MAKING COMPOST
GUIDE FOR AGRICULTURAL PERSONNEL

IICA/Jamaica

Miscellaneous Publication #366
Series ISSN-0534-5391

MAKING COMPOST

Guide for Agricultural Personnel

by

Bo-Myeong Woo

&

Franklin E. Rosales

September 1982

00000474

CONTENTS

AGRICULTURE IN JAMAICA Collection
of papers of the Office of IICA in Jamaica

MAKING COMPOST

Guide for Agricultural Personnel

Bo-Myeong Woo 1/

Franklin E. Rosales 2/

INTRODUCTION

Among the oldest agricultural countries are those in the Orient, especially China, Korea and India. These have long been the most densely populated countries. How have these and other oriental countries been able to supply food to their people over a period of at least 40 or 50 centuries without the importation of appreciable amounts of either food or fertilizers? Published literature that gives the essential details of their agricultural system in the early years of their history is scarce. King (mentioned by Golucke) has, however, supplied considerable information based on his travels in Japan, China and Korea in 1911. As he emphasized, there is every reason to believe that the farming practices that he observed in the early years of this century had not changed appreciably for many centuries. The following are some of his observations particularly on composting with the emphasis chiefly on China and Korea. (3)

"The key to the maintenance of a permanent agriculture over the centuries in the Orient has been the addition to the soil of every possible material that the farmer considered would contribute nutrients to his crops. Such materials consisted chiefly of various kinds of organic matter, including human and animal manures, crop residues, canal muck, and vegetation from hill lands and canals. All ashes were saved and returned to the land directly or indirectly"......

"Composting was the channel by which many of the plant nutrients were prepared for application to the soil. Many of the waste plant materials were weedy with wide carbon-nitrogen ratios, and the oriental farmers learned early that such materials can be utilized most efficiently via the compost pile. Even most animal manures were not applied directly, but also first went into the compost pile. Wood ashes, canal

---

1/ Soil Conservation Specialist, Associate Professor from Seoul National University, Korea assigned to IICA/Jamaica for two years by a Tripartite agreement between the Government of Jamaica, the Republic of Korea and IICA/Jamaica.

2/ Agricultural Research Specialist, IICA/Jamaica

muck, tree leaves, straw, water plants and anything else that was obtainable all found their way into the compost heap. In most cases thick layers of canal mud or grass sods were used to build up the compost heap. After a few months with interim stirring, decay had proceeded to where most woody materials had largely disintegrated and application could be made directly to the crops. This was done either before seeding, or as a side dressing to the growing crops. In either case it was worked into the soil promptly, thereby assuring rapid and efficient utilization of all the nutrients".

However, the development of a truly systematic approach to composting began with Sir Albert Howard's work in Indore, India, in the early 1930's, in which he systemized the traditional procedures in collaboration with F. K. Jackson and Y. D. Wad (3,4,5). His process became known as the "Indore process" because of the locale of his activities.

The Indore process involves piling on open ground to a height of about 1.5 m (5 ft), or placing in pits alternate layers of readily putrescible materials such as garbage, night soil, animal manure, or sewage sludge, and relatively stable organic matter such as straw and leaves. The mass is usually turned twice during the composting process.

Many different processes and mechanical device were made after Sir Albert work with interest in agriculture as well as in non-agricultural uses such as treating "night soils" in regions lacking sewage facilities. Nonetheless, the boost in research on composting came in the mid 1960's both as a result of funds made available through the 1965 "Solid Wastes Act" in U.S.A., and of a beginning of public concern in its environment quality.

The late 1960's not only brought a deepening public concern with preserving the quality of the environment, but also a willingness to do something about it. One of the spin-offs of this renewed concern with conservation and the environment is a renewed interest in composting.

The transition has been made from the point at which the worth of the compost product was judged primarily upon the monetary value of its nitrogen, phosphorus, and potassium (NPK) content. The NPK monetary value of compost has been recognized for what it is - quite minor in

terms of environment betterment and improvement of soil quality. Maximum productivity of the soil is the proper criterion - not a balance between cash value of increased crop production per dollar spent on the NPK needed to bring about the increase. Thus the effect of the compost product on the lasting improvement of the soil was receiving its due attention. Another application beginning to receive attention was that of incorporating compost into the soil to prevent nitrogen contamination of ground waters by converting it (nitrogen) into a relatively insoluble form, namely, microbial protoplasm. The nitrogen is released in a gradual manner through the death and decay of the microbes. Attention was focused on this desirable trend as a result of the growing alarm over the increasing contamination of water supply attending the excessive use of inorganic nitrogen fertilizers in large-scale agriculture.

Today the technology for making compost is more structured, however, there is still room for improvement in the methodologies involved in pre-treatment steps, especially for sorting and grinding of urban wastes as raw material ingredients.

GENERAL TECHNIQUES IN COMPOSTING

Definition of Composting

"Composting is a biological process for converting organic solid wastes into a stable, humus-like product whose chief use is as a soil conditioner. Modern composting is aerobic and combines mesophilic and thermophilic temperatures. As a biological process it is subject to the constraints of all biological activities, i.e., limitations improved by microbial population and genetic traits, and by environmental factors. Costs are comparable to those for incineration. Simply stated, composting is the biological decomposition of the organic constituents of wastes under controlled conditions". (3)

Principles of Compost Formation

Composting speeds natural decomposition under controlled conditions. Raw organic material is converted into compost by the action of micro-organisms (fungi and bacteria). During initial stages of composting, micro-organisms increase rapidly. As the materials decompose, some kinds of micro-organisms predominate but as they

complete a certain function, these micro-organisms decline while others build up and continue the decomposition.

As micro-organisms decompose the organic materials, temperatures within the pile approach 60° - 70°C (140° - 160°F). This kills some of the weed seeds and disease organisms. However, in cooler sections of the heap such sterilization does not occur.

Organisms that are largely responsible for the breakdown of the organic materials require larger quantities of nitrogen than are found in the biomass. Therefore, adding nitrogen fertilizer or materials supplying required amounts of nitrogen is necessary for rapid and thorough decomposition. During the breakdown period this nitrogen is tied up, and not available for plant use. It is released, however, when the decomposition is complete, and the compost is returned to the garden.

