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Composting and Liquid Formulations: Panacea to Better Yield in Agriculture: A Review

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Liquid formulations, including aqueous, oil, and polymer-based products, often use polysaccharides to alter fluid properties. Liquid inoculants offer cost-effective alternatives to solid carriers, particularly benefiting small producers in India by overcoming transportation and processing challenges. Ideal liquid inoculants are non-toxic, low-cost, uniform, nutrient-supplemented, and support rapid microorganism release and growth. Effective formulations stabilize organisms, ensure

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easy field delivery, protect against environmental factors, and enhance microbial activity. Rich in nutrients and organic matter, compost enhances the texture, structure, and moisture retention of soil, improving soil qualities and crop productivity. It boosts soil enzyme activity and microbial populations, promoting nitrogen fixation and nutrient availability. Organic manure applications increase soil fertility, water retention, and reduce bulk density. Field and horticultural crops, such as potatoes, chillies, and tomatoes, show significant yield improvements with compost, which also suppresses plant diseases and weed populations.
These findings underscore the importance of adopting liquid formulations and composting as sustainable agricultural practices.

Keywords: Composting; organic manures; soil enzymes; soil microorganisms; liquid bioinoculants.

1. INTRODUCTION

Unwanted substances that cannot rise rapidly into the air or flow directly into streams are known as solid wastes. These wastes include garbage, paper, wood, glass, plastics, ash, agricultural wastes, sewage, sludge from hospitals and mining wastes. Recycling solid and liquid wastes is hampered by the presence of pathogens, unwanted heavy metals, dangerous concentrations of micronutrients, and nitrate risks, among other issues [1].

The majority of MSW in India is made up of biodegradable materials, which mostly consist of food and garden waste and account for around 50% of all MSW. A few details of Indian MSW India generates roughly 1,15,000 tonnes of solid garbage each day, with a 5% annual growth (CPCB). The amount of waste produced per person is expected to increase by roughly 1.33% annually [2].

Organic wastes: Organic wastes include solid and liquid wastes such as crop residues, excreta, garbage, domestic wastes and sludges etc., [3]. In India, average per capita generation of solid wastes during 2020-21 is 119.07 gm/day and in Delhi it is around 400 gms/day and Tamil Nadu around 190 gms/day [4]. The main supply of recyclable organic materials comes from rural wastes, such as field crop remains in one form or another. By conservative estimates, 350 to 375 million tonnes of crop residues are produced annually from all field crops [5]. The annual productions of residues by principal crops were 270 million tonnes, which could supply 5.6 million tonnes of NPK [6].

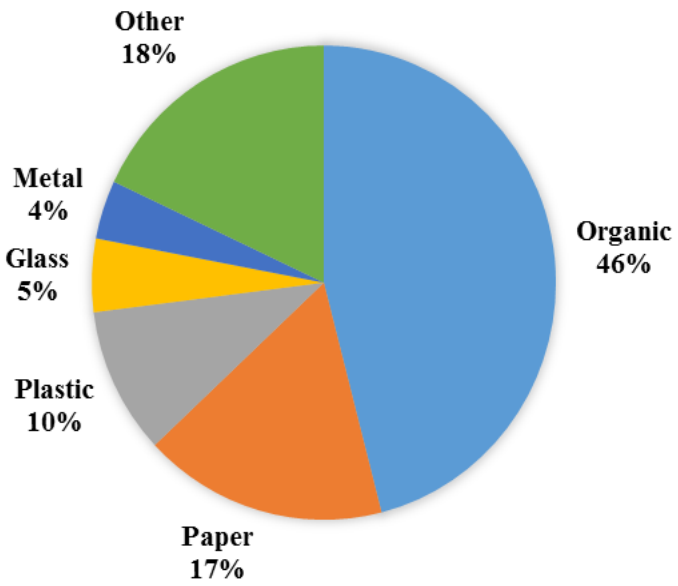

Fig. 1. Composition of Municipal solid waste
(Ranjith Kharvel Annepu, 2012)

Resources found in the biodegradable garbage dumped in landfills can be used with the appropriate solid waste management system. Up until 2030, carbon disposed of in landfills with gas recovery could be used as a source of energy for a few years afterward. Important nutrients include phosphorus, nitrogen, and other elements. The prospects for producing energy and fertiliser from solid waste are appealing due to the possibility of recovery, reuse, and substitution of alternatives acquired from other sectors.

Vegetable waste makes up the majority of Indian MSW. Vegetable trash from vegetable markets, eateries, canteens, juice bars, and home kitchens makes up the majority of the vegetable waste in MSW. Every town, city, and region has a vegetable market that produces 221.43 million tonnes of waste [7].

Because they are organic in nature, agro-industrial wastes can be utilised in agriculture to raise the soils' organic matter content. In addition to being nutrient-dense, these organic components also enhance the physico-chemical characteristics of the soil, which raises soil fertility and productivity [8]. About 679.3 and 369.5 million tonnes of crop residues and animal dung were produced annually in India. The most voluminous solid waste from sugarcane factories are pressmud, the annual generation of pressmud was 6.4 million tonnes [9].

