USE OF COMPOSTED ORGANIC WASTES AS ALTERNATIVE TO SYNTHETIC FERTILIZERS FOR ENHANCING CROP PRODUCTIVITY AND AGRICULTURAL SUSTAINABILITY ON THE TROPICAL ISLAND OF GUAM.

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Abstract
One of the major problems of agricultural soils in the tropical region of the Pacific is the low organic matter content. Composted organic material is being applied on agricultural fields as an amendment to provide nutrients and also to enhance the organic matter content and improve the physical and chemical properties of the cultivated soils. Composted organic material contains essential nutrients for plant growth, especially N and P (Beltran et al., 2002). Land application of composted material as a fertilizer source not only provides essential nutrients to plants, it also improves soil quality and effectively disposes of wastes. In our soil program at the University of Guam, we are evaluating the use of organic material as an alternative to synthetic fertilizers. Our goal is to develop management strategies and use available resources for improving crop production while conserving resources and preserving environmental quality. Our case study project is designed to improve soil fertility status by using composted organic wastes, and assessing how the N and other essential nutrients contribute to long-term soil fertility and crop productivity without application of synthetic fertilizers. In our pilot project, compost is produced from ground typhoon debris mixed with: animal manure, fish feed, shredded paper and other organic wastes. Mature compost is then applied on the field at the rate of; 0, 30, 60 and 120 tons per acre as soil amendment on the eroded Cobbly soils of Southern Guam. Corn is planted and monitored for growth performance and yield. The effect of land application of composted material on the soil organic matter (SOM) content and other properties as the soil quality indices are being evaluated in this pilot study.

Additional Keywords: Soil quality, organic matter content, fertility, soil degradation,

Introduction

Among the problems inherent to tropical soils, soil acidity, characterized by low pH, excessive aluminum, deficient calcium, and low organic matter is the most serious (Hue, 1992). Tropical soils are often unproductive because some of these soils are prone to strong phosphate fixation that renders phosphorus unavailable to plant. Soils that are prone to strong phosphate fixation (adsorption to oxides and clay minerals) often require extremely high phosphate fertilization application in order to alleviate the effect of phosphate fixation. Soil acidity and mineral deficiencies can be corrected by lime and fertilizers. Unfortunately, lime and fertilizers are not always easy options available to small and resource-poor farmers (Hue, 1992). However, it has been reported (Hue, 1992, Beltran et al., 2002) that green manures and composted organic material increase SOM, provides nutrients for plant growth, alleviate aluminum toxicity, and render phosphorus more available to crops. This increased availability of phosphorus is probably caused by the reaction of organic matter-derived molecules with soil minerals (Hue, 1992).

Unique Characteristics of Soils of the Pacific Region and their Management

Under the hot and humid tropical environment, weathering of soils has been rapid; thus, large areas of Ultisols and Oxisols occur in these regions (Motavalli, 1997). The inherent poor chemical properties of Ultisols and Oxisols pose problems for agriculture in these regions. The fertility of these soils is often limited by the properties brought about by the high iron and aluminum contents, low activity clay, and low organic-matter content. Much rain and high temperature in these regions is also very influential in rapid organic matter decomposition, which may also release H^+ ions that acidify the soil and increase exchangeable Al to toxic levels that limit root growth in the subsoil. Another general problem with soils of the tropics, is the deterioration of soil physical conditions. The degradation can take many forms, and has a variety of consequences including low fertility status due to poor soil quality (Lal and Pierce, 1991).

In addition to its slow release nutrient capability, organic matter is largely responsible for aggregation, soil moisture holding capacity and other improved physical properties of the soil. Thus, increasing soil organic matter content must be the first step in any farming practice in the Pacific region. If productivity is to be maintained, an agricultural system able to preserve a satisfactory physical condition in the soil must also be developed. Fuller (1951) stated that the continued productivity of the soils in the tropics depends largely upon the replenishment and maintenance of the soil organic constituents. Organic matter additions are the only means of making some soils economically productive (Cook and Ellis, 1987).

The phenomenon of cation exchange has been said to rank next to photosynthesis in importance to agriculture (Cook and Ellis, 1987). Well-decomposed organic matter has a very high cation-exchange capacity that adds to the buffer capacity of the soil. Organic matter has the ability of holding against leaching substances other than cations. Hence, a good supply of soil organic matter makes it safe to apply rather large applications of fertilizer at planting time and thus avoid the need for a second application (Cook and Ellis, 1987). Nyamangara et al. (2003) reported that the organic waste (composted manure) application even enhanced the use efficiency of mineral N fertilizer by crops when the two were applied in combination.

