy requirement ~78% of total per capita energy requirement is fulfilled by crop-based products, while ~20% energy is contributed by other products i.e. meat, milk and eggs. Thus, meeting out the food demand of ever growing human and animal population from decreasing land resource under agriculture is the major challenge in present scenario which can be only attained by increasing the agricultural production. Use of synthetic fertilizers, high yield cultivars and mechanization in agriculture has played a

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significant role in increasing the agricultural production of under developed and developing world during green revolution era(Singh *et al.*, 2019).

Although, the growing soil health and environmental quality related issues followed by declined agricultural productivity in post green revolution era has led debates about the use of these synthetic agro-chemicals and fertilizers in agriculture. Other than this, the increasing price of synthetic agro-chemicals, changes in soil matrix i.e. acidification and/or alkalization ground water pollution, nutrient fixation, degradation of soil flora and fauna and rapid decomposition of organic matter has drawn attention of agricultural researchers to find out an alternative sustainable way of nutrient application in agriculture. There is need to look for a cost effective and environmental friendly substitute for inorganic fertilizers and other synthetic agro-chemicals (Meena *et al.*,2021). Transformation of on farm and off farm organic wastes into nutrient rich fertilizers and/or soil conditioners i.e. compost is an age old strategies to transform the organic materials into compost. As per the study conducted by Singh et al. (2005) on nutrient absorption by rice crop showed that 40% of N, 30–35% of P, 80–85% of K, and 40–50% of S absorbed by rice is remained in the rice residue which can be used as potential substrate for composting.

Composting can be defined as decomposition/mineralization followed by partial humiliation of organic materials by the biological metabolic action of microorganisms i.e. bacteria, fungi, actinomycetes etc. under optimum conditions over a period of time to a stable end product. The end product is known as compost. Many types of organic matter, such as leaves, straw, fruit and vegetable peelings and manures can be used to make compost. The degraded end product is completely different from the original organic materials which have characteristics of dark brown colour, crumbly in nature with a pleasant smell (Meena *et al.*, 2021). Being easily available, cost-effective and easy to prepare, compost is an important source for improvement of soil and crop quality. Compost improves the structure of the soil. It allows more air into the soil improves drainage and reduces erosion. Compost helps to stop the soil from drying out in times of drought by holding more water.

Compost helps in improvement of soil physico-chemical properties as it adds the nutrients to the applied soils as well as acts as a binding agent for the soil particles; thus, increase the nutrient availability for the plants which results into better crop yields (Meena et al., 2021). Usually the compost prepared by conventional methods contains low nutrient

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content and also consumes a lots of time in preparation of compost. In past two decades, preparation of compost with addition of different substrates i.e. organic matter, minerals, biological materials and/or mixture of substrates have gained popularity among various stake holders. Such types of composts are known as enriched compost as they are enriched with a particular or more than one nutrients (Barthod et al., 2018).

Enriched compost contains high organic matter along with high nutrient contents. Addition of additives for enrichment of compost has direct positive impacts on various compost parameters i.e. quality of compost, maturity, nutrient and heavy metal contents in compost, bioavailability of nutrients in compost, environmental impact of composting process in terms of emission of greenhouse gases and other volatile compounds such as oxides of nitrogen, sulphur and organic compounds.

Types and sources of additives used for compost enrichment

To improve the quality of compost, a wide range of additives are used for compost enrichment. These additives have been classified into three main categories as follows:

- Organic additives
- Mineral additives
- Biological additives

Biological additives

Inoculation of composting material with different types of microorganisms is known as biological additives in enriched composting. Mostly thermophilic microbes harvested from the compost pile during the heat phase are used for biological additives in enriched composting. *Bacillus, Lactobacillus, Clostridium* and *Alcaligenes* are predominant biological additives used for compost enrichment (Wakase et al., 2008).

Organic additives

Use of a large number of on farm and off farm organic substrates i.e. mature composts, residual straws, grass clippings, crushed wood pallats, crushed hardwood materials, weed residues, crop residues, fruits/vegetable peels, livestock wastes etc. covers under organic additives category. The organic additives are choose based on their C/N ratio for rapid decomposition of organic material and prevention of nitrogen leaching during composting period. In recent period, bio char has gained popularity as highly stabilized organic additives for enriched composting (Waqas et al., 2017).