Composting: Composting is a biological conversion of heterogeneous organic substrate, under controlled conditions into a hygienic, humus rich and relatively biostable product that conditioned the soil and nourished the plants [10]. All available organic waste materials can be converted into value added organic manure by adopting suitable biodegradation process technology [11].

The aerobic, thermophilic process of composting is extensively employed in the recycling of organic residues, including yard wastes, food wastes, agricultural wastes, and biosolids. Compost's temperature, nutrient, and oxygen gradients promote a wide range of microbial activity and quick conversion of organic matter [12]. The organic portion of a solid waste is biologically broken down in controlled conditions to provide nutrients to plants without harming the environment or the crop [13].

Principles of composting: Microorganisms are the principal biological agents for operation of the composting process. They are active in the degradation of insoluble higher molecular weight organic compounds cellulose, chitin, protein, waxes and paraffin etc. They derive energy required for their growth and metabolism by mediating oxidation reduction reaction of the organic substrates and thereby decomposed the organic matter [14].

The microbe multiplied and emitted carbon dioxide, water, other organic compounds, energy, and other substances by using organic waste as a food supply. The most resistant leftovers from the decomposition of organic matter made up the composting process' end result. product, the biomass of dead microorganism and other microorganism together with product from chemical reaction between these matters [14].

Factors facilitating composting: In addition to the final product's quality and acceptability for use as a fertiliser or soil supplement, the physical and chemical characteristics of organic wastes play a significant role in the microbial degradation process [15]. Determining the rate of decomposition requires knowledge of the relative amounts of carbon, nitrogen, phosphorus, sulphur, and other nutrients as well as the substrate's quality [16].

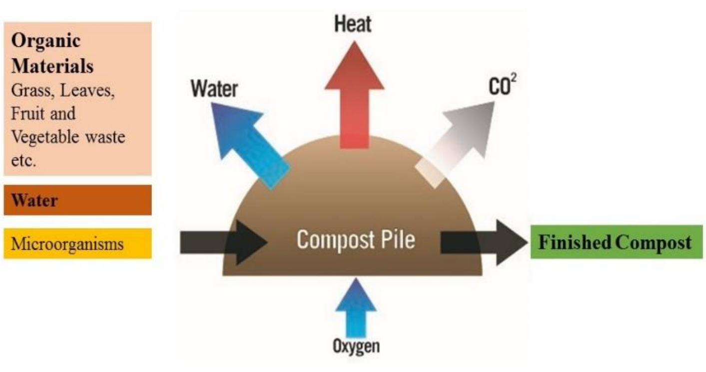

Fig. 2. Principles of composting process

Table 1. Optimum conditions required for composting

Sl.	Parameter	Conditions required
1.	C/N ratio of feed	25 to 35
2.	Particle size	10mm for agitated systems and forced aeration, 50 mm for long heaps and natural aeration
3.	Moisture content	50 to 60 %
4.	Air flow	0.60 to 1.8 m^3air/day/kg volatile solids during thermophilic stage or maintain oxygen level at 10 to 18 %
5.	Temperature	55 to 60°C held for 3 days
6.	Agitation	No agitation to periodic turning in simple systems and short bursts of vigorous agitation in mechanized systems
7.	pH	Neutral
8.	Heap size	Any length, 1.5m height and 2.5 m wide for heaps using natural aeration. With forced aeration, heap size depends on need to avoid overheating
9.	Activators	Use of efficient cellulolytic and lignolytic microorganisms and bio fertilizers

[17]

2. METHODS OF COMPOSTING

Indore method of composting: [18] invented the Indore approach. A large amount of trapezoidal cross section is needed for this procedure. The heap is approximately 4 meters long, 1 metre wide, and 1 metre tall. A 20 cm layer of carbon-rich material and a 10 cm layer of nitrogen-rich material were alternately added onto the heap. Ultimately, it was covered with hay or dirt to act as a thermal insulator. As a result, a high temperature soon rises and the pace of decomposition is extremely fast. All types of organic waste available in the farm such as crop residues, fallen leaves, stalks, stems, etc. This process is accelerated by periodically turning the materials.

Windrow composting: Through aerobic decomposition, the organic material found in garbage can be transformed into a stable substance. The carbon from organic molecules is used as a source of energy by aerobic bacteria, while nitrogen is recycled. Organic compounds are oxidised to carbon dioxide and oxides of nitrogen. The temperature rises as a result of exothermic reactions. Composting in open windrows is recommended in areas/regions with greater ambient temperatures. This method of distributing refuse results in about twenty windrows, each measuring three meters in length, two meters in width, and one metre in height. The total volume of the windrows cannot exceed nine cubic meters. The windrows can be flat, well-drained, paved, or unpaved. On the sixth and eleventh days, each windrow is turned outside towards the centre in order to kill insect larvae and supply air. A front-end loader or a compost turner with specialised design is used to turn the rows on a regular basis (12). The windrow is broken down on the sixteenth day and the oversize contrary material is removed by manually operating rotary screens with a mesh size of approximately 25 mm square. The screened compost is then stored in heaps measuring approximately 2 meters wide by 1.5 meters high and up to 20 meters long for about 30 days to ensure stabilisation before sale [19].