Compost Methods

Compost methods can be classified on three general bases, namely, oxygen usage, temperature, and technological approach. If oxygen usage is the basis, the division is into aerobic and anaerobic. When temperature serves as the basis, the division comes mesophilic and thermophilic. Finally, using technology as the key, the classification is into open or windrow and mechanical or "enclosed" composting. The terms in each of the classifications are practically self-explanatory.

Aerobic composting involves the activity of aerobic microbes, and hence the provision of oxygen during the composting process. The opposite prevails in anaerobic composting - i.e., anaerobic bacteria accomplish the decomposition and oxygen (air) is excluded from the composting mass.

Aerobic composting generally is characterized by high temperatures, the absence of foul odours, and is more rapid than anaerobic composting. Anaerobic decomposition is characterized by low temperatures (unless heat is applied from an external source), the production of odorous inter-mediate (reduced) products, and generally proceeds at a slower rate than does aerobic composting. The main advantage in anaerobic

composting is that the process can be carried out with a minimum of attention, but most of the modern composting is basically aerobic.

In mesophilic composting, as the term implies, the temperatures are kept at intermediate levels (15° tc 40°C), which in most cases is the ambient temperature. Thermophilic composting is conducted at temperatures from 45°C to 65°C. In practice, most processes include the two ranges.

Compost systems falling under the category of "Open" or "windrow" are those in which the entire process is carried out in the open. The manner of arranging the material for handling or processing usually is to stock the materials in elongated piles, i.e., windrows. In mechanical systems, on the other hand, the greater part of the initial composting activity takes place in an enclosed unit, the digester. It might be pointed out at this time that most mechanical processes involve windrowing towards the end of the process to allow the composting material "to mature".

Types of windrow systems range from the rather primitive one designed by Sir Albert Howard to the relatively advanced one developed at the University of California in the 1950's. (3) In the windrow systems, aeration is accomplished by periodically turning the piles in a manner such that all particles are exposed to comparable conditions at some time during the course of the active period of the compost process.

Materials for Composting

The content of chemical components valuable as fertilizer, ease of handling and transport, as well as structure and moisture content, are decisive factors for the compost manufacturer in determining the use of raw materials for composting.

From the biological point of view, the adaptability of these materials to compost fermentation is important. One should know whether the materials will decompose and in what way, the specific structure, where aeration is necessary or not, the moisture content and bacterial action needed for producing the best results.

Many types of organic materials can be used for composting - grass clippings, sod, leaves, hay, straw, weeds, manure, chopped corncobs, corn stalks, saw-dust, shredded newspaper, wood ashes, hedge clippings, and many kinds of plant refuse from the garden as well as the farm lands. Twigs should not be used because they decompose very slowly. (2)

It is best not to use diseased plants from the flower or vegetable garden for composting if the compost is to be returned to the garden later. Although some diseases are killed by heating during compost formation, unless the compost is turned frequently and thoroughly and allowed to remain unused for several years, some of these disease organisms may be returned to the garden with the compost. If diseases have not been a problem, this precaution may not be necessary. Also, it is best to avoid composting weeds heavily laden with seeds. Even though some seeds are killed during composting, if the quantity of seeds is extremely high, many seeds may be returned to the garden when the compost is used and create an unnecessary weed problem.

Most garbage may also be used in the compost heap, with exception of grease, fat, meat scraps, bones, glass and metallic substances. These may attract dogs or other animals, and may develop an odour during decomposition. Fats are slow to break down and greatly increase the length of time required before the compost can be used.

It has been found that fermentation piles do best with an original moisture content between 50% and 60% and that unfavourable conditions prevail below 30% (no action) and above 70% (too sticky and anaerobic). A mixture of source materials should therefore be regulated according to moisture content. If the mixture is too dry it is a simple matter to add the necessary amount of water at the macerating stage or to the piles. If the mixture is too wet, drier materials should be added in order to balance the excessive moisture.

In as much as a 100% moisture content is the desideratum, the maximum permissible moisture content then becomes the optimum moisture for a given material. The maximum permissible moisture content for various wastes are listed in Table 1 (3).

Table: 1 Maximum permissible moisture content

Types of wastes	Moisture content (%)
Theoretical	100
Straw	75 - 85
Wood (sawdust, small chips)	75 - 90
Paper	55 - 65
"Wet" wastes (vegetable trimmings, lawn clippings, garbage, etc)	50 - 55
Municipal refuse	55 - 65
Manure (without bedding)	55 - 65

In selecting raw materials for composting, the Carbon-Nitrogen ratio (C/N) should be considered. Carbon and nitrogen are a nutritional requirement in compost formation. The ratio of these two components is sometimes critical; the limiting one is usually the maximum (25 - 30 to 1) i.e., 25 to 30 parts of carbon to one of nitrogen. Too high a C/N ratio slows the process, whereas too low leads to a nitrogen loss in the form of ammonia.

For home composting, the C/N requirement can be met by adjusting the proportion of "green" garden debris or of garbage to "dry" garden debris. Examples of green garden debris are lawn clippings, green leaves, green plant stems, roots, flowers, etc. Dry debris refers to dried grass (hay), matured flower stalks, branches (excluding leaves), straw, others.

The green material is rich in nitrogen and hence increasing the ratio of "greens" to "dry" lowers the C/N ratio. The C/N ratio can be lowered through the use of manures. Poultry manure is the most effective because of its high nitrogen content. Dog Faeces would also be a good source of nitrogen.

One may wonder how he can determine the C/N ratio of his raw material. Unfortunately, determining the C/N ratio involves the conducting of some exacting and expensive tests. Consequently, some trial-and-error coupled with good judgement is necessary. A useful way to assure an adequate ratio is to follow the old Indore method in setting up the pile, i.e., layering. Dry layers are alternated with "green" or moist layers. Each layer is from 10 to 15 cm in depth (4 to 6 inches).

Dry material is used for absorbing the excess moisture, as well as to imparting structural strength to the pile. It keeps the pile "porous" and prevents compaction.

