

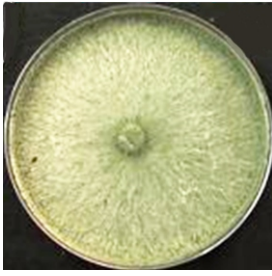
जैव खाद

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त्वरित वानस्पतिक खाद प्रौद्योगिकी : विकास से परिनियोजन तक

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नाभिकीय कृषि एवं जैव प्रौद्योगिकी प्रभाग, भाभा परमाणु अनुसंधान केंद्र, ट्रम्बे, मुंबई-400085, भारत



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सारांश

कृषि क्षेत्रों, पवित्र स्थलों में पुष्पांजलि, उद्यानों, बाजारों और रसोईघरों वानस्पतिक से उत्पन्न जैव अपघटनीय अपशिष्ट की समस्या का सामना करने के लिए त्वरित खाद प्रौद्योगिकी (आरसीटी) विकसित की गई। आरसीटी में एक एकल सेल्युलोजाइटिक कवक ट्राइकोडर्मा कोनिनिओप्सिस और संबंधित प्रोटोकॉल शामिल हैं। टी.कोनिनिओप्सिस को उगाना आसान है और इसमें गुणात्मक वृद्धि के लिए न्यूनतम बुनियादी ढांचे की आवश्यकता होती है। आरसीटी को अपना आसान है, इसके लिए अपशिष्ट के सुनिश्चित पृथक्करण या मानव शक्ति के विस्तृत प्रशिक्षण की आवश्यकता नहीं है। इसलिए, समाज के सभी वर्गों के अकुशल लोगों को नियोजित किया जा सकता है। यह प्रक्रिया कार्बन पृथक्करण की अग्रगामी है, और प्राप्त खाद जैविक कृषि/खेती के लिए उपयुक्त है। खुले स्थानों में सौंदर्य सुधार, सार्वजनिक स्वास्थ्य एवं स्वच्छता में सुधार, बीमारियों में कमी और पोषक तत्वों का पुनश्चक्रण इस तकनीक के कुछ दूरगामी परिणाम हैं। जबकि कई नगर निगमों द्वारा आवास समितियों से अपशिष्ट उठाव से इंकार किया जा रहा है, आरसीटी जैसी प्रौद्योगिकियां प्रभावी अपशिष्ट प्रबंधन में मददगार हो सकती हैं तथा स्वच्छ भारत मिशन में योगदान कर सकती हैं। विशेष रूप से, आरसीटी को कई कंपनियों को लाइसेंस दिया गया है जिन्होंने इसे देश भर के लोगों के लिए सरलता से सुलभ बनाया है।

Bio Composting

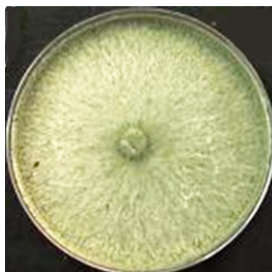
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Rapid Composting Technology: From Development to Deployment

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ABSTRACT



Trichoderma koningiopsis culture

Rapid Composting Technology (RCT) was developed to confront the problem of biodegradable waste arising from settings such as agricultural fields, flower offerings at holy places, gardens, markets and kitchens. RCT comprises of a formulation consisting of a single cellulolytic fungus *Trichoderma koningiopsis* and the associated protocols. *T. koningiopsis* is easy to grow and requires minimal infrastructure to multiply. RCT is easy to adopt, does not require strict segregation of waste or elaborate training of manpower. Hence, unskilled people from all sections of the society can be employed. This process leads to carbon sequestration, and the compost obtained is suitable for organic agriculture/farming. Aesthetic reclamation of open spaces, improvement in public health and sanitation, reduction of disease incidence and nutrient recycling are some of the far reaching consequences this technology. With several municipal corporations declining to lift garbage from housing societies, technologies such as RCT can help in effective waste management and contribute to the Swachh Bharat Mission. Notably, RCT has been licensed to several companies who have made it easily accessible to people across the country.

