Chapter XI: Sweet sorghum bagasse – A source of organic manure

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I. Introduction

Bagasse or silage is an important by-product in the sweet sorghum-based ethanol industry. Above ground biomass distribution in sweet sorghum forms 90% of the total biomass produced and that includes stem, leaves and panicle with grain. It is estimated that bagasse makes 30% of the total biomass of sweet sorghum, which is composed of cellulose (15-25%), hemi cellulose (35-50%) and lignin (20-30%) with Net Calorific value: 4,125 Kcal kg^{-1} (ash free); depending on the genotypes (Grassi 2001). Approximate composition of sweet sorghum bagasse is given in Table 1. It is estimated that 6-7 kg of bagasse will be produced for every liter of ethanol produced from sweet sorghum. Even though bagasse has multiple uses such as being a source for energy cogeneration, animal feed and organic manure, it is important to work out the trade-offs between its uses as a source of bio-fuel and carbon balance in the whole production-to-consumption chain. In this context, recycling of bagasse into organic manure and using it in the crop husbandry is an environmentally safe measure of sequestering carbon in the soil. Sweet sorghum is promoted in the semi-arid regions where organic carbon content in the soil is generally low and the application of bagasse as organic manure assumes great importance for sustaining the soil fertility. The direct application of bagasse to the soil causes temporary lock up (immobilization) of soil nitrogen (N) due to wider C: N (~35:1) ratio and hence, it is important to bring down the C: N ratio by vermicomposting to use it as organic manure. Composting is the value addition method for enriching organic residues with low N content and this can be done either through microbial flora or along with earthworms. Generally, composting of organic residues with earthworms is referred to as vermicomposting, which is a rapid and simple method. The composition of vermicompost is superior in terms of macro and micro nutrients; besides, it is rich in plant growth promoting substances. The composting of sweet sorghum bagasse with earthworms is focused in the project and protocol was standardized for the same through laboratory and on farm trials.

Grassi (2001) reported that vermicompost prepared from sweet sorghum bagasse contains 35.5% carbon, 1.0% nitrogen, 7% ashes and 65.5% volatile matter.

Table 1. Chemical composition of sweet sorghum bagasse analyzed at ICRISAT.

Composition	Content (%)
Carbon	34.5
Nitrogen	1.0
pH	7.0
EC dS/m	3.9

II. Vermicomposting

Vermicomposting is a biological process by which earth worms are used to convert organic materials into compost. Various studies have shown that vermicomposting of organic waste accelerates organic matter stabilization (Neuhauser et al. 1988); (Frederickson et al. 1997) and gives a product rich in chelating and phytohormonal elements (Tomati et al. 1995) which has a high content of microbial agents and stabilized humic substances (Ferruzi 1986). Earthworms consume organic residues equivalent to their body weight and produce 50% of the total intake of organic residues as castings. In short, earthworms, through a type of biological alchemy, are capable of transforming garbage into 'gold' (Vermi Co 2001, Tara Crescent 2003). The worm castings are rich in available nutrients and microbial flora. There are nearly 3600 types of earthworms which are grouped under three types (Box 1).

Box 1

Anecic (Greek for "out of the earth") are burrowing worms that come to the surface at night to drag food down into their permanent burrows deep (3.5 m) within the mineral layers of the soil and produces 5.6 kg casts by ingesting 90 and 10 per cent of soil and organic wastes respectively.

Endogeic (Greek for "within the earth") are also burrowing worms but their burrows are typically shallower, feeding on the organic matter already in the soil and hence coming to the surface rarely.

Epigeic (Greek for "upon the earth") are living in the surface litter and feed on decaying organic matter. They do not have permanent burrows. These "decomposers" are the type of worm used in vermicomposting, which are typically 10 to 15 cm long consuming 90 percent organic waste materials and 10 percent of the soil. Example: Eisenia fetida and Eudrilus eugenae. *Source: Card et al. (2004)*

III. Protocol for vermicomposting

The protocol for vermicomposting developed at ICRISAT (Wani et al. 2002) included the following points.

