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BIOCONVERSION OF BANANA ORCHARD WASTE INTO AN EFFECTIVE SOIL CONDITIONER BY COST-EFFECTIVE AND ECO-FRIENDLY MANNER

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ABSTRACT:

The banana orchard waste with C/N ratio 34.4 was converted by solid substrate fermentation (using mixed culture, warm, humid and aerobic conditions, 60 days) to saleable soil conditioner (SC) having C/N ratio 17.3, organic carbon (34 %), N (2 %), P (0.3 %) and K (2.6 %), for its use in horticulture. Its cost was estimated to be US $ 49/- per MT at semi-commercial production scale. It exhibited improved WHC, promoted beneficial soil microflora, amended texture to soil and thereby, increased overall productivity. The policy of its production and trade is therefore, anticipated to promote (i) rural industrialization, (ii) conservation of natural resources, (iii) partial substitution of chemical fertilisers, (iv) improvement in beneficial microflora and productivity of soil, (v) sustenance of horticulture in eco-friendly way and (vi) benefit producer as well as consumers. Efforts in this bioprocess technology of SC production and its socio- & eco-economics are communicated in this article.

KEYWORDS: *Soil conditioner, Recycled banana orchard waste, Bioconversion, public policy and SC trade.*

INTRODUCTION:

Jalgaon district annually witnesses cultivation of banana on 39,300 hectares land. After banana harvesting, this area produces voluminous waste of banana pseudostems, accounting for approximately 3.4 million MT organic matter. In the absence of its alternate use or recycling for enrichment of organic carbon content of soil, which is already as low as 0.10-0.15 % (Agriculture Epitome, 1996), it is incinerated upon natural (solar) drying, causing a considerable loss of nutrients, approximately 5338 MT N, 782 MT P and 7650 MT K. Continuation of this practice for the last three decades, compounded with indiscriminate application of chemical fertilisers and flood irrigation, has resulted into undesirable changes into physico-chemical texture and microbiological profiles of soil. The net result has been stagnation of banana yield to an average 53 MT/h. To arrest degradation of soil and conserve such a huge drain of nutrients in pseudostem waste, it is necessary that forgotten merits of recycling of organic waste be restored by converting it into a plant growth-stimulating SC, vital for augmenting banana agricultural productivity, by partially alleviating dependence on chemical fertilisers.

Secondly, production of inorganic fertilisers is capital, energy and pollution intensive. Several environmentally hazardous products like oxides of nitrogen and sulphur, fluorides and particulate matter arising during their manufacture has contributed to the pollution of air, water and soil. Their continued application has contributed to increased soil salinity, alteration of soil microbial flora, pollution of groundwater and soil erosion. With the realisation of these problems, there is a renewed interest in the development and use of organic nutrients for sustainable agriculture. In this communication, we report the process of converting banana pseudostem waste into a plant growth-stimulating soil conditioner, useful for augmenting the agricultural productivity and partially alleviating the dependence on inorganic fertilisers.

MATERIALS AND METHODS:

Collection of pseudostem waste: After harvesting banana bunches, rest of the biomass (excluding root system) was cut and collected near the site of SC preparation.

Chopping of the waste: Disease-free pseudostems along with leaves were mechaniclly chopped into pieces of 1-2 cm long size and treated further for efficient composting.

Adjuvant: Urea solution (0.5 % w/dry w) was used as an adjuvant to serve as food for composting organisms.

Inoculum: *Volvariella volvaceae*, a ligninase-rich fungus was produced in bio-reactor, using growth medium, comprised of soya flour 0.5 % (w/v), Corn Steep Liquor (CSL, 60 % TSS) 1.7 % (w/v) and Tween-80 0.01 % (v/v), pH 5.5 at 30 ^{o}C for 48 h to yield 10-11 g dry mycelial mass/L. Prior to use, it was blended.

SC preparation: Composting pit of 2 m x 1 m x 1 m size was dug and its bottom was layered with 10 cm fine black cotton soil from banana harvested farm. On this layer, chopped pseudostem (CP) was layered. In this way, whole pit was filled by alternate layers of CP and soil (10 % w/dry w of the substrate). Intermittently, it was sprinkled with adjuvant and inoculum (5 % v/dry w of substrate). The whole matrix was thoroughly mixed by turning up and down. The heap of composting mix was 0.5 m high above the pit, covered with leaf trash and stalks of *Sorghum* to arrest desiccation of uppermost layers due to sun (Ramamurthy *et al*., 1995).