Passively aerated windrows: By providing air to the composting materials through perforated pipes installed in each windrow, the passively aerated windrow system eliminates the requirement for turning.

Because of the chimney effect produced when the hot gases rise upward out of the windrow, the pipe ends are open, allowing air to flow into the pipes and through the windrow. The compost base or heap is topped with aeration pipes. When the composting process is finished, the pipes are taken out and the items that have composted are gathered.

Bangalore method: The Bangalore technique, which produces compost from city waste and night soil in trenches, was created by Acharya in 1934. In this procedure, pits of a depth, width, and length of roughly one metre each were used. Initially, a 15 cm layer of trash was deposited into the trench and spread out using racks. After that, night dirt was dumped and covered with trash in a five-centimeter layer. Subsequently, a 15 cm layer of refuse is applied on top of this, and so on until the pit is filled up to a height of 15 cm above ground, with a final layer of trash on top. This could have a dome form and be covered in dirt. This could have a dome form and be covered in dirt. Anaerobic decomposition produced high-quality organic manure while being somewhat slow and effectively resolving one of the trickiest issues with hygienic disposal of the offending wastes.

Aerated static pile: It is a piped aerator system that provides air to the composting materials with the help of a blower. Larger piles are permitted and direct process control is provided by the blower. Once the pile is established, the materials are not turned or disturbed in any way. The active compost period lasts three to five weeks when the pile has been constructed correctly and there is an adequate air supply [20].

In-vessel composting: Composting materials that are contained inside a structure, container, or vessel is referred to as "in-vessel composting." In-vessel composting systems can be made up of concrete bunkers or tanks made of plastic or metal that have temperature and air flow controls utilising the "bioreactor" concept. Typically, probes inserted into the mass monitor temperature and moisture levels to enable the maintenance of ideal aerobic decomposition conditions. The exhaust is then extracted through a biofilter, and the air circulation is carried out via buried tubes that enable the injection of fresh air under pressure. This method was primarily employed to process municipal organic waste, including treating sewage biosolids to a safe, stable form in preparation for its recovery as a soil amendment [21].