Organic matter serves as a very important source of plant nutrients. Micronutrients may be satisfactorily supplied by decomposing organic matter. This is especially true during the production of crops that have specific micronutrient needs. For instance, it may be necessary to supply boron in the fertilizer for alfalfa on a boron-deficient soil, because its need for the element is quite high. A corn crop, on the other hand, does not have special boron needs and it is easily injured by direct application of borax (Cook and Ellis, 1987). Therefore, corn planted after an alfalfa season can adequately take its boron from the decomposing alfalfa residue (green manure) or from the nutrient rich composted organic material (Cook and Ellis, 1987). Other micronutrients may be likewise furnished from decomposing organic matter (Cook and Ellis, 1987). This is because decomposed organic matter (humus) possesses chelating properties. These properties bring about covalent bonding between the organic matter and ions of copper, zinc, manganese, and iron. In alkaline soils or in acid soils after liming, such metallic nutrients remain in solution and in a state of availability to plants (Cook and Ellis, 1987). This is because composted organic matter has the potential to reduce the pH to an acceptable value where soils are alkaline (Rainbow et. al., 2002).

Compost: Source of Organic Matter for Soils of the Pacific Region

Among the practices recommended for improvement of the soil quality and soil fertility in tropical regions is the application of composted organic wastes, which slowly release significant amounts of nitrogen and phosphorus (Muse, 1993; Zibilske, 1987; Eghball, 2001). Frequently, the regular use of organic material (compost) is a prerequisite for sustained upland soils with inherent low natural fertility (Schoningh and Wichmann, 1990). As reported by Nyamangara et. al. (2003), management of soil organic matter by using composted organic waste is the key for sustainable agriculture. Increasing soil organic matter has the added benefit of improving soil quality and thereby enhancing the long-term sustainability of agriculture (Laird et al., 2001). Within the possibilities of economical procurement of organic matter, a farmer should “feed” the soil organisms for maximum activity, which means frequent additions of easily decomposed organic matter (Cook and Ellis, 1987).

Compost does several things to benefit the soil that synthetic fertilizer cannot do. First, it adds organic matter, which improves the way water interacts with the soil. In sandy soils, compost acts as sponge to help retain water in the soil that would otherwise drain down below the reach of plant roots, protecting the plant against drought. In clay soils, compost helps to add porosity to the soil, making it drain easier so that it does not stay waterlogged and does not dry out into a bricklike substance. Compost also inoculates the soil with vast numbers of beneficial microbes (bacteria, fungi, etc.) that promote biological activity of the soil (Muse, 1993; Zibilske, 1987). These microbes are able to extract nutrients from the mineral part of the soil and eventually pass the nutrients on to plant (Johnson, 1996). Furthermore, properly processed compost reduces soil borne diseases without the use of chemical control (Rynk et.al.; 1992, Minnich and Hunt, 1979). The disease suppressing quality of compost is just beginning to be widely recognized and appreciated. Farm fields treated with compost are also less prone to erosion. In short, high quality compost will do more for soil fertility and soil quality than commercial fertilizer.

The use of composted organic waste as fertilizer and soil amendment not only results in an economic benefit to the small-scale farmer but it also reduces pollution due to reduced nutrient run-off, and N leaching (Nyamangara, 2003). Most subsistence and small-scale farmers will be able to adopt the composting technology if they are introduced to it by participating in programs of research or demonstration of technologies. This provides them the means to accept the technology, but they will convince their peers to accept the technology with more effectiveness than government employees could convince those peers.

Case Study

In our soil program at the University of Guam, we are investigating the use of composted organic material as alternatives to synthetic fertilizers. More specifically, we are studying the effect of organic matter and inorganic soil constituents in order to improve soil productivity and maintain environmental quality. Our goal is to develop management strategies and use available resources to increase SOM for improving crop production while conserving resources and preserving environmental quality. Our case study project is designed to improve soil fertility status by using composted organic wastes, and assessing how the nitrogen and other essential nutrients contribute to long-term soil fertility and crop productivity without application of synthetic fertilizers.

Material and Methods

The composting procedure is being conducted at the Inarajan Agricultural Experiment Station in the district of Inarajan village in Southern Guam. In our case study at the research station of the University of Guam, we used primary and secondary waste from household, commercial (hotels and restaurants), tree trimmings from the roadsides, chicken, hog and horse manure from local farmers and ranchers and wood chips from typhoon debris for compost production. There are many methods of composting organic materials. These include active windrow (with turning), passively aerated windrow (supplying air through perforated pipes embedded in the windrow), active aerated windrow (forced air), bins, silos, and anaerobic digestion (Humenik, and J.R. Miner, 1983). In this project, we used passive composting piles by supplying air through perforated pipes embedded in the pile and occasionally mixed the compost by using backhoe.