Maintenance and monitoring: Change in temperature was monitored every day using soil thermometer and moisture maintained to 50-60% by sprinkling enough water on the heap after determining its % moisture. Every week, the heap was turned upside down for thorough mixing, aerating the composting mix and minimising anaerobic situation.

Analysis: Cellulose and crude fibre contents were estimated in CP and SC after 30 & 60 days as per Ranganna (1997). Organic carbon, organic matter, N, P, K were determined as per Tandon (1993). After 30 and 60 days, bioefficacy of SC was assessed by sowing wheat seeds in SC fortified soil (Test) and only soil (Control) and by comparing their percent germination, height, biomass, root ramification and chlorophyll contents (Ramamurthy *et al*., 1995). Each set and test was in triplicate and their averages were considered. These analytical findings are summarised in Table 1.

RESULTS AND DISCUSSION:

Due to poor biodegradability *per se* phyto-inhibitory characteristics and low bulk density, banana pseudostems were disposed off by either incineration or discarding on the boundaries of farms. An alternate outlet to disposing this waste has been explored, which has (i) potential of giving a useful and saleable product (SC), (ii) inherent traits of phyto-promotion increasing agro-productivity in the short range and (iii) capacity to render Indian agriculture sustainable in the long range.

Soil Addition: Chopped banana pseudostem waste (CP) due to its smaller size provided more surface area for microbes to interact, which resulted into accelerated SSF, conserving 60 days instead of 360 days. The bottom of pit was layered with a 10 cm thick black cotton fine soil from banana farm, to retain its soluble entities in the composting mix, which otherwise might have lost to deeper strata of earth by leaching and causing pollution. Similarly, dry soil was added to CP (i) as a supplementary inoculum and diluent for retarding anaerobic conditions, (ii) to reduce an excess of moisture, (iii) to absorb ammonia liberated and (iv) to improve the appearance of SC (Gaur, 1995).

Solid State Fermentation (SSF) of CP: Initially, the inoculated ligno-cellulolytic fungus and organisms from soil/substrate established themselves, using easily assimilable nutrients and adjuvant in the composting mix, proliferated, stabilised and acted upon CP to degrade its complex structure of lignin to smaller molecules (Ramamurthy *et al*., 1998).

Initial mesophilic stage favoured the proliferation of inoculum fungus and microbes from soil/substrate. This resulted into rise in temperature above 40 ^{o}C, consequent to which, mesophiles retarded and replaced by thermophiles. In both phases, degradation of pseudostem was concurrent with elimination of pathogens, if any. Under aerobic and humid conditions, mixed culture biodegraded pseudostem into a matrix rich in fulvic and humic acid in 60 days (Phirke *et al*., In press). During this period, profiles of temperature and moisture were monitored as depicted in Fig. 1. SC harvested at 60 days upon analysis gave the following chemical attributes (Table 1).

From Table 1, it is clear that CP with C/N ratio 34.4 was phyto-inhibitor, while after 60 days it became phyto-promotor (C/N ratio 17.3) as confirmed from bioefficacy. This has been possible due to degradation of lignin by ligninolytic enzymes from *V. volvaceae* and change in physical structure by SSF catalysed by a consortium of aerobes from substrate and soil. The novelty is conservation of a bioresource, retaining its N, P, K nutrients for recycling. Higher (25-30 %) qualitative (preservable at ambient temperature for two weeks) yield of banana, most probably, was a reflection of nutrients-rich matrix provided by SC (Phirke *et al*., 1999). Cumulatively, SC has shown the following characteristics:

It improved water holding capacity of soil, especially sandy soils used for experimental trials, thereby reducing frequency of irrigation.

It prevented water logging in clayey and loamy soils and promoted sustained release of moisture to root system, thereby sparing plants from water stress and in turn promoted sustained growth rate (Rajor *et al*., 1996).

It increased porosity of the soil, thereby making more oxygen available to the root system, in turn increasing it's ramification, energy level and thereby resistance to soil pests.

It provided organic carbon to the soil which has capacity to make available chemical fertilisers on sustained basis, thereby conserving the use efficiency of chemical fertilisers in most economical way without causing pollution to underground reservoirs of water and at the same time affording sustained growth rate to the plants.

It improved cohesiveness of soil particles, thereby reducing the chances and rate of soil erosion.

Its humus content has the capacity to minimise certain pests like Nematodes and soil pathogens, presumably due to its siderophore content (Talegaonkar, 2000).