Other raw materials that are useful or even required, are phosphorus, and an array of trace elements. Generally these substances are present in sufficient quantity in plant debris and manures. In addition, to keep the pile from becoming too acid in its reaction, lime is added for home composting. Most micro-organisms cannot thrive under acid conditions or may even be killed. Actually, the ideal pH level for most micro-organisms is 7.0, a level that corresponds to "neutrality".

Good average compost is obtained if the total nitrogen content of the source materials is between 0.8% and 1.7% with an average of 1.0% to 1.5%. The aim should be to obtain this optimum range. Below 0.7% total nitrogen there is a slow and delayed fermentation until the optimal C/N relationship is obtained. Above 2.0% there is the danger of nitrogen (ammonia) losses. Fermentation piles of more than 2.0% nitrogen contain unstable forms of nitrogen (especially ammonia) and need careful handling. The fermentation of such piles should be interrupted as soon as sufficient decomposition takes place. They should be dried at once and kept dry in order to stop any further fermentation. They can be pushed together in large piles which will excluse air and reduce the exposed surface. As long as they are dry they will keep alright. While nitrogen content below 2.0% will produce a material which will last for many months unchanged, the higher nitrogen compost should be processed at once. Compost having more

than 1.7% nitrogen may have the odour of ammonia. The strong odour of ammonia will lead one to think there is a great deal of ammonia. (6)

Procedures for Compost Production

1. Location for the compost pile

   Locate the pile in a convenient but inconspicuous place. If the compost is to be used mainly in the garden, a nearby location should be chosen. Since the compost pile needs to be kept moist, a convenient source of water is helpful. Compost should never get soggy wet or the decomposition process will stop. Therefore, do not locate a compost heap where drainage is poor and water may stand, even for short periods.

   The pile may be on any open, surface-drained area, although a shed roof might be advisable over that portion of the piles still in the active composting stage. In colder conditions of climate, it would be advisable to completely protect the active portion of the piles by providing sides to the shed.

   A shaded area is also desirable for best composting. However, do not locate compost heaps close to trees. Tree roots are easily attracted to the loose, moist, organic material developing at the bottom of the pile. During the summer (in temperate regions), roots of some trees may spread rapidly throughout the lower areas of the heap, and make the compost difficult to dig and use.

2. Size of the compost pile

   The size of the pile varies greatly with the amount of material available. Windrows may be of any convenient length, but the depth of the pile is somewhat critical. If piled too high, the material will be compressed by its own weight, pore space is lost, and the mass becomes anaerobic. In some instances, the maximum practical effects may be governed by the equipment used for stocking the ground refuse, or by the tendency of the pile to get excessively hot - above 70°C.

A pile that is too shallow loses heat too rapidly, and optimum temperatures for thermophilic organisms are not attained. In addition, loss of moisture is excessive, especially near the edges of the pile and the rate of composting is thereby retarded.

Although experience demonstrates the most suitable height of pile for any particular refuse, a maximum of 1.5 or 1.8 meters (5 to 6 ft) is recommended for general composting materials including freshly ground municipal refuse. As the material loses volume during decomposition, any desired height of pile can be maintained by reducing or expanding the width of the windrow at the time it is turned.

The initial width of a windrow probably will not exceed 2.5 or 3 meters (8 or 10 ft) at the base for convenience in turning. In dry weather, the cross section is usually made trapezoidal, with the top width governed by the width of the base and the angle of repose of the material, which is something like 30 degrees from the vertical. In rainy climates or in wet weather, the cross section of the windrow should be approximately semi-circular like a haycock in order to shed water. In that case, the maximum permissible height of pile will govern its maximum width.

Other than maximum and minimum heights of pile, there is nothing critical about the stacking of ground refuse for composting; hence in each individual case, experience with the materials handling equipment employed will establish the best practice to be followed.

A pile should not be less than 1.5 m wide and 1.0 m high. Anything smaller is too small to decompose properly.

In case of the home gardeners, an average gardener might want to pile about 1.5 m wide by 1.5 m long by 1.5 m deep. Where more compost is available the heap should still be

about 1.5 m wide (for easy working) and any convenient length.

The average gardener may find that if adequate raw material for composting is available two or three small piles provide greater flexibility than a single large one. In this way, a pile may be built and allowed to start undisturbed, while a second pile seems as a place to put organic materials as ideal: one finishing, one in the process of decomposition, and one to which fresh materials are being added. In this way there is almost a continuous supply of compost.

The urban gardener may not have enough material to build several piles, or may not have room for them. In such a situation, a single, tall pile may be satisfactory. Although not ideal, fresh materials may be added to the top, and decomposed material dug out from the bottom. This does not allow for turning, which aids complete decomposition and heating. Nevertheless, with limited space and material such a pile serves a definite and useful purpose.

3. Enclosures and shapes for the compost pile

Although it is possible to stock the compost in a loose pile, decomposition is best and space is used more efficiently if it is made in some type of bin or enclosure.

Many materials may be used. The sides should be loose enough to provide some air movement through them. One side should open for easy turning and removal of the compost.

Woven wire fencing (hog wire, chicken wire, chain link), wood slat fencing (snow fence), cement blocks, bricks, or scrap lumber can be used to enclose a compost heap.

Fencing materials need corner supports, although a small round heap made of slatted fencing needs little or no support. If woven wire fencing is too loose to contain fine materials,

line the enclosure with plastic (containing some aeration holes) to keep the pile neat and speed decomposition.

Bricks, or concrete blocks, may be piled without mortar, but space should be left between some of them to allow adequate air movement through the sides.

Scrap boards are suitable for sides since there is normally enough space between them for air movement. Lumber is gradually ruined by exposure to the damp compost, and occasionally boards have to be replaced as they decay. The pile may be round, square, rectangular, or other convenient shape.

4. Compost piling methods

Compost pile construction is usually described in terms of layers. In practice such layers are not well defined. Layering is not totally essential, but provides the quickest and most complete decomposition. Normally the pile may be started directly on the ground. However, to provide aeration to the bottom of the pile and to improve drainage, a trench may be dug across the base of the area and covered with stiff wire mesh before the layers are begun.