In the second stage of the experiment we applied the final products of the composted organic wastes on research plots as a source of fertilizer in order to evaluate the agronomic value of the organic compost on crop production from the soil under study. Also the effect of compost as soil ameliorant for enhancing soil quality and improving soil properties is being evaluated.

Twelve field plots (25 X 18ft^2) were set up at the Irajan experiment station in Southern Guam for this project. The soil under study for this investigation is Akina series (Very fine, kaolinitic, isohypothermic Oxic Haplustalf) formed in residuum derived from the volcanic deposit (USDA-SCS, 1988). Composted organic wastes were applied at 0 (control), 30, 60, and 120 tones per acre where each rate was replicated three times.

Results

The results of the initial data indicated that under the unique climatic conditions of Guam, land application of organic compost enhanced soil quality and increased soil fertility and crop yield. As shown in table 1, considerable improvement in bulk density, soil organic matter content, nutrient distribution and other soil quality parameters occurred with the application of composted organic material.

Table 1. Showing improvement for some of the soil physical and chemical properties as they are affected by different treatment from the first trail during the dry season (March – June, 2003).

Treatment	Bulk Density (gm/cm^3)	Organic Matter (%)	Moisture Content (%)	NO3 (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
0 t/a(cont)	1.18	5.36	26.01	3.28	30.09	206.83	3416.17	171.40
30 t/a	1.01	5.64	25.86	4.96	52.34	744.97	3779.88	297.59
60 t/a	0.98	6.57	28.07	5.89	61.02	1053.36	4748.70	431.20
120 t/a	0.91	9.46	32.16	16.01	76.65	1418.70	5492.18	787.92

Following the first harvest from dry season (March – June) the same plots were used for re- planting during the wet season (August to October) of 2003. Data obtained from the second trail indicated that as the compost application rates were increased from 0 tones per acre to 120 tones per acre the soil CEC (cation exchange capacity) as one of the major soil quality indexes were also increased (Table 2) indicating a considerable improvement in nutrient exchange capacity of the soils treated with organic matter amendments.

Table 2. Showing improvement for some of the soil physical and chemical properties as they are affected by different treatment from the 2nd trail during the wet season (August - October, 2003)

Treat	PH	OM (%)	D_b (gr/cm^3)	Ca	Mg	K (mg/kg)	NO_3	P	CEC (meq/100g)
0.0 T/A	7.9	3.4	1.03	3178.6	625.6	217.0	13.1	17.8	2.17
30 T/A	7.8	4.6	0.98	3300.6	1018.9	485.4	40.5	35.8	2.62
60T/A	7.8	5.4	1.02	3495.1	1564.6	748.5	55.5	44.6	3.24
120T/A	7.6	7.2	1.01	4312.4	2072.4	1064.7	76.7	58.4	4.16

Yield results from the dry season trail showed gradual increase in crop yield as compost application rate was increased from 0 tons per acre (control) to 120 tons per acre of compost application (Fig. 1). A point must be made that these plots were under production prior to this experiments and the yield results from spring 2003 carry the effect of previous fertilization on these plots. Data from the second corn harvest (Fall of 2003) also showed considerable yield increase (Figure 2) as the result of increased compost application rates on soils under treatment.

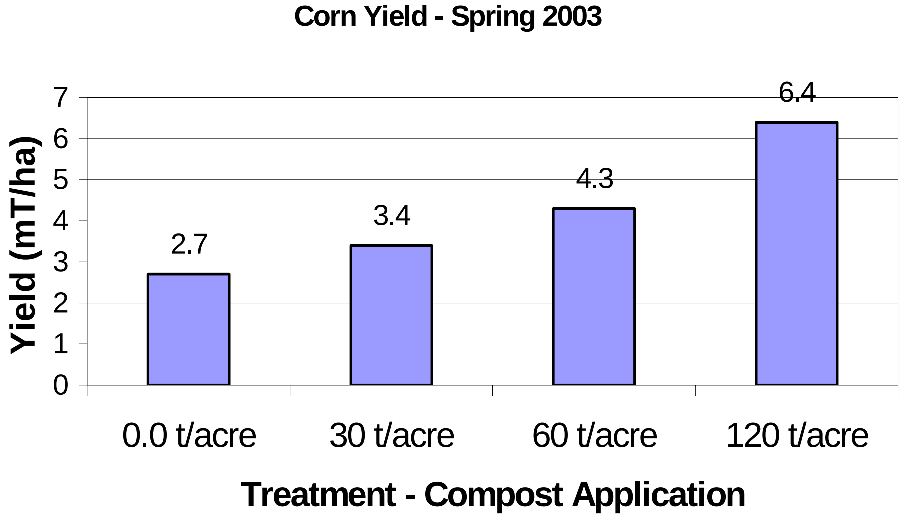

Figure 1.Yield results from the dry season trial (Spring harvest) showing gradual increase as compost application rates were increased from 0 to 120 tones per acre.