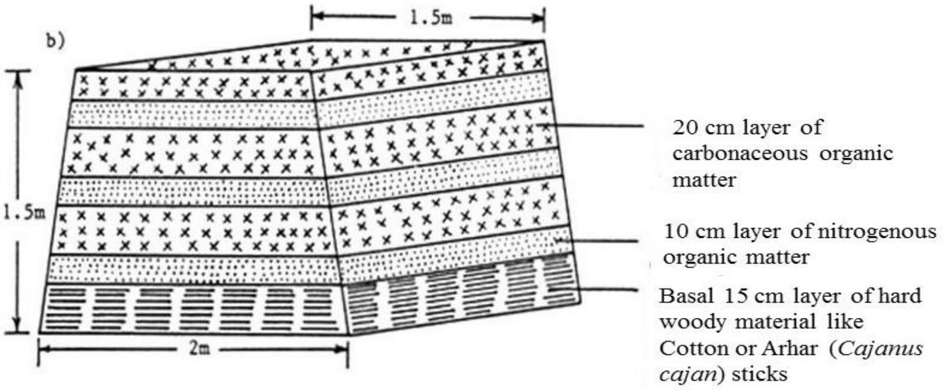

Fig. 3. Indore method of composting

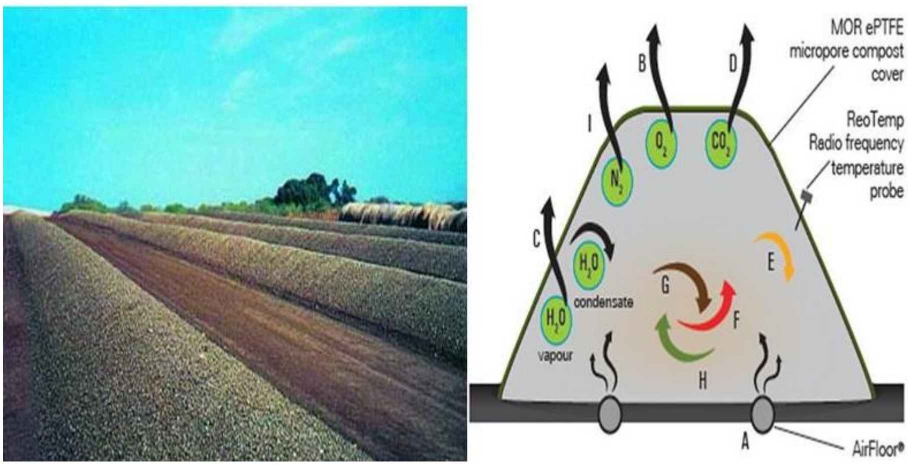

Fig. 4. Windrow method of composting

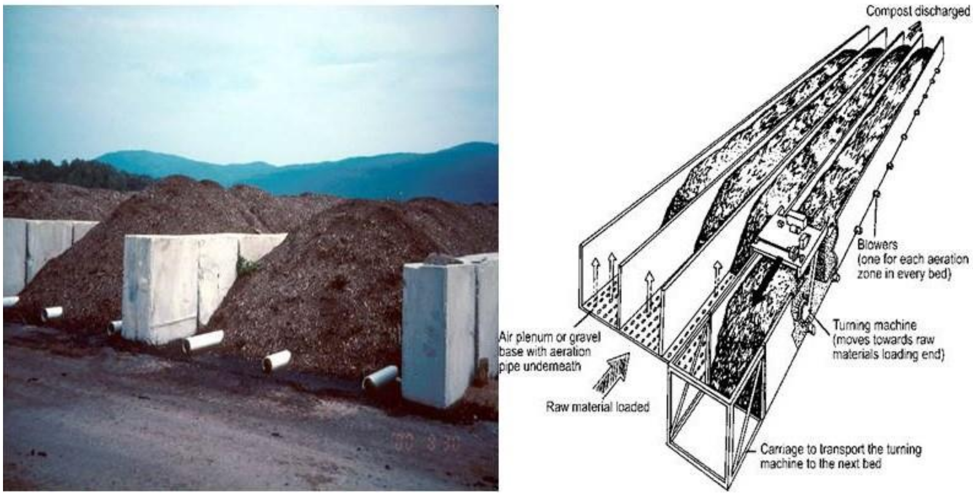

Fig. 5. Passive Aerated Windrow method of composting

Fig. 6. Bangalore method of composting

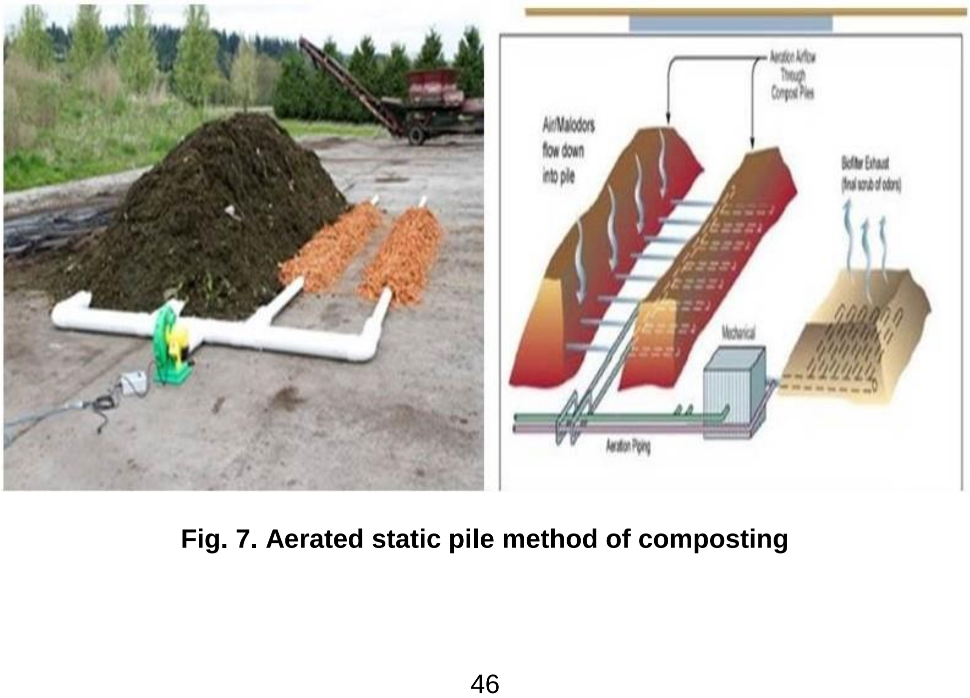

Fig. 7. Aerated static pile method of composting

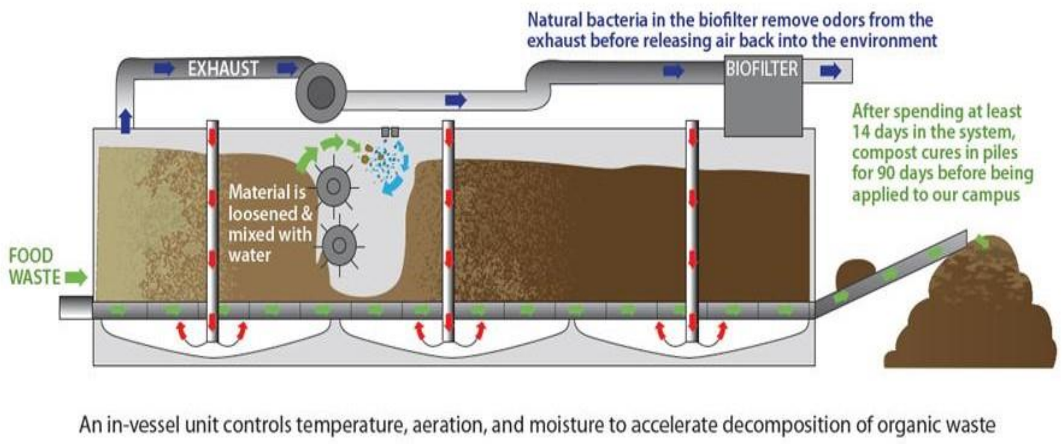

Fig. 8. In-Vessel method of composting

Biochemical changes in composting process: Microorganisms break down organic molecules, including cellulose, lignin, proteins,sugars, and carbohydrates, during the composting process. It is easier for carbohydrates to break down than it is for lignin to do so. A lot of things influence the composting process. Water, nutrients, and oxygen are necessary for the metabolism and cell formation of aerobic bacteria. Microbial activity releases heat, which raises the temperature if it is confined within the composting matter. When the temperature rises, it passes from a mesophilic to a thermophilic phase and back again. The microbial population shifts during these transitions, which has an impact on how quickly organic matter decomposes [22].

The kinds of organisms that participate in the composting process are influenced by the pH of the biodegradable material. Throughout the composting process, there was an inherent link between temperature and pH variation over time. In the early phases of mesophilia, the pH is lower (acidic), and as the temperature of the composting mass rises, the pH rises as well [23]. The most biodegradable organic compounds decompose during composting, and some of the leftover organic material is transformed into molecules that resemble humic acids.

The loss of organic carbon content as CO_2 during composting resulted in an increase in macro and micronutrients. Over time, the concentration of nutrients increased because native carbon was mineralised and the overall volume of wastes decreased. It has been established that phosphatase, amylase, cellulase, and dehydrogenase are crucial enzymes involved in the mineralisation of nutrients. The variety of the microbial population, which in turn reflects the composting process, is substantially reflected in the enzyme activity. Cellulase is one of the enzymes that plays a crucial degradative role in the composting process. Phosphatase is a broad term for microbial activity in compost and plays a role in the use of alternate phosphorus sources [24].

During the mesophillic phase of the process, the amount of this enzyme rose and stayed steady in the latter stages. According to [25], the addition of organic amendments improves the involvement of enzymes like catalase and dehydrogenase in intracellular microbial metabolism.

