Sustainable Treatment of Banana Industry and Crop Residue Wastes for Crop Production Using Effective Microorganisms

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EARTH College in Costa Rica is dedicated to finding solutions to agricultural problems by developing alternatives that maintain levels of production while cultivating healthy foods, preserving the health of farmers, and not polluting surrounding ecosystems. This research was undertaken at EARTH College, which is a centre for banana industry research in Central America.

The banana industry in Costa Rica is the second largest industry in the country. This industry creates many by-products that result from the harvesting and processing of bananas. These by-products are bananas that are rejected for export, banana peels, banana stems, and liquid wastes. Currently these wastes are dumped in landfills, rivers, oceans and unregulated dumping grounds. When they reach these destinations, they form huge masses of putrefying wastes that attract insects and scavengers, spread disease, contaminate groundwater, and have foul odors that can be smelled for miles around (Leon, 1997).

Effective Microorganisms (EM) are currently being used in many countries as a beneficial microbial inoculate for processing organic materials so that they can be recycled back into agricultural systems (Afzal et al, 1994). Experiments were carried out in Costa Rica using EM to process all forms of banana wastes into rich amendments that can improve soil structure and increase crop yields and quality. The products made using wastes from the banana industry can be used as beneficial microbial inoculates for soil regeneration and fertilization (Higa, 1996).

Guidelines for making bokashi with solid waste from the banana industry are the results of trials being conducted at EARTH College to develop an efficient bokashi production system from banana wastes under the actual condition of a banana plantation. EARTH College has 280 ha of commercial banana plantation. At every harvest, 2 to 3 tons of bananas are rejected as wastes in the packing plants. This means 32 to 48 tons of wastes per month. (EARTH College has a banana paper factory. Thus, wastes of banana flower stalks are being converted into banana papers.)

Trials were undertaken with rejected green bananas from the EARTH College packing plant, banana stem fibre from the EARTH College banana paper processing plant, banana peels and liquid wastes from the Compañia Mundimar banana purée processing plant. These materials were processed for agricultural use. Controlled experiments were carried out using EM and liquid waste applied to sweet corn. General guidelines were determined for quickly and efficiently making large quantities of solid waste into bokashi.

Materials and Methods

The experiments with liquid waste were undertaken separately from experiments with solid waste. The materials and methods for liquid waste and corn experiment are presented first, followed by solid waste studies.

Liquid waste from the banana purée processing plant was used. The liquid was collected as it left the factory and entered the first of two facultative anaerobic ponds. The first pond operates with an average BOD of 1,113 kg/day, an average pH of 3.9, and total suspended solids of 24.7% (Lopez, 1995). This wastewater consists of organic solids, sugars, and other forms of nutrients that result from mashing bananas. According to tests done at EARTH College, the wastewater entering the first pond has 19.1 ppm of nitrogen, 1.1 ppm of phosphate, and 15 ppm of potassium.

Corn was cultivated with three different irrigation treatments and three replications of each treatment. Corn was grown in a randomize complete block design of 9 blocks. Each block was 2.4 (2.4 m. There were 32 plants in each block, for a total of 288 plants.

Each block was manually weeded on the same days. Each block received one of three different kinds of irrigation treatments every 8 days:

- Treatment 1: Addition of 16 litres of water.
- Treatment 2: Addition of 16 litres of wastewater before it enters the first pond + 16ml of EM.
- Treatment 3: Addition of 16 litres of wastewater before it enters the first pond.

Ten corn plants from each of two replications of each treatment were harvested on the same day. Immediately after harvesting, the following information was collected:

- The weight of all ten corn plants with ears from each replication
- The weight of all ears with husks from each replication
- The weight of all ears without husks from each replication
- The number of ears of each corn plant
- The weight of the largest ear without husks of each corn plant
- The length of the largest ear of each corn plant
- The diameter of the largest ear of each corn plant
- The stage of development of the largest ear of each corn plant
- The number of rows of the largest ear of each corn plant
- The number of kernels of a randomly selected row of the largest ear of each corn plant

Solid wastes from the banana industry are processed alone or mixed with other easily obtained materials. Other materials used are nitrogen fixing legumes, rejected seed yams, citrus rinds, hearts of palm shells, fish meal, corn meal, cacao shells, cow manure, rice husks, sawdust, carbon, and ash. The materials are chopped, mixed well and inoculated.