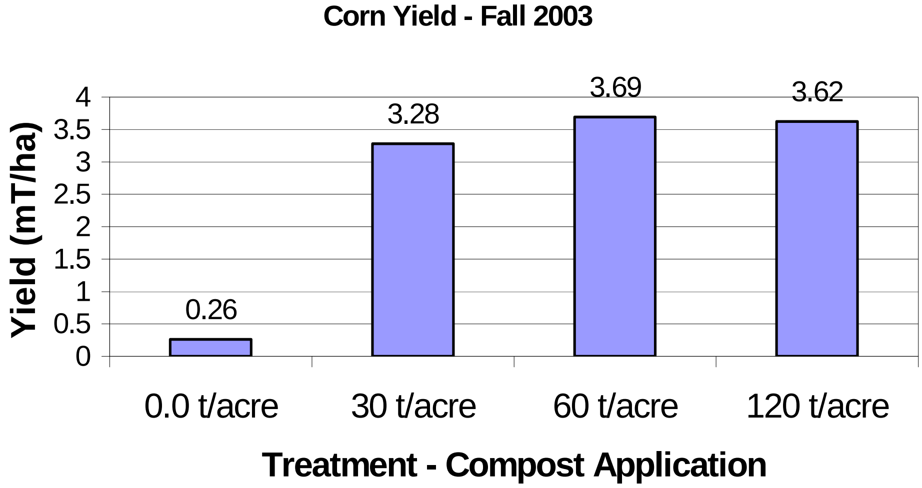

Figure 2. Yield results from the wet season trial (Fall harvest) showing gradual increase as compost application rates were increased from 0 to 90 tons per acre.

The 120 tones per acre of composted application rate however showed decreased in yield as compared with 60 tones per acre of compost applied (Figure 2). This was an indication that additional application suppressed the grain production probably due to lush green vegetative growth that was observed during the growing season (Figure 4). In addition to yield increase, the quality of corn crop was also improved as the result of increasing compost application rate (Figure 3).

Figure 3. Showing that in addition to yield increase, quality of corn crop was also improved as the result of increased application rate of compost.

Figure 4. Showing lush green leaves (left: 120 ton/acre, right: 0 ton/acre) production during the wet growing season that might have suppressed the grain production for Fall harvest.

The third trial of the same corn plant is presently being established with the highest application rate to be at 90 tones per acre. The result from the third trial is expected to establish an optimum level of the compost application rate before it is recommended to the local farmers who are already using organic material as the source of soil nutrient for their crops.

As is evidenced by the data thus far evaluated, land application of compost organic wastes enhanced soil quality/fertility significantly. With continued application of compost prior to each planting event, the soil quality should be further enhanced and the yields should increase as well. This is an ongoing experiment and complete data and analysis is expected to be available for presentation at the time of the conference.

Concluding Remarks

For sustainable agricultural systems within small-scale farming in the Pacific islands, composting can be a good option for developing effective plant nutrient management strategies in many situations. The use of plant and soil diagnostics can easily be incorporated into an agricultural system that uses composed organic material as the main source for a soil fertility program under the environmental conditions of the Pacific islands. Transitioning these farming practices into a sustainable agricultural system is also fairly easy as long as the desire is there. However, the real or perceived economic incentives to use composted organic material as soil amendments need to be introduced with further emphasis among the small scale farmers of Guam and the other farmers in the Pacific region with similar environmental conditions. Here at the College of Agriculture and Life Sciences of the University of Guam, the soil and plant analysis laboratories geared their plant and soil diagnostics programs to include organic waste testing and analysis in order to promote low input agriculture systems that uses composted organic material as the main source for soil fertility and soil quality enhancement. The on-going research programs are designed to specifically address the soil conditions and nutrient status that are unique for Guam and other island of the Pacific with similar environmental conditions. Some of the unique soil properties such as phosphate fixating capacity or aluminum toxicity that are common in Guam and the other islands of the Pacific may be corrected by implementing management strategies that include application of organic material to improve the fertility status of these soils without the use of commercial fertilizers. Our preliminary findings clearly indicate that productivity can be improved by proper use of composted organic materials and the environment also benefits through the reuse of organic wastes that otherwise would be buried in the land field. Evaluation of sustainability is an integral facet of our research projects and our plant and soil testing and analysis programs are geared to address the problems associated with unique properties of soil in the Guam and other neighboring islands that are in poor fertility as a result of low organic matter content.

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