Role of microbes in composting: A vast and diversified microbial community, primarily composed of bacteria and fungi, is found in composts and is essential to the breakdown of organic matter throughout the several temperature stages of composting. Mesophilic bacteria, usually belonging to the genera Lactobacillus and Bacillus, are predominant at the start of the composting process [26]. Due to their ability to break down soluble and easily degradable substances like sugars and the heat created by their metabolic processes, their populations greatly expand in the early stages of composting. Thermus, Bacillus, and other thermophilic bacteria take over the breakdown process as the temperature rises to roughly 40°C, at which point they become the dominating groups in the microbial community. Most people agree that the process of composting is aerobic and driven by microbes. But anaerobic microorganisms have also been found in composting processes, including, Bacteroidetes and Clostridium (Partanen et al., 2010; Danon et al., 2008). This conclusion may be explained by the fact that the composting process is a co-function of anaerobic and aerobic processes due to the restrictions in oxygen transport from the free air space into the heterogeneous solid particles of the composting mass [27,28].

Although fungi have been shown to be the primary degraders of cellulose and lignin, the majority of research on composting microbes has concentrated on bacteria [29]. In the mesophilic stages, yeasts and moulds have been identified; in the thermophilic stages, thermophilic fungi from the Pezizomycota, Zygomycota, and Ascomycota (such as Penicillium) have been identified; in the cooling and curing stages of the composting process, basidiomycota become prevalent [30]. According to [31], the highest temperature at which thermophilic fungi may thrive is up to 55 °C; greater temperatures usually inhibit fungal growth. Fungi typically have no effect at all during the thermophilic phase because of this. There is one exception: when composting substrates with particularly high cellulose and lignin content, fungi continue to be important degraders during the composting process.

Because fungi have a competitive advantage when there is a shortage of accessible substrate, which leads to the predominance of difficult-to-degrade components like lignin and humus, the ratio of fungi to bacteria frequently increases during the curing phase of composting.

3. PREDOMINANT MICROORGANISMS IN COMPOSTING PROCESS

Bacillus: *Bacillus* sp. is mesophilic bacteria which consume most of the readily degradable carbohydrates and proteins. They are involved, especially, in the degradation of proteins, aminoacids, peptones and blood meal [32,33] observed that introduction of thermophilic bacterium *Bacillus licheniformis* accelerated the process of composting.