Public policy: With an increase in the cost of seeds, chemical fertilisers, pesticides, labour wages and electricity for irrigation, cultivation cost per hectare has gone up, while productivity has remained stagnated or at times reduced. Such persistent trend in the last decade has alarmed the farming community and a perception that agriculture may remain non-remunerative in future too, has compelled them to search for alternatives to replace their wrong practices, if any. Incidentally, the work of Kale and colleagues (1992, 1993) has proved that (i) chemical fertilisers alone are no good for increasing agro-productivity, (ii) soil conditioners alone too could not restore the productivity and (iii) their judicious application offered synergistic effect, reflected in increasing the agro-productivity (Ramamurthy *et al*., 1995; 1998). Impetus in favour of using SC was, therefore, strengthened by the realisation that organic carbon content in most of the soils has depleted to for inadequate level, which can hardly provide organic matrix for the sustenance of microflora. These findings, realisation of rendering a fertile soil non-fertile by short circuiting soil microbial activity and personal experience of stagnated agro-productivity by using chemical fertilisers alone, convinced the farmers that there is a vast scope for reducing the application of chemical fertilisers. A reduction in the use of chemical fertilisers also reduces the (i) cost of cultivation, (ii) frequency of irrigation, (iii) rate of soil salinisation and (iv) underground pollution and thus, provides the scope for reverting the microbial processes necessary for soil fertility utilising SC. This scenario has inherent potential of reviving texture and productivity of the soil.

As the traditional use of cattle dung compost or night soil manure is no more possible due to their shortage and logistic constraints, public opinion is veering around the preparation and use of SC to revive traditional, forgotten but healthy agricultural practices.

Trade: Traditionally, soil conditioners were naturally prepared in the open pits, without any processing and hence, the whole process required 52 weeks. With biotech inputs (culture, adjuvant and optimised process parameters), it needs meagre 8 weeks. The present work is generic in nature, utilising any biodegradable and locally available solid organic biomass for SC preparation. (Patil and Kothari, 2000). The choice of banana pseudostem has been made in view of its abundant, easy, economical and all time availability. Secondly, it would give optimised nutrient resource for supporting banana crop, SC application being a process of recycling (Table 2.) Thirdly, it being a major cash crop in Jalgaon district, transport and logistics of pseudostem or SC are not costly. Therefore, it should serve as an ideal substrate for SC.

Environmentally, pseudostem recycling certainly conserves chemical fertilisers, promotes microbial growth and has maximum possibility of giving sustainably higher and qualitatively better yields of banana. Such experiment has already been successfully conducted by us (Phirke *et al*., 1999) and is being repeated on large scale, with excellent prospects of qualitatively and quantitatively higher yields. Broadly, these trials consumed 50 % less chemical fertilisers, around 60 % less water (as also electricity) and afforded healthy plants without compromising the yields. The vigour and health of banana plantation in experimental (SC-applied) crop as against fungal infestation in control (without SC application) crop around our trial farms, indicated that an inherently healthy plant has least susceptibility to fungal infestation, presumably due to siderophores (Talegaonkar, 2000). Such scenario permits arresting or atleast minimising the application of fungicides which have not provided visible protection to the crop, but certainly has deteriorated the fertility of soil. Thus, the experimental data and its demonstration trials has made public perception and confidence in favour of SC.

India is a signatory to World Trade Organisation (WTO), which has opened vast era of exporting banana in the nearby countries. Banana grown on soil conditioner with minimal or no use of chemical fertiliser/pesticides is desired by the consumers as a result of public awareness of hazardous effects of fertilsers/pesticides on quality of produce and health. Therefore, there is an ample scope for large scale preparation of SC and its utilisation for agricultural, horticultural, floricultural and forestry purposes (Phirke *et al*., In press). Cost-wise too, SC is an economical partial substitute to chemical fertilisers, providing short term benefit due to higher yields (Ramamurthy *et al*., 1998) and long range benefits of preserving soil fertility/productivity (Rajor *et al*., 1996).

Thus, looking at (i) simplicity of technology, (ii) shorter duration for preparation of SC, (iii) abundent availability of banana pseudostem as substrate, which has no alternate application in sight, (iv) its stability, permitting problem-free transport and application, (v) short range benefits to farmers by virtue of economical inputs, (vi) immediate benefits to consumers for superior quality banana, (vii) long range benefits to eco-system and (viii) far reaching implications of waste recycling for stabilising soil fertility through microbial action, as also wealth creation for society and government, SC trade enjoys national as well as international approval too (Sharma *et al*., In press).

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REFERENCES:

Agriculture Epitome. (1996). Department of Agriculture, Government of Maharashtra, India.