Begin the pile by spreading a 15 to 20 cm layer of organic matter over the area. If there are different materials available, use the coarsest on the bottom. Shredded or chopped materials decompose fastest, so if a shredder is available, coarse organic matter should be run through it. Materials that tend to mat, such as grass clipping, should be placed in layers only about 10 cm thick. Moisten, but do not soak, the layer or organic material.

Over the layer of plant material, sprinkle a complete garden fertilizer with a nutrient ratio of 1:2:1 or 1:1:1. One cup for about 2.m^2 of top surface should be adequate. An equal amount of ground limestone may also be added to the compost unless the finished compost is later to be used for acid-loving plants.

If fresh animal or poultry manure is available, a 3 to 5 cm layer may be substituted for the commercial fertilizer.

Next, add a layer of soil (or sod) 2 to 3 cm thick. The soil contains micro-organisms that help to start the decomposition process. If there is not an adequate source of topsoil, a layer of finished compost may be used as a substitute for the soil.

Continue to alternate the layers of organic materials, fertilizer or manure, and soil until a maximum height of about 1.5 m or 1.8 m is achieved. Firm each layer as it is added, but do not compact it to the extent that movement of air through it is excluded. Water each layer as it is added.

5. Turning practices

The compost pile must be kept moist (but not soggy) for proper heating and decomposition. Inadequate moisture reduces microbial activity. Excess moisture may cause undesirable decomposition and offensive odours.

During dry weather it may be necessary to add supplemental water with weekly soaking. Covering with plastic can reduce moisture loss and aid decomposition during extremely dry periods. A plastic covering also protects the pile from becoming too wet during period of heavy rainfall. Sometimes plant leaves such as coconut and bananas can be used effectively as a covering material, particularly in tropical countries.

Since aeration in windrow composting is accomplished by turning, the pile is turned fairly frequently so as to obtain the rapid, nuisance free decomposition characteristic of the thermophilic aerobic process. Uniform decomposition essential to rapid composting is insured by turning the outer edges into the center of the pile at each turn.

In this manner, any fly larvae, pathogens, or insect eggs which might survive at the cooler surface are exposed to the lethal temperatures of the interior of the pile. This means that neither a simple over-turn nor a vertical expansion of the pile constitute adequate turning. An inward mixing of material from both sides of the pile is required.

In practice, turning may be easily done by slicing through the pile and inverting each slice. Where space is available, it may be done by shifting the entire pile into another bin, to be moved back. The main objective of turning is to shift materials from outer parts of the pile closer to the center where they are better able to heat and decompose.

Another reason for a particular turning operation might be reduction of the initial moisture content, and reclamation of a compost pile which has become anaerobic. Anaerobic conditions usually result from too great a moisture content for the normal turning schedule practiced. Excess moisture may be inherent in the particular refuse being composted, or it may result from continual soaking by rain, especially during periods of turning, when composting is done in the open. Anaerobic conditions may also occur as the result of equipment breakdown, a long period of unusually bad weather, or other interruption of a normal turning schedule.

The pile should be turned immediately if at any time a strong ammonia or other offensive odour is detected. In general, the time for the first turning is about two to four weeks after starting the pile. A hot temperature in the center indicates that the pile is decomposing properly. Failure to heat might be caused by too much water, improper aeration, too little nitrogen, or too small a pile. During the course of the first turning and thereafter, materials in the absorbent and wet layers should be mixed. In other words, the layering of "wet" and "dry" materials is discontinued with the first turning.

As materials decompose, the pile should shrink to about half of its original height. In the University of California studies (7) the reduction in volume with garden debris was as much as 60 to 65%. On the other hand, when municipal refuse having a heavy concentration of newsprint was composted, the reduction in volume was from 30 to 35%. The length of time required will vary with size of pile and time of year. If heap fails to decompose, it may be necessary to re-stack with some new materials.

The frequency of turning and the total number of turns required during the composting process are governed largely by the moisture content. In some cases, if the moisture content of the municipal refuse materials is more than 70%, turn very frequently (every two to three days) until the moisture content is reduced to less than 70%, then follow the normal schedule.

Once the normal schedule is followed, it is not necessary to determine moisture content after the initial analysis. Experience soon enables the operator to estimate the need for adding moisture and the adequacy of a turning schedule. A good rule of thumb is to begin a schedule of the turning at the onset of any foul odours that are noticed when a pile is disturbed either by turning or by digging into it for inspection purposes.

During warm weather the pile should be turned about two to four weeks interval. In cool weather, decomposition is slower and frequent turning is not necessary. During the winter (in the temperate regions), little decomposition occurs except in very large piles.

Where time is not an important constraint, the turning schedule can be modified to allow longer intervals between turning. The same approach applies when nitrogen conservation is an important consideration, because turning accelerates nitrogen losses.
No turning should be done during a rainfall, because all parts of the open stack will be exposed to rain and an increase in moisture content will result.

To bring up the moisture content of a pile, water can be added most effectively during the turning operation, at which time the exposed material absorbs water. The outer parts of unsheltered piles have a tendency to dry out during sunny weather, in which case surface sprinkling should be practiced to promote uniform decomposition.

6. Monitoring the process

The best way to monitor the process is by recording the movement of the temperature. This can be done by using a hot-bed thermometer to check the temperature inside the pile. The temperature inside the pile (about 35 to 40 cm from the surface) should rise to 43° to 49°C within 24 to 48 hours after starting the process. It should reach 55°C or higher until all of the readily decomposable material is stabilized. Then the temperature will drop. When it drops to around 43°C, the material is ready for first turning. (8).

If the temperature does not rise, or if it drops suddenly, the pile may be too wet, too dry, or the C/N ratio is too high. If the moisture content is too high, the material will develop a bad odour. If it is too low, the material will have a dry appearnace. If the C/N ratio is too high, no odour will be noticiable, and the material will glisten if the moisture content is satisfactory.