Pseudomonas: *Pseudomonas* is a gram negative, heterotrophic bacteria and cellulolytic in nature and also produce proteolytic enzymes [34], which convert protein in the waste to aminoacids. Some species of *Pseudomonas* are the most efficient in dissolving phosphates [35].

Lactobacillus: Lactobacillus convert glucose and other carbs into lactic acid. In addition, lactic acid is apotent sterilising agent that inhibits dangerous microbes and speeds up the breakdown of organic materials, eliminating the negative effects of organic matter that hasn't decomposed [36].

Pleurotus: *Pleurotus* is a basidiomycetous lignolytic fungi capable of growing on a wide range of agricultural wastes of different compositions [37]. The organism is also capable of detoxifying phenolics and producing biopolymerising enzymes [38].

Trichoderma: *Trichoderma* is a mesophilic fungi capable of degrading cellulose to glucose. The cellulose complex of organism consists of three different hydrolytic enzymes- endoglucanase, exoglucanases and cellobiase [39]. Efficient cellulolytic cultures such as *Trichoderma* sp. accelerate composting by about one month [40]. An efficient strain of *Trichoderma* sp. shortened the composting time for rice straw by 20 days [41]. While studying the composting of a mixture of crop residues, grass and tree leaves, [42] found appreciable effect of fungal inoculation on compost quality. It was also reported that *Trichoderma viride* was the best when compared to *Paecilomyces fusisporus* and *Aspergillus niger*. Inoculation with *Trichoderma viride* enhanced the organic matter degradation process and the degree of organic matter humification [43].

Aspergillus: Aspergillus species are thought to be the primary microbiological suppliers of enzymes that break down cellulose. Aspergillus sp. is a common commercial producer of β-glucosidase due to its strong synthesis of the enzyme in the extracellular medium. The genome of A. terreus NIH 2624 is known to contain genes encoding various potential cellulose-degrading enzymes, including 5-exoglucanases, 22-endoglucanases, 18-β-glucosidases, and 7-xylanases. Additionally, genes with conserved domains are found in this genome, indicating the presence of multiple cellulase genes [44].

Actinomycetes: Actinomycetes are crucial for the breakdown of complex organic compounds like cellulose, lignin, chitin, and proteins during composting. Through the action of their enzymes, they are able to chemically break down resistant materials like newspaper, bark, and woody stems that are relatively unavailable to most other types of bacteria and fungi, even though they do not compete well for the simple carbohydrates that are abundant in the early stages of composting. Actinomycetes come in different species. While some are visible during the thermophilic phase, others become significant during the colder curing phase, which is when the most resilient compounds are left. Actinomycetes like warm, humid environments with a pH of neutral to slightly alkaline.

In compost, actinomycetes produce long, thread-like filaments that branch off and resemble grey spider webs. In the outside 10 to 15 cm of the pile, towards the end of the composting process, these filaments are most frequently observed. They can occasionally be seen as progressively larger circular colonies.

Different formulations of microbial inoculants: Making inoculants with a potent bacterial strain that can decide whether a biological agent is successful or unsuccessful requires careful formulation (Bashan, 1998). The process of formulating usually involves putting the active component, or microorganisms, in an appropriate carrier and adding additives to help stabilise and preserve the microbial cells during transit, storage, and delivery to the intended location. A product's formulation must remain stable during manufacturing, distribution, storage, and transportation-regardless of whether it is new or upgraded. According to [45], the formulation should also be simple to administer, shield the target organism from damaging environmental elements, and preserve or improve the organism's activity in the field. The formulation's cost-effectiveness is a crucial factor as well. Thus, before the final product is delivered, a number of important aspects, including user choice, must be taken into account.

Powder Formulation: The suitability of groundnut wastes, namely pulverised shells, as a starting material for cellulolytic fungal inoculum cultures intended for the quick composting of organic leftovers was assessed [46]. Alkali and alkaline-earth metals can be found in crystalline, hydrated aluminosilicates called zeolites. Their three-dimensional, negatively charged, porous silica-oxygen tetrahedral honeycomb network serves as the foundation for their structure. Exchangeable cations of sodium, potassium, magnesium, and calcium balance the negative charges. It has been documented that Pseudomonas sp. can survive on zeolite and other air-dried mineral powders when used for plant pathology biocontrol [47].

Granulars: Along planting the seeds, the inoculants are sprayed straight into the furrow. The range of sizes is 0.35 mm to 1.18 mm. Since 1975, these inoculants have been commercially marketed and are widely used [48,49]. Granular forms are synthesised into bead-like shapes. These can be utilised in two sizes: micro (100–200 µm) as a powder for seed coating, or macro (1–3 mm in diameter) as granules. These inoculants represent a novel, as of yet untested, advancement in vaccination technology [50].