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Mineral additives

The mineral materials such as rock phosphate, mica, zeolite, Kaolinite, lime, clays, red mud (by product of alumina production) or fly ash (by product of coal industry) etc. are majorly used as mineral additives for compost enrichment. Low cost and high availability, capacity to absorb the heavy metals and reduction in greenhouse gas emission from composting etc. are the advantageous effect of mineral additives used for compost enrichment (Barthod et al., 2016).

The additives have positive and significant effect on temperature, aeration, pH, moisture content and nutrient availability in composting material. Inclusion of organic, mineral and/or biological additives during composting helps in stimulation of biological activity in composting material and lead to early start and long duration of thermophilic phase as compared to regular composting. Incorporation of additives like kaolinite, zeolite, sulfates, rock phosphate, ashes, chalk and bio char etc. during composting increase the thermophilic phase from 2 to 3 weeks and thus shorten the composting process. Inclusion of additives increase microbial metabolic activities followed by rapid temperature increase which further fasten the composting process (Waqas et al., 2017).

The readily available carbon and higher nutrient content in additives influences the microbial biodiversity of composts. Additives with easily degradable nutrient contents like jaggery, rockphosphate, kaolinite, waste mica, fish pond sediments, mushroom substrate, and/or biochar etc. proliferate the microbial diversity of organic wastes and thus increase the enzymatic degradation of composting materials (Zhang et al., 2017).

Addition of organic additives like crushed plant branches, bio-char, woodchips or sawdust, residual straws increase the natural porosity and aeration of compost piles. Presence of low moisture content and numerous pores in these organic additives supports formation of inter and intraparticle voids which further increase the microbial diversity in the composting piles (Czekala et al., 2016).

The microbial activity and organic matter degradation of composting pile is influenced by the oxygen uptake rate in the pile which is further controlled by the moisture content of the composting materials. The additives are used to offset and optimization of moisture content in the composting materials. Mostly the additives of fibrous nature like sawdust, cornstalk and/or spent mushroom substrate etc. which have capacity to absorb the

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leach ate are used during composting. Other than this to control the loss of moisture during the early stage of composting can be controlled with the use of clays like bentonite, fly ashes, rokphosphateetc (Soares et al., 2017).

Enriched composting

The amount of different types of on farm residues viz. crop residues, leaves, straw, stubbles and twigs etc. has enormously increased with the introduction of green revolution in Indian Agriculture. Presence of wider C:N ratio in these residues and slower rate of decomposition results into preparation of poor quality compost from these products. Thus, in the recent time enrichment of composting material along with various additives has gained popularity because of increased rate of decomposition of composting material and higher nutrient status in compost by these additives.

Enrichment of compost by adding nitrogen, phosphorus, clay minerals and/or inoculation with different microbial consortia is highly popular across the globe. Compost enrichment can be done by two ways:

- Physical addition of additives during composting
- Addition of additives with ready compost by mixing.

The microbial assimilation and insertion into humic substances of nutrients takes place in the process of physical addition of additives during composting. Other than this, a substantial part of nutrients is adsorbed on the chelating agents present in the composting materials. While, Adsorption and chelation of additives by the humic substances takes place when additives are mixed with ready compost.

Compost enrichment with nitrogen

The C:N ratio of the composting material plays a crucial role during composting process as it regulates the microbial mineralization and immobilization of organic matter present in the composting material. Based on the various studies conducted across the globe the processes of mineralization and immobilization have been divided into three following categories:

Table 1. Range of C:N ratio and its impact on microbial mineralization and immobilization.

S.No.	C:N Ratio	Process
1.	<20:1	Mineralization
2.	20:1-30:1	Equilibrium between Mineralization and immobilization

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3. >30:1 Immobilization

Thus, for rapid decomposition of composting material with wider C:N ratio (>30:1) the mineral nitrogen is added during compost preparation. The added mineral nitrogen serves as tarter for the microorganisms involve in the decomposition process. Enrichment of compost with mineral nitrogen range from 1.8% to 2.5%. Enrichment beyond 2.5% mineral nitrogen leads to associated losses of nitrogen along with production of free ammonia (NH_3).

The spray of urea solution followed by physical blending can increase the nitrogen content up to 5-7% in the ready compost. Other than that, addition of nitrogen in ready compost brings down the C:N ratio from 20:1 to 10:1 and nitrogen content >2.5% (Biswas et al., 2009).