KEYWORDS: Rapid composting technology, Organic agriculture, Nutrient recycling

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Introduction

Inordinate urbanization has multiplied the number of authorized and unauthorized garbage dumps strewn across all cities. Their proximity to habitable areas often poses health risks due to toxic leachates and gases. Open burning and self-ignition of garbage in large cities results in the release of thousands of tonnes of deadly fumes with fine particulate matter (Ghosh 2014). On the other hand, at least 50% of garbage generated in India is biodegradable and hence amenable to biological processing (Ghosh 2014). Several technologies such as generation of bio-gas, aerobic and anaerobic composting, vermicomposting, insect-based degradation, are in vogue, each with its share of pros and cons. However, the basic aim of all these technologies is to turn waste into wealth, return it back to the source and derive economically beneficial products. The initiative towards a "Clean India" gave rise to the Swachh Bharat Mission in October 2014. The Swachh Bharat Mission includes a focus on scientific municipal solid waste management, including segregation at source, collection, transportation, processing, and disposal (Wikipedia & <https://sbmurban.org/>). The effectiveness of any waste-processing technology largely depends on its societal acceptance, environmental compatibility, ease of operation, and economic feasibility. Technologies, that mimic natural biodegradation processes, while being eco-friendly and cost-effective, are more likely to achieve widespread adoption. In this article we describe the development of an aerobic composting technology which uses a single cellulolytic microbe that can be easily multiplied at ambient conditions. This technology provides a scalable solution towards managing biodegradable waste (from kilograms to tonnes) at the source of generation.

Technology development

Aerobic microbial degradation of biodegradable waste, commonly termed composting, not only converts organic waste into nutrient-rich compost but also reduces greenhouse gas emissions compared to anaerobic decomposition.

In natural ecosystems, a diverse group of microorganisms- including bacteria, fungi, and actinomycetes participate in the decomposition process. The addition of lignocellulolytic inoculum at the onset of composting has been shown to enhance the rate of waste degradation significantly (Zhang et al. 2014). It is noteworthy that cellulose, the most abundant natural polymer, is difficult to degrade. Therefore, a fungal strain with high cellulolytic activity, *Trichoderma koningiopsis*, was isolated from the bark of a mango tree as a

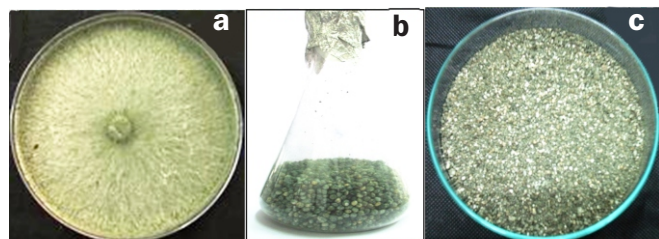


Fig.1: (a) *Trichoderma koningiopsis* culture, (b) *T. koningiopsis* growing on sorghum grains (c) *T. koningiopsis* Formulation for field application.



Fig.2a: Different stages of composting process in lab/pilot scale.

promising candidate for degrading cellulosic waste (Fig.1). A user-friendly formulation was developed using commonly available sorghum grains as carbohydrate source for mass multiplication of the culture with reasonable shelf life and ease of application (Fig.1).

Protocol Development for Bio-degradation of Various Biomasses

The protocol for biodegradation was systematically developed through a stepwise scale-up approach, beginning with small-scale laboratory experiments, followed by pilot-scale studies in drums of approximately 100 kg capacity, and finally validated at large-scale (tonnes) under real life conditions of waste generation and processing (Fig.2).

The ideal Carbon/Nitrogen ratio was maintained in the range of 20-40, while moisture content of the feed was maintained within 40-60% (Garg and Tothill 2009)-a critical input. Since waste, such as kitchen waste and dry leaves, inherently vary in their initial moisture and nutrient composition, customized protocols were developed for each category optimizing the dosage of microbial culture and



Fig.2b: Large-scale composting in pits followed by automated sieving.

bulking agents /adsorbents (e.g., coco peat), frequency of upturning (aeration), addition of water (for dry biomass) as required, as well as choice of shredder.

Change in pH, Temperature and Moisture (%) during composting

During the entire period required for composting of kitchen waste, distinct changes in pH, temperature and moisture content, were observed. The pH increased from acidic (~4.3) to alkaline (~8.5) by day 11-13. After Day 13, it stabilized and subsequently declined toward neutral (~7.2-7.8), indicating compost maturation. (Onwosi et al. 2017 and Lin et al. 2018).

Changes in moisture content during composting are dynamic and critical for microbial activity and decomposition efficiency. Moisture content initially ranged between 60-64% and showed a gradual decline with intermittent fluctuations, reaching ~33-35% by day 25.

Changes in temperature during composting, reflects the trend of active thermophilic degradation followed by stabilization during the maturation phase. (Antunes et al. 2016). The rapid increase in temperature from 35°C (ambient) to a peak of 66°C by day 5 confirms intense microbial activity and establishment of thermophilic conditions, essential for accelerated decomposition and effective pathogen reduction. Subsequently, the gradual decline in temperature from day 6 onwards reflects a reduction in readily degradable substrates and a transition towards the stabilization phase.