7. Additional processing and storage of compost

When compost is ready for use, it should be dark and crumbly, with much of the original identity of the materials lost. Finished compost should have an "earthy" smell. Normally, compost will be ready for use in 3 to 6 months, depending on the types of organic materials used and the climatic conditions during the composting period. After the material is adjudged sufficiently stable to store, it is ready for application, i.e., in large scale agriculture, land reclamation, etc.

For many purposes particularly in urban and garden compost, the finished compost is easier to use if it is first screened through a "1-inch wire mesh screen" to eliminate coarse or incompletely decomposed materials.

In practice, the usual procedure is to sort the compost into fractions on the basis of quality. This is usually done by screening the material. The coarsest material is destined for the "rough" applications, while the finest is reserved for the home gardener for "luxury" crops.

Often the material remaining after the separation of the coarser fraction is ground and screened. Grinding compost is less a chore than grinding raw refuse due to the fact that the material has been rendered more amenable to grinding because of having been composted. The major benefit of the second grinding is the increase in "eye" appeal.

Properly composted material can be stored without danger of subsequent generation of nuisances. Although decomposition will occur during storage unless the moisture content is too low for bacterial activity, the rate of decomposition will be very slow, and no odourous intermediates are formed.

If compost becomes old, it still makes a good soil amendment, but nitrogen may be lost through volatilization or leaching. For this reason, compost should be used as soon as possible after it is finished.

VALUES OF FINISHED COMPOST

Soil Conditioner Value

It should be realized that not all decayed or broken down organic matter is compost, in the true sense of the word. Compost is more correctly defined as a completely digested, earthy matter having the properties and structure of humus. At present many products are called "compost" which have not yet reached the humus state, or have gone too far, resembling good soil, but lacking organic matter. There are many different kinds of compost with quite different fertilizer values and effects upon the soil.

Finished compost may be designated by the general term "humus". When used in the soil, humus has many characteristics beneficial both to

the soil itself and to growing crops and vegetations. In conjunction with commercial fertilizers, humus exhibits certain additional and very desirable characteristics. Acids resulting from the metabolic breakdown of organic material form a complex with the in-organic phosphate. In this form, phosphorus is more readily available to higher plants. Both phosphorus and nitrogen are involved in a storing effect peculiar to humus. The precipitation of phosphorus by calcium is inhibited and the nitrogen once converted into bacterial protoplasm is rendered insoluble (1). Thereafter, the nitrogen becomes available as the bacteria die and decompose.

The effect of compost in the soil is the reduction of leaching of soluble inorganic nitrogen and the making of rates of availability more nearly equal to that at which plants can utilize it. The gradual decomposition of insoluble organic matter by micro-organisms results in a continual liberation of nitrogen as ammonia, which is then oxidized to nitrates.

The physical effects of humus on the soil are perhaps more important than the nutrient effects. Soil structure may be as important to fertility as it is to its complement of nutrients.

Good compost consists of a small amount of soil along with decomposed or partially decomposed plant and animal residues. As a soil amendment, compost improves both physical condition and fertility. It is especially useful for improving soils that are low in organic matter.

The organic matter in the compost makes heavy clay soils easier to work by binding the soil particles together. Such aggregation of the soil particles helps improve aeration, root penetration, and water infiltration, and reduces crusting of the soil surface. Additional organic matter also helps sandy soils retain water and nutrients.

Although compost contains nutrients, its greatest benefit is in improving soil characteristics. Therefore, it should be considered a valuable soil amendment, and not a fertilizer, since in most cases, additional fertilization will be necessary to achieve maximum growth and production.

Other beneficial effects of bacterial metabolism associated with humus includes an increased ability of the soil to absorb rapid change in acidity and alkalinity, and the neutralization of certain toxic substances.

Main Chemical Value

While qualitatively the chemical composition may be fairly similar from one compost to another, in as much as organic matter is the substrate; quantitatively the variation will be great. The variety is due to differences in type or combinations of types of material being composted.

In one instance the material may have a high nitrogen (low C/N) content; while in another, nitrogen may verge on being limiting. The gamut of total elements also varies. Mixed municipal refuse may have a wider range of trace metals than would a particular crop or manure.

It should be understood that the formula of an organic fertilizer product derived from wastes and agricultural residues can be expressed in terms of chemical analysis and figures. However, these figures cannot be compared exactly with the same figures of a mineral fertilizer since the action and efficiency of the components of organic composts, such as nitrogen, phosphate and potash are quite different in the soil as well as the availability to roots.

In general, compost has a nitrogen-phosphorus-potassium (NPK) content not high enough to permit it to be designated a fertilizer in the legal sense. Therefore, unless fortified with one or all of the three elements, it cannot be legally sold as a fertilizer. The usual designator is "soil conditioner". The legal NPK requirement for fertilizer varies from country to country.

APPLICATIONS AND EFFECTS OF COMPOST

Rate of Application and General Effects for Crop Production

Compost can be used for almost all kinds of crop production and also for potting house plants or for starting many seeds.

The rate of application is determined by the fertilizer value of the compost, its costs for production, the equipment necessary for spreading and the time element, that is, how much the farmer can afford to travel over the field for spreading.

The intrinsic value of compost application is evident only after a time. Unless the farmer is already familiar with, and educated to appreciate the importance of organic matter in soil and the function of soil life, he will learn about the intrinisic value only by experience and time.

The practical application rates of compost range between 2.5 and 7.5 ton/hectare (1 and 3 ton/acre) of air dry and dehydrated products and 12.5 to 17.5 ton/hectare (5 to 7 ton/acre) of wet (50% moisture) products or even more. A compost with 1% total N, at the rate of 2.5 ton/hectare (1 ton/acre) provides 22.5 kg/hectare (9kg or 20 lb/acre), and so on. If the N content is 2% these figures double 45 kg and 90 kg of N per hectare which is enough in most cases. (6)

In the compost most of the nitrogen is present in form of a stable organic nitrogen. This nitrogen is slowly but steadily released over a much longer period of time than the readily available ammonium or nitrate. Ordinarily ammonium and nitrate ions are easily lost in the ground water, in rain or irrigation as the plant roots do not make use of all of it at once. Only part of the ammonia and nitrate is preserved in the soil, namely that fraction which is absorbed by the natural soil humus or transformed by the microlife in soil.