Liquid formulation: In order to address the issues with formulations based on solid carriers, new inoculant formulations that guarantee longer survival, no contamination, and ease of application are required. Many of the liquid-based inoculant formulations that have been introduced recently have been demonstrated to be more resilient to harsh environmental conditions and devoid of other issues that arise with preparations based on solid carriers [51].

In addition to the targeted microorganisms and their nutrition, liquid bioinoculants are unique formulations that include specific cell protectants or compounds that promote the longer shelf life and tolerance to unfavourable conditions [52].

Products with liquid formulations are usually aqueous, oil-based, or polymer-based. Gums, carboxymethylcellulose, and derivatives of polyalcohol are examples of polysaccharides that are commonly employed to change the fluid characteristics of liquid formulations [53]. Many of the challenges involved with processing solid carriers could be solved by developing a liquid inoculant formulation with high field performance characteristics that uses inexpensive components that are easily accessible to small producers [54]. The use of liquid inoculants is becoming widespread, especially in India where employing carriers to transport, pulverise, neutralise, sterilise, and other processes is quite expensive [55].

Fig. 9. Liquid formulation of microbial inoculants

A good liquid inoculant should have the following qualities: it should be non-toxic, inexpensive, easily obtainable, uniform, able to adapt to standard cell culture conditions, receptive to nutrient supplements, release microorganisms into the soil quickly, support their growth and survival, and be simple to handle during the mixing and packaging process [56,54]. The GCMS analysis of beejamruth revealed the presence of bioconversion-repelling chemicals called gentamicin and lovastatin. Cryopreservation uses macrocyclon, an antibacterial, and 8-heptadecene dioicacid. A viable and efficient substitute fertiliser for producing food that is safe and of high quality and can meet the demands of contemporary India is Beejamruth [57]. Fresh preparation and usage were made of liquid organic formulations such as Jeevamruth, Panchagavya, and Panchagavya formulations using groundnut oil cake and sesame oil in place of ghee. Compared to control plants, treated plants had higher amounts of photosynthetic pigments and higher root oxidation activity. The treated plants with liquid formulations also had significant levels of soluble protein and total sugar content [58].

Basic concept of liquid formulation: Chandra [59] reported that there are four basic characteristics in formulation. They are:

- To maintain the organism's stability throughout distribution, storage, and production.
- To provide in the most suitable way and with ease to the field.
- To increase the microorganism's persistence by shielding it from detrimental environmental elements at the target place (field).
- To improve the organism's activity at the target site by boosting its reproduction, interaction, contact, and activity.

Values of compost in agriculture: Applying compost to agricultural land is necessary to preserve the quality of the soil and water while optimising agronomic benefits. Nitrogen availability is the primary factor that determines effective agronomic utilisation [60].

Effect of organic manure on soil properties: At the lowest possible cost, compost that is similar to natural humus protects the soil.

Even though compost has less nutrients than mineral fertilisers, scientific testing have shown that it can be an efficient manure substitute. The value is increased by the organic components and the presence of macro and micronutrients [61].

It has been demonstrated that adding compost to cultivated soil can enhance its physical, chemical, and microbiological properties, increase moisture availability, decrease the amount of water needed for plant growth, and boost crop yield [62].

Physical properties: Organic manures enhance the tilth, texture, and structure of the soil. While clayey soils grow more arable, sandy soils get more compacted [32]. Because it is an organic matter source, composted coir pith has a very high water-holding capacity—more than five times its dry weight—which helps to retain more moisture in the soil [63].

According to [64], the application of organic manures enhanced the amount of water that alluvial soil could hold, ranging from 11.9 to 22.8%. There was a noticeable rise in porosity values in the plots when organic manure was treated.

In plots treated with organic manure, the bulk density of the soil decreased significantly on both the surface (10–15 cm) and subsurface (15–30 cm) levels [65].

Chemical properties: Since compost is created from plant leftovers and their byproducts, it includes every component that makes up a plant. As a result, its addition raises the soil's overall supply of these elements. It offers macro and micronutrients alike. Additionally, by lowering the intake of some minerals, such as aluminium, organic manure mitigates the harmful effects on plants [32].

Plots treated with coir pith showed the highest soil organic C content and CEC capacity in light-textured soils [66]. The amount of accessible N in the soil was enhanced by applying poultry manure, either by itself or in conjunction with FYM [67]. In their study, [68] examined the effects of various manure regimens on the characteristics of the soil and found that the application of organic manures significantly and favourably affected the soil's fertility. The treatments that were given organic manures had a noticeably higher level of organic carbon.

In addition to increasing available nitrogen content [69], phosphorus and potassium content [70], and crop potassium use efficiency [71], the combined application of coir pith and inorganic fertilisers also increased available nitrogen content. The addition of organic manures improved the availability of zinc and iron while having little influence on the availability of manganese and copper [72].