To prepare EM for inoculating the materials, molasses is dissolved in water and EM is added to this solution with a final ratio of 1 part EM and 1 part molasses to 100 parts water. This solution is sprayed on the materials to achieve a final moisture content of 30-40% (Phillips et al, 1995).

Processing solid waste into bokashi should take place under shelter that will protect the materials from direct sunlight and precipitation. The more surface area of the materials available to the microorganisms, the quicker they will populate more of the materials. It is very important that the materials have the correct moisture content for the fermentation process that takes place. The best moisture content is 30-40%. If the water content and microbial populations are controlled there are fewer insects attracted, no foul odors, and a quicker population of the materials with white mycelia. Therefore if it is a bokashi of mainly banana wastes, it is important to dry the materials first because the water content is 80-90%. At EARTH College the banana wastes are cut by chopper and mixed with sawdust to control humidity. After inoculating EM, the mass is mixed every day for ventilation for two weeks. When this process is complete, the EM banana bokashi is applied to the commercial banana plantation. Chemical analysis of EM banana bokashi and traditional compost were compared.

Results

During the fall of 1996, Toledo (1996) studied the use of EM to treat the wastewater generated by the Mundimar, S.A., banana purée processing plant. The use of EM in the wastewater treatment controlled the odor produced by the floating solids in the ponds. Twelve days after the application of EM to the ponds, the pH of the second pond reached 6.4 and there was a noticeable increase in the development of algae (Toledo, 1996).

In general the corn plants grown with treatments of EM + Waste showed the best results in yield, precocity, and quality of ears and grain. The next best results were with the plants treated with Water. The poorest growth, development, and yield were obtained from the plants treated with Waste.

The effect of treatments on fresh weight of sweet corn plants and weight, length, and diameter of fresh ears without husks are presented in Table 1. There were no statistically significant differences in the fresh weight of plants among the different treatments. The weight, length, and diameter of an ear without husks was significantly higher with EM + Waste than with Waste. EM + Waste was significantly higher than just Water for the average diameter of an ear without husks.

Table 1. Effect of treatments on fresh weight of sweet corn plants and weight, length, and diameter of fresh ears without husks.

Treatment	*EM+Waste*	*Water*	*Waste*	*Average*
Fresh weight of plant (g)	995.0 a	907.5 a	722.5 a	875.0 a
Weight of ear without husks (g)	133.5 b	109.0 ab	91.5 a	111.3 ab
Length of ear without husks (cm)	18.25 a	18.04 a	16.16 b	17.5 a
Diameter of ear without husks (cm)	13.26 b	12.00 a	11.65 a	12.30 a

aTreatment means in a column sharing the same letter are not significantly different from each other according to Duncan's Multiple Range Test.

The average number of ears harvested was highest from EM + Waste, followed by Water, with Waste the lowest (Table 2). The average number of rows of grain and the average number of grains also were higher with EM + Waste. This was followed by the plants with Waste; the lowest value was with Water. The stage of development of the ears was measured by assigning a number to each ear sample that corresponds to three possible stages of development: pre-milk stage (1), milk stage (2), and post-milk stage (3). The average stage of development of the ears was highest with EM + Waste and was equal for the other two treatments.

Table 2. Effect of treatments on ears per plant, development of ears, rows per ear, and mature per row.

Treatment	*Number of ears*	*Stage of Development*	*Number of rows*	*Number of grains*
EM+Waste	1.65b	2.40b	14.10a	37.50b
Water	1.30a	1.55a	13.50a	26.80a
Waste	1.15a	1.55a	13.00a	30.25a

aTreatment means in a column sharing the same letter are not significantly different from each other according to Duncan's Multiple Range Test.