Organic matter influences favourable plant growth even at times nearer harvest, while excessive available ammonia and nitrates from inorganic sources tend to force plants to vegetate and delay maturity. The danger of lodging of grains exists when there is excessive rainfall and too easily available nitrogen, a case that seldom occurs with the organic treatment.

The farmer or gardener has to become familiar with these fundamental differences, then he will be able to apply the organic formula to advantage. Organic N will be much longer lasting. In fact, in soils

with a high organic matter content the after-effects will still be evident in the second, sometimes even in the third year, so that a new application is not needed every year. If combined with a conserving crop rotation with legumes this lasting effect can be extended even further.

Many farmers admit that they cannot improve their soils with mineral fertilizers along and they realize the need of organic matter to accomplish such a goal. Levels of 1.5% organic matter, or below, in the soil has been found to be critical; 1.0% or less is dangerous. Only above 2.0% organic matter in the soil will stabilize the soil's fertility.

If we consider the estimation (6) that one acre-foot of soil weighs 2 million pounds then 40,000 pounds or 20 tons of 2.0% organic matter are needed to reach the level mentioned above. Rarely that much manure or compost can be applied to field crops. Ten tons of fresh manure per acre are generally considered to be a good application and this means only 300 to 400 lbs or organic matter.

To raise the organic matter level from 1.5 to 2.0% would mean then to add 10,000 lbs of organic matter. Compost feeds soil micro-organisms and should be thought of not as a fertilizer because of its NPK value but, much more important, as beneficial microlife which, if nourished, increased and stimulated, is far above the efficiency performed by man.

Without organic matter a soil becomes crusted, hard and is more difficult to work. There are increased expenses of cultivation. There is a reduced water absorption and water holding capacity of the soil. A soil with a high organic matter will stay moist longer into a drought than a mineralized soil. There are changes in the protein content and feeding value of the crops. There are losses of trace materials or tying-up, i.e., important nutrients (phosphates, potash, others) become unavailable and thereby necessitating correction.

In view of all these factors the farmer may start immediately on a proper soil management programme on an organic basis with a view to a

long range programme and see whether or not he needs any additional fertilization.

The initial cost of organics, manures and compost, is only seemingly higher, while over a long programme of 4 to 10 or more years the cost situation becomes entirely different. The farmer and economist who only compares two prices (fertilizer and compost) on the bags, commits a serious mistake and actually does not think with reality. Some good and prosperous farmers know this while others do not realize the complex nature of the problem. In this case educational and/or extension programme is necessary.

Effects on Soil Conservation

The effect of increased soil organic matter content on soil erosion is quantified by the soil erodibility factor, K, in the universal soil loss equation (10). The change in the K factor, which results from a change in organic matter, can be estimated from a soil erodibility nomograph. This nomograph shows that an increase in organic matter content of 1% on some soils, for example changing the organic matter content from 3 to 4%, will reduce the K factor by 10%.
This would, in turn, reduce the potential for soil erosion by this percentage. This does not take into account changes in the structure index or permeability class, which might also be improved by increasing the organic matter content.

The infiltration capacity of fallow soils increases as soil organic matter content increases.

In addition, the application of compost is an obvious solution to land reclamation in areas where the top soil has been moved or lost due to the various terracings or by the soil erosion processes.

The problem in such areas is to stop erosion and to supply a substrate on which a crop plant can take hold. Compost would supply both needs very readily. A kindred type of reclamation is the protection of hillsides denuded of vegetation by fire.

Roles of the Urban and Gardener's Compost

Disposing of leaves, grass clippings, and other refuse is often a problem for gardeners, particularly in urban areas. These by-products of the garden and landscape can be turned into useful compost with no more effort than it takes to bag and haul them away.

In many cases the compost will serve the same function as peat moss and thereby reduce gardening cost. Returning these organic materials to the land perpetuates natural biological cycles, and is an ecologically sensible means of using organic wastes.

Compost is also valuable mulching material to use around garden and landscape plants. It may be used as a "top-dressing" for lawns and, when it contains a small amount of soil, as a growing medium for house plants or for starting seedlings.

However, especially for starting seeds, the compost should be sterilized before use. Length of time for sterilization varies with volume. The moist compost or soil mix should be placed in a pre-heated oven (93 to 94°C) and heat until the center of the mass reaches a temperature of about 70 to 71°C and maintain that temperature for 30 minutes. A probing-type thermometer (meat or candy) may be helpful for determining whether the center has been properly heated. Excess heating is not necessary and can be harmful. Be sure to remove the soil as soon as it has been sterilized, and allow to cool completely before use.

Special Application in Composting with Dairy Manure

Composting has an attractive potential in the disposal of animal wastes. This type of eastes poses major problems which are aggravated as the rate of production of them increases, but they are especially amenable to composting due to their highly putrescible nature.

Their physical characteristics are such that they readily give rise to nuisances in the form of objectionable odours and attraction of flies. This type of wastes has a high moisture content which makes incineration an expensive operation. The problem is more severe with dairy animal wastes because their moisture content generally far surpasses that of other animal wastes.

Burning this material in a sanitary landfield not only is an unpleasant operation but also increases the danger of polluting ground and surface waters.

For the treatment of dairy manures containing no bedding materials, a system was developed by Senn at the University of California at Los Angeles School of Public Health as a part of a project aimed at developing methods for disposing of dairy wastes. (3). In essence, the process entails air-drying the manure until its moisture content drops to 60% or less. In an on-going process, the drying step needs to be done only once, i.e., at the initiation of a given operation. The dried material is mixed with fresh material in a proportion such that the mixture does not "cake", and is placed in a bin. The bin is equipped for forced bottom aeration. No problem is encountered in aerating the material in this manner, provided the moisture content is not excessive. By the time the material is composted, its moisture content is low enough to permit it to serve as a moisture absorbent for fresh manure.

A variation is to spread the composted material in the cow's stalls to serve as a bodding for the animals and to absorb moisture from fresh manure. This system is applicable to any animal wastes.