Strain Improvement through radiation induced mutagenesis

Due issues with lower sporulation rates observed with *T. koningiopsis*, it was desired too improve this aspect by

gamma radiation-induced mutagenesis. After exposure to 1.2 kGy dose, one mutant that consistently showed higher and light-independent sporulation was selected. The mutant strain, named as TKDG, will now be included in the modified RCT.

Successful Applications of RCT

In-situ Banana Trash

Bananas are a perennial crop where the pseudo-stem innately collapses after bearing fruits or are felled after harvesting. For every ton of banana fruit harvested, roughly 3 tons of pseudo-stem, 150 kg of rachis, and 480 kg of leaves are produced, along with 100 kg of discarded fruits (Subagyo and Chafidz 2020). Banana by-products such as pseudo-stems and leaves are sometimes returned to the soil to serve as extra nutrients. But, often these discarded into large open-air dumps rendering them unsuitable for chemical and biological breakdown (Torres-León et al. 2018). In a feasibility study at Nandurbar district of Maharashtra, banana pseudo stems and fruit axis were spread along the furrows in the fields parallel to irrigation channels. Controlled dose of RCT formulation (Magic D, product from M/s. Tanay Agronics) was applied through the channels. It was observed that while the outer layers of the pseudo stem dried up the inner layers progressively decomposed in 1.5 months and reintegrated into the soil (Fig.3). This saved much of the labour cost involved in gathering, transportation and burning at dumping grounds.

Farm Yard Manure (FYM)

The term "farmyard manure" describes a decomposing mixture of farm animals' excreta, urine, & leftover debris from roughages or cow feed. A well-decomposed farmyard manure typically includes 0.5% N, 0.2% P₂O₅, and 0.5% K₂O. Common procedures used by farmers to make farmyard manure are flawed with leaching and volatilization causing nutrient loss.



Fig.3: (a) 1st step of manual spraying of culture or sending through drip irrigation, (b) Appearance of the field-furrow after 15 days, (c) after 30 days, (d) final compost after 2 months of application of formulation.

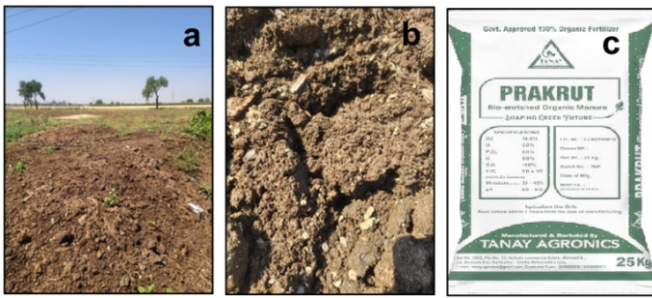


Fig.4: On-field animal dung composting and (a. field and b. close-up view); c. A new product with enhanced Nitrogen content developed by Licensee Tanay Agronics.

Better techniques for FYM preparation that reduce time of decomposition are required. In order to expedite this process, rapid composting formulation was added as 500ml (10^8 /ml) per tonne of animal dung. Within 1.5 to 2 months decomposed manure was obtained with: Nitrogen 0.8%, P_2O_5 0.5%, K_2O 0.8% - a considerable improvement over traditional processes which takes about 5 months to mature (Fig.4).

Composting of Kitchen waste

The Homi Bhabha Centre for Science Education adopted RCT in 2018 after the decision of the Brihanmumbai Municipal Corporation to discontinue garbage collection throughout Mumbai. In order to facilitate decentralized waste

management, discarded chemical storage drums were repurposed and modified to function as composting units with perforations for adequate aeration. Since implementation, the system has been consistently processing approximately 75 kg of kitchen waste per day, demonstrating operational efficiency and sustainability.

Another notable example is the Kailash Chandra Housing Society located in Mahindra Nagar, Malad. The society generates nearly 250 kg of biodegradable waste daily, all of which is treated on-site using “rapid composting technology” implemented by Chij Agro Industries, a licensee of BARC (Fig.2b). Additionally, around 300 kg of garden waste is processed on-site monthly. The compost produced is utilized within the society's gardens and also serves as a bulking agent for subsequent composting cycles.

Conclusion

This technology is in line with the 12th Sustainable Development Goal of The United Nations, which calls for efficient use of the world's natural resources, reduced waste generation, and reduced post-harvest losses (World Bank Annual Report). This goal can be achieved by integrating the concept of circular economy (CE) into each stage of a product's/food/biomass' life cycle allowing the transformation of waste into valuable products and the concomitant reduction of harmful emissions (Schroeder 2020). Rapid composting technology with many products in the market (Fig.5) is playing its part towards a sustainable future.



Fig.5: A collage of products launched and marketed through online shopping portal.

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