Gaur, A. C., Neelakantan, S. and Dargan, K. S. (1995). Organic manures. ICAR, New Delhi, India, p. 1-159

Kale, R. D. and Bano, K. (1992). Niche diversions- a limiting factor for recommendation of earthworms for biotechnology. *In*: Proc. Natl. Symp. Organic Farming, Pune-411 030 (India), p. 42-44

Kale, R. D. and Sunitha, N. S. (1993). Utilisation of earthworms in re-cycling of house-hold refuse, a case study. Consortium Rural Technology, New Delhi (India), p. 75-79

Patil, R. P. and Kothari, R. M. (2000). Generic technology for the recycling of organic solid waste for improving soil fertility towards sustainable agriculture. *In*: Proc. State Level Seminar on Soil Technology for Sustainable Agriculture, Rahuri Chapter of ISSS, MPKV, Rahuri (January 18-19).

Phirke, N. V., Patil, R. P., Chincholkar, S. B. and Kothari, R. M. (1999). Eco- & farmer-friendly strategy for enhancing productivity of banana. *In*: Proc. National Seminar on Entrepreneurial Opportunities in Biotechnology (6-7 September, 1999), Nanded-431 606 (India), p. 1-11

Phirke, N. V., Patil, R. P., Sharma, R. K., Kothari, R. M. and Patil, S. F. (2001). Eco-Friendly Technologies for Agriculture, Horticulture, Floriculture and Forestry for 21st Century. *In*: The Environment 2001: Global Changes and Challenges (Ed. Ram Prakash).

Rajor, A., Sharma, R., Sood, V. K. and Ramamurthy, V. (1996). A sawdust-derived soil conditioner promotes plant growth and improves water holding capacity of different types of soils. *J. Ind. Microbiol.* 16 : 237-224

Ramamurthy V., R. K. Sharma, K. R. Yadav, J. Kaur, Dev Vrat and R. M. Kothari (1995). *Volvariella*-treated eucalyptus sawdust stimulates wheat and onion growth. *Biodegradation*, 7:121-127

Ramamurthy, V., Sharma, R. K. and Kothari, R. M. (1998). Microbial conversion of ligno-cellulosic wastes into soil conditioners. *In*: Advances in Biotechnology (Ed. A. Pandey), Educational Publ., New Delhi, p 433-438

Ranganna, S. (1997). Handbook of analysis and quality control for fruit and vegetable products, 2nd Ed. Tata McGraw-Hill Publ., New Delhi.

Sharma, R. K., Ramamurthy V. and Kothari, R. M. (In press). Soil Conditioner- a vital bioresourse for sustainable agriculture and forestry. *In*: *Bioresource Biotechnol*. (Ed. A. Kanniyan), TNAU, Coimbatore.

Talegaonkar, S. K. (2000). Application of pressmud for plant growth promotion. Ph.D. Thesis, North Maharashtra University, Jalgaon-425 001 (India)

Tandon H. L. S. (Ed) (1993). Methods of analysis of soils, plants, waters and fertilisers. Fertilisers Development and Consultation Organisation, New Delhi, India, p. 1-144