- Vermicomposting involves two stages of decomposition for high cellulosic materials: initial microbial decomposition, followed by vermicomposting through inoculation with earthworms.
- The quantity of raw materials required are organic waste (low N and C
- rich materials) and cow dung slurry (as primer/starter for initiation of decomposition with microbes) in the ratio of 10:15.
- Rock phosphate is also recommended @ 2 kg for every 100 kg of organic materials for improving nutritional quality of the compost.
- Initially, layers of organic materials are spread to a thickness of 15-20 cm
- in the composting pit or tank, over which rock phosphate and cow dung slurry are sprinkled. Then, organic materials, rock phosphate and cow dung slurry are sprinkled repeatedly to a height of one meter from the ground level.
- Finally, the entire heap of materials is sealed with cow dung slurry and allowed for decomposition for 15 to 20 days during which temperature builds up due to microbial decomposition.

- Earthworms are released through cracks developed over the sealing of cow dung after the decomposition is completed. Normally 500-700 earthworms are required for decomposing 100 kg organic materials.
- The composting process is completed in 45 days from the time the earthworm are released into the heap. Low-value organic materials like weeds and parthenium are converted into value-added compost.

Fig. 1. Vermicompost preparation in rings.

Fig. 2. Vermicompost tank.

Fig. 3. Releasing earthworms.

Fig. 4. Sieving vermicompost.

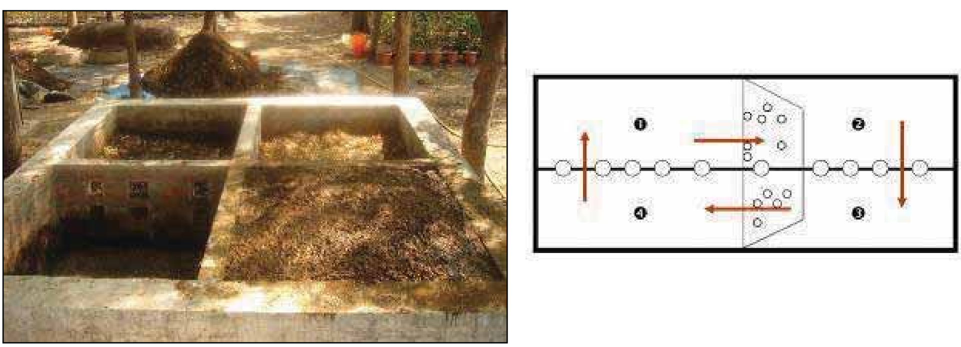

Fig. 5. ICRISAT commercial model with four chambers showing different stages of vermicomposting (left) and diagram showing the cycle of composting and movement of earth worms (right) Source: Nagavallemma et al. (2004).

IV. Commercial production of vermicompost

- The commercial model of vermicomposting developed in ICRISAT consists of four partitions. The walls contain holes that facilitate the movement of earthworms from one chamber to another after the composting process is completed, which helps to continuously generate composts and saves labor (Figs. 1-5).
- Vermicompost is generally applied by the farmers to high-value crops like vegetables and fruits.
- This commercial model is used by village women's self-help groups (SHGs) as a micro-enterprise for earning additional income, as well as a way to dispose of household and farm organic residues in environment-friendly manner. It also provides much needed organic manure for building soil health.

V. Recycling experiment using sweet sorghum bagasse (cement ring method)

An experiment on temperature dynamics during the process of vermicomposting was conducted at ICRISAT, Patancheru, India. Cement rings of 90 cm diameter and 30 cm in height were filled with sweet sorghum bagasse by adding cow dung slurry and rock phosphate on each layer of residue. Then the rings were completely sealed off with thick cow dung paste and watered at regular intervals (2 to 3 days). Both chopped (5-10 cm length) and unchopped bagasse of sweet sorghum was taken in different proportions along with cow dung slurry. Rock phosphate (2 kg) and earthworms (500-750 in numbers) were added in equal proportion in all the treatments and maintained at 50% water holding capacity.