Economic and Administrative Aspects of Composting

The development path followed by a country should make full use of its abundant natural resources - those with a low social cost - while economising on those which are scarce. Most developing countries are characterized by rapid population growth and to varying degrees by limited cultivable land and foreign exchange reserves. Their aims should therefore be to employ techniques which raise the productivity of the land using the energy of human beings and other domestically available resources rather than inputs, particularly capital and equipment, that impose net demands on foreign exchanges.

Under these circumstances the organic matter content of composts has an important economic role to play. It increases returns to land by increasing yields, using labour and waste materials having a low social cost; the foreign exchange requirement is insignificant and the

investment needed can often be provided simply by labour.

The factors commending compost as socially desirable are likely to become more significant over time. As the man-to-land ratio increases under the influence of population growth and to a lesser extent soil erosion and the spread of cities, yield-increasing and labour-using techniques will become more desirable. At the same time, deficit trading positions will restrict imports of inorganic fertilizers or of the means to manufacture them domestically.

In general terms then there is a strong economic case to be made for the fuller use of organic materials as manures in developing countries, particularly those which lack unused cultivable land.

The urgent need for small farmers to raise food production in developing countries demands that this neglect be put right. Attention should be turned in two main directions.

First, social cost-benefit analyses should be carried out of technically feasible alternatives to determine which systems of collecting, processing and distributing compost make the best use of countries scarce resources.

Second, at the farm level, attempts should be made to understand the economic and social pressures on decision-makers which lead to the evolution of particular production patterns. In particular, much greater attention than hitherto should be directed to the costs to the farmer and his family of different fertilising practices. The constraints on the wider use of compost whether of land, labour, markets, water, transport, or a combination of these should be identified, technical research may then be directed to their resolution.

As a useful first step, the agricultural public sector might bring together data from farm management projects including some demonstration projects to provide a basis for systematic development of composting techniques as well as its effects on soils and crops. And also, the Agricultural Extension Services should recognise that compost practices are necessarily elements of an interwoven system; the strategy to

encourage their use must involve wider changes including better livestock and crop husbandry as part of truly mixed farming systems; better irrigation; better draft equipment, and above all, better transportation.

FUTURE CONSIDERATIONS

Today many large scale producers as well as small farmers and gardeners in different countries are showing interest in alternative farming systems. Some of these producers have developed unique systems for soil and crop management, organic re-cycling, energy conservations, and pest control.

It is necessary to gain a better understanding of these organic-compost farming systems. The extent to which they are practiced in the other places, why they are practiced, why they are being used, the technology behind them, and economic and ecological impacts from their use. Action should also be taken to identify the kinds of research and education programmes that relate to organic-compost farming.

As one attempts to develop relevant and productive agricultural programmes there is always a need to look forward to increasing communication between the field farmers, research organizations and agricultural administration.

One of the major challenges to agriculture in this decade will be the development of farming systems that can produce the necessary quantity and quality of food crops without adversely affecting to the soil resources and the environment. In this context, compost has a number one position as a variable that can be easily adapted in any scale farming system.

One must be aware nevertheless that regardless of claims as to the merits of a particular method of preparing compost, there is really no one method that is superior. Many methods can be used, and in fact the detailed procedures must be varied in accordance with the

raw products available for composting. The basic aim is to bring about rather rapid and thorough decomposition of the organic materials used without undue loss of the nutrients as gases or by leaching, and with the production of an end product that has desirable physical properties. It should also have a final composition such that, when applied to soils, it will gradually release the major and minor nutrients to the growing crops.

REFERENCES

1. Allison, F.E. 1973. Soil Organic Matter and Its Role in Crop Production. Elsevier Scientific Publishing Co. pp 420 - 436

2. Cooke, R. L. 1970. Soil Management for Conservation and Production. John Wiley & Sons, Inc. New York. pp 432 - 437

3. Colueke, Clarence G. 1972. Composting. Rodale Press, Inc. 110 p.

4. Hortenetine, C.G. 1970. Effect of Garbage Compost on Soil Processes. USDA HEW. PHS.

5. Howard Albert, "Agricultural Testament"

6. Pfeifer, Ehrenfried E. 1956. The Compost Manufactures Manual. The Pfeifer Foundation Inc. 137 p.

7. Seifert, Alwin. 1962. Compost. Faber and Faber Ltd. 124 p.

8. USDA. 1978. Making and Using Compost. Fact Sheet AFS-4-5-1. 4 p.

9. USDA. 1978. Animal Manure for Crop Production. Fact Sheet AFS-405-3. 4 p.

10. Youngberg, Garth. 1980. Organic Farming. Journal of Soil and Water Conservation. 35(6): 259 - 264 pp.

AGRICULTURE IN JAMAICA

Collection of papers of the Office of IICA in Jamaica

1977-1978

No. I - 1	Fritz Andrew Sibbles, "Basic Agricultural Information on Jamaica Internal Document of Work", January 1977
No. I - 2	Yvonne Lake, "Agricultural Planning in Jamaica", June 1977
No. I - 3	Aston S. Wood, Ph.D., "Agricultural Education in Jamaica", September - October 1977
No. I - 4	Uli Locher, "The Marketing of Agricultural Produce in Jamaica", November 1977
No. I - 5	G. Barker, A. Wahab, L.A. Bell, "Agricultural Research in Jamaica", November 1977
No. I - 6	Irving Johnson, Marie Strachan, Joseph Johnson. "Land Settlement in Jamaica", December 1977
No. I - 7	Government of Jamaica, "Agricultural Government Policy Papers", February 1978
No. I - 8	Jose Emilio Araujo, "The Communal Enterprise" February 1980
No. I - 9	IICA and MOAJ, "Hillside Farming Technology - Intensive Short Course", Vols, I and II, March 1978
No. I - 10	Jose Emilio Araujo, "The Theory Behind the Community Enterprise - Seminar in Jamaica", March 1978
No. I - 11	Marie Strachan, "A National Programme for the Development of Hillside Farming in Jamaica", April 1978
No. I - 12	D.D. Henry, "Brief Overall Diagnosis of Hillside Farming in Jamaica", April 1978
No. I - 13	Neville Farquharson, "Production and Marketing of Yams in Allsides and Christiana", May 1978
No. I - 14	R.C.E. McDonald, A.H. Wahab, "Fertility Assessment of Newly Terraced Hillside Soils Using the Microplot Technique - the Allsides Case Study", 1978
No. I - 15	IICA - IDB "Course in Preparation and Evaluation of Agricultural Projects", Vols. I and II, November 1977
No. I - 16	Neville Farquaharson, "Production and Marketing of Dasheen in Allsides and Christiana", June 1978