Compost enrichment with phosphorus

Enrichment of compost with phosphorus can be done with addition of 5% rock phosphoate, super phosphate and di calcium phosphate (DCP) during filling of compost pit. Microbial assimilation of soluble phosphorus takes place during compost enrichment with phosphorus. Enrichment of compost with sparingly soluble rock-phosphate is most rational and practical approach among phosphorus enrichment. Besides the solubilization of sparingly soluble phosphorus rock-phosphate also provides calcium, sulphur and micronutrients in the composting material. Rock-phosphate enrichment can increase the availability of 50-70% sparingly soluble phosphorus to the plant when the enriched compost is applied to soil.

Other than this, compost enrichment through addition of soluble phosphorus fertilizer sources increase the phosphorus use efficiency of P fertilizers as it reduces the P fixation. The phosphorus content in the compost can be increased up to 5% with amalgamation of single super phosphate in the compost (Biswas et al., 2009).

Compost enrichment with potassium

Use of potassium containing minerals like Feldspars and mica is most common practice followed for compost enrichment. Release of various low molecular organic acids viz. citric, maleic, acetic acid and tartaric acid etc. during microbial decomposition of composting materials improve potassium availability in the compost. Other than the mineral additives, potassium can be increased by addition of various organic additives i.e. banana skin, water hyacinth and dry potato vines (1% K content) in the composting material (Biswas et al., 2009).

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Use of Bio-inoculants for enrichment

Inoculation of final compost product with nitrogen fixing microorganisms and/or phosphate and potassium solubilizing microbes can enhanced nutrient content in the final product of compost. Various microbes like *Clostridium, Azospirillum, Azotobacter* etc. are used as nitrogen fixers in the compost heap. Phosphate solubilizing microbes like *Bacillus sp., Pseudomonas spp.* And *Aspergillus sp*. are used as bio-inoculant during compost enrichment with rock-phosphate. Other than this, different cellulolytic and lignolytic microbes viz. Paecilomycesfusisporus, Trichodermaviride, Phanerochaetechrysosporium, Trichurusspiralis etc. are used for rapid decomposition of composting material. Release of different low molecular weight organic acids such as gluconic acid, tartaric, citric etc. enhanced the nutrient release form the sparingly and/or insoluble organic compounds (Biswas et al., 2009).

Impact of enriched compost on soil health and crop productivity

Use of compost in agriculture particularly compost enriched with different additives not only supply different plant available macro and micronutrients but also significantly influences various soil physic-chemical and biological properties. Various research studies across the globe have proved that integrated application of different organic manures such as green manures, FYM, rock phosphate and waste mica enriched composts etc. improve soil properties by chemically (Nutritionally). In the post green revolution era addition of organic matter through composts has been considered a crucial source of sustainable soil health and crop production. Mixing of different kinds of additives with organic materials enhances the solubility of nutrients in soil solution and thus improve soil quality and productivity (Billah et al., 2020).

Composts are known as multi nutrient fertilizers as they contain the significant amount of valuable essential plant nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, zinc, manganese, copper etc. The nutrient content and other significant properties of compost like cation exchange capacity, electrical conductivity, C:N ratio, pH etc. depends upon the organic feedstock, composting process and enrichment of compost with various additives.

In various studies across the world it has been observed that application of stabilized organic matter through different types of composts significantly improve the soil cation

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exchange capacity which an important indicator of soil fertility evaluation in terms of nutrient retentions. Enrichment of compost with different kinds of additives has been found as liming effect in soil as it enrich the soil with cations such as calcium, magnesium and potassium. Similarly, continuous application of compost enhance the soil pH of acidic soils. The positive impact of compost application on soil physic-chemical and biological properties contributes to increase and stabilization of crop productivity and quality as the compost application equalize seasonal fluctuations in soil air, water and heat balances, nutrient availability (Agegnehu et al., 2014).

Conclusion

As per the traditional belief composting was natural phenomenon mostly used for organic farming purposes. But with introduction of new scientific techniques with accelerated speed and techniques of composting, it has become an essential component of sustainable agriculture for better growth and development of agriculture with no adverse impact on both human and environmental health. In recent time, various area, climate, social specific composting techniques have been developed by the agricultural researchers. Quality of compost and presence of nutrient in compost depends on the quality of composting material, techniques used for preparation and additives used for enrichment. The materials used for compost enrichment has significant effect on soil ecosystem services like soil fertility improvement, crop production, carbon sequestration, limit odour and GHG emission. Compost application maintain the soil fertility and crop productivity through retaining plant nutrients for longer time, maintaining soil physical properties and holding water. However, compost composition, compost enrichment with different additives have a significant effect on soil quality.

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