4. BIOLOGICAL EFFECTS

Soil microorganisms: Actinomycetes, fungus, and bacteria abound in compost, and their addition to soil not only adds millions of new microorganisms but also stimulates the millions of existing ones with the delivery of new humic materials [32]. The enhanced microbial activity leads to a rise in ammonification, nitrification, and N fixation. Additionally, compost encourages mycorrhizae, which coexist with plant and tree roots in a symbiotic relationship and are crucial in moving certain nutrients from the soil to the plants [32].

All biological changes that occur in the soil are exclusively caused by soil microorganisms. These are accomplished by a range of biochemical processes that are either fully or partially catalysed by an enzyme group [73].

Soil enzymes: An indicator of the microbial activity in the soil is thought to be the activity of soil enzymes. Consequently, it would be predicted that any management strategy that affects the soil's microbial population would result in changes to the soil's enzyme activity, and the degree of enzyme activity can be used as a gauge of soil fertility [74]. Dehydrogenase activity in soil can be measured to provide correlational data on the biological activities of soil microbial populations [75]. Soil phosphatase activity is increased by organic manures [76]. The activities of urease, catalase, dehydrogenase, and amylase in soil were enhanced by the addition of organic matter [25,77].

Effect of organic inputs on crops: Organic manuring has an impact on all crops, but the amount of that impact varies depending on a number of variables, including the compost's maturity, degree of humification, C/N ratio, application time and method, soil type, agroclimatic conditions, and soil moisture regime during the crop's growth [32].

Increased yield and nutrient uptake were clearly associated to either the enhanced physical condition or the nutrient contents of the organic manure or wastes, according to a number of pot culture and field tests [78,79,80].

Plots with organic manure added consistently yielded 10–30% more than those with organic fertiliser applied alone [11]. According to the results of a field experiment to test the effects of Jeevamruth and Beejamruth on fenugreek, which was carried out at the Research Farm, Department of Sustainable Organic Agriculture, Tamil Nadu Agricultural University, Coimbatore, the treatment T3 (Jeevamruth @ 5% spray) had the highest plant height, root length, and single plant weight [81]. Because ghee is expensive, a study was done to see how long panchagavya would last using groundnut oil cake and sesame oil instead of ghee. One month and six months following the addition of components, respectively, were sampled. A produced extract was subjected to a variety of biochemical property analyses using GCMS. Every Panchagavya formulation had phenol, alcohol, ester, and fatty acid derivative. The organic product's ability to resist rancidity was aided by the presence of gamma tocopherol and vitamin E in panchagavya made with groundnut oil cake. However, the fatty acids in panchagavya made with sesame oil caused it to go rancid, which shortened its shelf life [82].

Field crops: According to [83], applying nitrogen through compost sped up metabolic activities, which improved the synthesis of protein, amino acids, and carbohydrates and increased the uptake of these nutrients in wheat and black gramme. In their 1995 study, Subbaraj and Ramaswami examined the impact of organic amendments on groundnut oil output. They found that the treatment involving composted coir pith had the greatest oil content, ranging from 34.7 to 47.7%. In soil treated with coir pith, [84] observed an increase in root length, panicle length, grain yield, density, and panicle per grain.

According to [67], the application of organic manures, particularly composted poultry manure, either alone or in combination with FYM improved the growth parameters and yield of cassava [85] found that organically treated soils produced higher wheat and grain yields than control.

Horticultural crops: According to the findings of over thirty potato tests, applying organic manure increased yield by four to thirty percent over control [32]. Additionally, reports of increased yields in tomatoes, sweet potatoes, onions, fenugreek, and chillies were made. Cucumbers can be grown in glass houses using organic waste materials as a growing medium, with promising results [86]. Fruit production on the compost-applied field began 10 to 12 days earlier, according to [87], and compost treatments displayed a noticeably better yield. Applying compost also has the added benefit of suppressing the growth of weeds and a variety of plant diseases [88,89].

It is possible to go into further detail about the environmental effects of employing liquid formulations and compost. This demonstrates how important it is for them to reduce greenhouse gas emissions and promote biodiversity. When Panchagavya formulation was applied to maize plants, the plants' root and shoot lengths increased, and the growth parameters of the seedlings were also improved [90]. Application of Jeevamruth and Beejamruth as a 5% spray was noted as a feasible organic technique to increase soil and eco-friendly fenugreek production [81]. Plant height, root length, and single plant weight were high in Jeevamruth 5% sprayed plants.

5. CONCLUSION

In conclusion, liquid formulations and compost play crucial roles in enhancing agricultural productivity and sustainability. Liquid formulations, particularly inoculants, provide cost-effective and efficient means of delivering beneficial microorganisms to the field, addressing the logistical challenges faced by small producers. They offer advantages in terms of stability, ease of application, and environmental protection, significantly improves soil physical, chemical, and biological properties, leading to better crop produces. The practice of manure enhances soil structure, moisture retention, and microbial activity, contributing to sustainable agricultural practices. Both liquid formulations and compost applications are vital for improving crop performance, supporting environmental conservation, and promoting sustainable agriculture, especially in resource-constrained settings.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. ChatGPT was used for editing this manuscript.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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