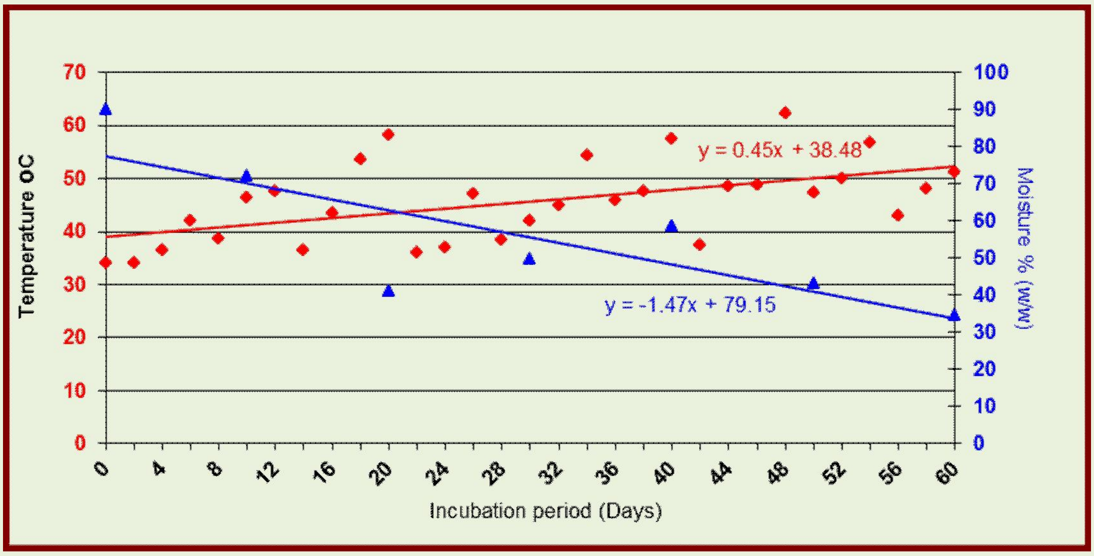

Fig. 3.1: Temperature and moisture variation trends during SC formation

Table 1. Physico-chemical changes in chopped pseudostem during conversion to SC

Characteristics	CP	After 30d	After 60d	Final saleable packed SC (% w/w)
Dry matter (Kg)	100	91.5	77.3	65
Moisture (% w/dry w)	90.0	54.2	34.7	35.0
Organic matter (% w/dry w)	93.1	84.3	69.8	58.6
Cellulose Content (% w/dry w)	11.3	10.1	8.2	6.8
Crude fibre (% w/dry w)	12.8	10.9	8.5	7.2
Total carbon (% w/dry w)	54.0	48.9	40.5	33.9
N (% w/dry w)	1.57	2.15	2.34	1.97
P (% w/dry w)	0.23	0.34	0.36	0.3
K (% w/dry w)	2.25	2.79	3.04	2.6
C/N ratio	34.4	22.7	17.3	17.3
Bioefficacy	-ve	-ve	+ve	+ve

Percent germination, height and chlorophyll contents of Test similar or lesser to that of Control reflected -ve bioefficacy, while more than that of Control reflected +ve bioefficacy.

Table 2. Cost profiles for solid state fermentation of organic waste into soil conditioner

Sr. No	Inputs	Amount consumed	Rate (US $)	Total cost (US $)	Remarks
Medium (batch size of 100 L)					
1.	Soybean flour	0.5 Kg	0.2 /Kg	0.10	Prevailing market price
2.	Corn steep liquor	1.7 L	0.3 /L	0.50	Prevailing market price
3.	Tween 80	0.01 Kg	6.7 /Kg-L	0.10	Prevailing market price
4.	Raw water	80 L	0.45 /KL	0.05	20 % water being contributed during *in situ* medium sterilisation
Boiler and utilities					
5.	Steam for sterilisation (Kg)	20	0.12 /Kg	2.40	Autoclave of 250 L capacity.
6.	Compressed air (KL)	20	0.23 /KL	4.60	Assumed US $ 445/- cost of air compressor, 10 years life and 200 batches per year.
7.	Chilled water (5^{o}C)	0.5	4.45 /KL	2.23	Assumed US $ 1,112/- cost of chiller, 10 yrs life and 200 batches per year.
8.	Cooled water (KL)	1	2.23 /KL	2.23	Assumed US $ 556/- cost of cooling tower, 10 yr. life and 200 batches per year.
9.	Fermentor rent	-	-	4.45	Assumed US $ 4445/- cost of fermentor, 10 years life and 200 batches per year.
10.	Labour	-	1.12 / 8hr x 48	6.72	Three shifts
Inoculum development					
11.	Inoculum cost (L)	10	0.23 /L	2.30	Laboratory scale inoculum production.
12.	Miscellaneous	-	-	2.60	For any unforeseen expenses @ 10 % of

					the total cost of production.
13.	Cost of inoculum	100 L	0.29 /L	28.28	~ US $ 29/-
Conversion of 10 MT of fresh BP to 1189 Kg final SC					
14.	Banana pseudostem waste	10 MT	2.23 /MT	22.30	Notional cost
15.	Labour for transport and chopping	10 MT	0.56	5.60	Size reducer for chopping.
16.	Urea adjuvant (0.5 % w/w)	5 Kg	0.2 /Kg	1.00	As a ready source of nitrogen for organisms.
17.	Inoculum (5 % v/w)	50 L	0.29 /L	14.5	For enhancing composting.
18.	Raw water	1 KL	0.45 /KL	0.45	From MIDC, Jalgaon-425 001
19.	Labour	1	1.12 /dx 10	11.2	For regular aeration, monitoring and taking overall care.
20.	Miscellaneous	-	-	2.75	For any unforeseen expenses @ 5 % of the total cost of production.
21.	Total Production of SC			57.80	1189 Kg SC (35 % moisture & 65 % dry matter)
22	Production cost of 1 MT SC			48.95	~ US $ 49/- ready for sale and application

MIDC = Maharashtra Industrial Development Corporation 5. Sacred and Taboos In Biodiversity Conservation