VI. Temperature dynamics during the process

Temperatures in composting bins were recorded from the 3rd day onwards in the rings at every alternate day for about two months ie, before and after release of earthworms and atmospheric temperature was also recorded at the same time. The initial temperatures recorded in bins were very high ranging from 61^{o}C to 53^{o}C while after 15 days the temperatures decreased to 32^{o}C to 36^{o}C. Later there was a gradual decrease in temperature, which stabilized to 29^{o} C to 30^{o} C, which is suitable temperature for earthworm survival. Chemical analysis of bagasse revealed: N- 1.0175%, P -0.09% and K -0.375%.

VII. Compost harvest

Vermicompost prepared from chopped bagasse decomposed faster (within 140 days) than unchopped bagasse (upto 180 days) even though sweet sorghum bagasse overall took a longer period compared to parthenium. Harvested vermicompost was sieved through 2 mm sieve and earthworms were removed and reused for further vermicomposting.

VIII. Chemical parameters of vermicompost

Vermicompost prepared through this method was air dried at room temperature and used for analysis of chemical parameters. Results of analysis revealed that vermicompost prepared from unchopped bagasse showed higher values in all chemical parameters compared with chopped bagasse, and proved to be a rich source of all nutrients (Table 2). Bagasse and cow dung in the ratio 1:5 showed higher values of all chemical parameters followed by bagasse and cow dung in the ratio of 1:2 and 1:3.3.

Table 2. Chemical parameters of vermicompost prepared with sweet sorghum bagasse.

	Bagasse: Cow dung slurry							
	1:3.3		1:5		1:2		Mean	LSD
Parameters	C	UC	C	UC	C	UC	(log10)	(log10)
Chemical								
pH	6.8	7.0	6.7	7.2	6.9	7.1	7.0	0.5
EC dS/m	3.9	3.8	4.1	4.0	3.9	3.7	3.9	1.6
Avail-S in mg kg^{-1}	47.2	27.3	47.1	42.8	41.4	50.0	42.6	18.8
Avail-P in mg kg^{-1}	372.9	425.2	450.3	515.1	528.5	572.5	477.0	126.6
Exch-K in mg kg^{-1}	3280	4146	3811	4338	3797	4172	3924	1071
Exch-Ca in mg kg^{-1}	3170	2966	3414	3682	3543	3618	3399	603
Exch-Mg in mg kg^{-1}	2319	2358	2559	2669	2686	2699	2548	447
Exch-Na in mg kg^{-1}	340.2	598.8	331.9	350.9	339.1	333.9	382	297.9
Avail-Fe in mg kg^{-1}	2.1	1.4	2.4	2.1	2	2	2	0.88
Avail-Zn in mg kg^{-1}	16.3	20.4	27.4	53.1	62.5	28.7	348	50.3
Avail-Cu in mg kg^{-1}	5.8	5.5	6.5	7.8	7.6	8.2	6.91	3.09
Avail-Mn in mg kg^{-1}	27.4	24.7	27.1	30.2	27.4	27.6	27.4	6.6
OC %	8.3	8.7	10.2	11.2	11.2	9.6	9.9	3.8

Conclusion

There is scope for using the bagasse obtained from sweet sorghum as organic manure using the vermicomposting method. We can conclude that vermicompost prepared with sweet sorghum chopped bagasse and cow dung in the ratio of 1:5 has superior biological and chemical parameters and can be commercialized. Commercial scale model could provide valuable source of income for vulnerable groups in village and become an important value chain in disposing the by-product through a win-win approach. The project aims to standardize the economic aspects for preparing vermicompost considering the quantity of bagasse to be recycled through organic manure for registering positive carbon balance in the system. The economic design will be worked out in the context of micro enterprise for preparing vermicompost from bagasse in the decentralized model of sweet sorghum production.

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