The average height of the plants was highest with Water; EM + Waste was only second. The lowest value was with Waste. However, none of these differences were statistically significant. Throughout the growth of the corn plants we observed that the plants treated with EM +Waste were greener than those treated with Water or Waste.

Using the banana bokashi production system, all banana wastes from EARTH College are currently being converted to bokashi. Through these practices, the following guidelines have been developed for efficient banana bokashi production to manage a large quantity of banana waste. Materials should be chopped to maximize the surfaced area on which the microorganisms can act. A dry material such as saw dust should be added (10 –20% of banana waste) to reduce the total moisture content of the mixed materials. The process should be managed under a roof on a concrete floor with drainage. The materials should be mixed every day for ventilation. At EARTH College, a machine has been introduced for mixing. Finished bokashi should be added to the mass for re-inoculating effective microorganisms.

The results of chemical analysis of the EM banana bokashi and compost have indicated some good points of bokashi. Bokashi is 66% organic matter, whereas compost is only 22% organic matter. In compost, potassium content is lower than bokashi. The potassium would be drained during process of decomposition.

Discussion and Conclusions

The results mean that it is not desirable to use the wastewater as fertilizer by itself before purification. There is a decrease in the development and yield of sweet corn plants treated with the raw wastewater. However, the results indicate that this can be solved by applying EM with the raw wastewater.

In all respects except height, the application of raw waste + EM improved the precocity, size, and yield of the corn plants compared with applications of raw waste or water. The fact that the sweet corn plants treated with EM + Waste did not grow significantly taller than those grown with water means that growth must have been impeded at the early stages of development because nutrients were fixed by the microorganisms. However, upon the release of the nutrients they could have promoted the growth recovery of the plants and boosted their green matter. If the wastewater had been treated by EM before application, this would have allowed the nutrients to be available immediately upon application, therefore increasing the growth of the plants even more.

The Water treatment had higher means for all parameters than Waste except number of kernels. However, according to the Duncan test for homogeneity, the difference between means for number of kernels with Water and Waste was not significant. Therefore, based on the data, it appears that the application of raw waste resulted in lower precocity, size, and yield than the Water treatment. This leads us to believe that the raw waste is too strong to be applied by itself because it reduces the precocity and yield beyond what is achieved with only water.

The fact that the corn grown with waste + EM did better than that grown with water, but the corn grown with waste did worse than that grown with water, leads to the conclusion that the active difference is the addition of EM. The waste by itself is too undigested to be applied directly to the corn and may actually stunt growth and yield. However, when the raw waste is applied with a mechanism that can balance and digest it, growth and yields improve over those of corn grown just with water.

The action of the beneficial microorganisms in the first and second pond will reduce the odor to acceptable levels, as demonstrated by Toledo. The action of the beneficial microorganisms in the first and second pond will balance and digest the organic materials, which in turn will raise the pH to above 6.5. With the waste balanced and digested, as well as populated by beneficial microorganisms, it has great agricultural value because there are many nutrients and bioactive substances that are available to plants (Wididana, 1994). In this form the waste can be used to remediate damaged soils and improve crop yields (Harada et al, 1995). Applying the waste to the soil would reduce the load into the river; this can become a solution to the problem of pollution that occurs when this wastewater enters the river. This means that the waste from Mundimar has some economic value that should be tapped, given the appropriate treatment, rather than being perceived as a pollutant. A system like this would benefit Mundimar S.A., the surrounding communities, and the river ecosystem. A community project could be set up that allows the community to use the wastewater from the Mundimar ponds to fertilize their crops at a lower cost than buying chemical fertilizers. This community project can totally change the relationship between Compañia Mundimar, S.A., and its neighbouring communities.

With respect to the solid wastes, it can be assumed that these wastes have nutrient value. They have a high amount of organic matter and potassium compared with traditional compost. The wastes can be processed in two weeks to make bokashi, as opposed to several months to make compost. The EM banana bokashi can be applied as fertilizer and to maintain organic matter and potassium levels in crop production.

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