1978 - 1979

No. II - 1 O. Arboleda-Sepulveda (IICA-CIDIA), "Agricultural Documentation and Information Network in Jamaica", September 1978

No. II - 2 Victor Quiroga, "National Agricultural Information System", (NAIS-Jamaica) Project Profile, September 1978

No. II - 3 Joseph Johnson, "A Review on Land Reform in Jamaica for the Period 1972 - 1978", September 1978

No. II - 4 Neville Farquharson, "ABC of Vegetable Farming", A Draft High School Textbook, Vols. I, II III, and IV, February 1979

No. II - 5 Jerry La Gra, "Elements of an Agricultural Marketing Strategy for Jamaica", March 1979

No. II - 6 D.D. Henry, I.E. Johnson, "Agricultural Extension Service in Jamaica", March 1979

1979 - 1980

No. III - 1 H.R. Stennett, "Watersheds of Jamaica and Considerations for an Ordinal Scale of Their Development", July 1979

No. III - 2 IICA-MAJ "Hillside Farming in Jamaica", A Training Seminar, December 1978

No. III - 3 A.L. Wright, A.H. Wahab, H. Murray, "Performance of Six Varieties of Red Peas (Phaseolus vulgaris L.) on a Newly Terraced Ultisol in Jamaica", September 1979

No. III - 4 IICA Jamaica Staff, "Agro-Socio-Economic Sample Survey of Allsides - Trelawny, Jamaica", September 1979

No. III - 5 IICA-MOAJ, "An Approach to Agricultural Settlement of Hilly Lands", October 1979

No. III - 6 IICA-MOAJ, "Tree Crops of Economic Importance to Hillside Farms in Jamaica", October 1979

No. III - 7 Canute McLean, "Production and Marketing of Peanuts", November 1979

1980

No. IV - 1 Joseph Johnson, "Production and Marketing of Red Peas in the Hilly Areas of Jamaica", January 1980

No. IV - 2 Lyn Snuffer, "Rural Women" An Annotated Caribbean Bibliography with special reference to Jamaica", January 1980

No. IV - 3 Vincent Campbell, Abdul Wahab, Howard Murray, "Response of Peanut (Arachis hypogaea L.) on a Newly Terraced Ultisol in Jamaica", January 1980

No. IV - 4 P. Aitken, A. Wahab, I. Johnson, A. Sahni, "Agro-Socio-Economic Survey - Pilot Hillside Agricultural Project 'PHILAGRIP' Southern Trelawny", February 1980

No. IV - 5 Glenys H. Barker, "Bibliography of Literature relating to Research and Development in the Agricultural Sector of Jamaica 1959 - 1979", March 1980

No. IV - 6 Milton R. Wedderburn, "Allsides Farmers' Pre-Cooperative A Socio-Economic Assessment", March 1980

No. IV - 7 Adele J. Wint, "The Role of Women in the Development Process", April 1980

No. IV - 8 Milton R. Wedderburn, "The Co-operative Input in the Development of the Pilot Hillside Agricultural Project (PHILAGRIP)", April 1980

No. IV - 9 MOJ/IICA/CARDI, Fruit Trees Seminar - "Research and Development of Fruit Trees", June 1980

No. IV - 10 Henry Lancelot, "Traditional Systems in Hillside Farming, Upper Trelawny, Jamaica", June 1980

No. IV - 11 IICA/Jamaica, "Pilot Hillside Agricultural Project", (PHILAGRIP), Project Document. Vols. I, II and III, June 1980

No. IV - 12 A. Wahab, I. Johnson, P. Aitken, H. Murray and H. Stennett, "Highlights of the Pilot Hillside Agricultural Project at Allsides", July 1980

No. IV - 13 I. Johnson, A. Wahab, P. Aitken, H. Payne, "Benchmark for a Project Profile for Developing a Peanut Industry in Jamaica", July 1980

No. IV - 14 P. Aitken, A. Wahab, I. Johnson, "The Allsides Post Peasant", August 1980

No. IV - 15 Norma Munguia, Percy Aitken, Abdul Wahab, Irving Johnson, "Salt Extraction by Solar Energy", A Mini-project, September 1980

No. IV - 16 Abdul H. Wahab, Percy Aitken-Soux, Irving E. Johnson and Howard Murray, "The Allsides Project in Jamaica - Developmental Potentials of Hillside Agriculture", September 1980

No. IV - 17 P. Aitken, A. Wahab, I. Johnson, A. Sahney and N. Munguia, "Rural Women Survey", Vols. I, II, and III, October 1980

No. IV - 18 P. Aitken, I. E. Johnson, A. Wahab, "Assessment of Employment Among Small Hillside Farmers of Jamaica", November 1980

No. IV - 19 IICA/Jamaica "Pilot Hillside Agricultural Project", (PHILAGRIP), Final Project Document. October 1980.

No. IV - 20 P. Aitken, A. Wahab, I.E. Johnson, Bo-Myeong Woo, "IICA Evaluation of the First Phase FSB Allsides Project", (Internal Document of Work), November 1980

No. IV - 21 MINAG/IICA/CARDI - "Seminar on Multiple Cropping", December 1980

1981

No. V - 1 Norma Munguia, P. Aitken, A. Wahab, I. Johnson, "Smoke Curing of Fish (as a household industry in Rural Jamaica)", January 1981

No. V - 2 P. Aitken, A. Wahab, I. Johnson, "Under-employment - It's Relation to the Agricultural Sector and Considerations for its Management", January 1981

No. V - 3 D.D. Henry, J.R. Gayle, "The Culture of Grafted Pimento (as spice crop for Allsides, Jamaica)", January 1981

No. V - 4 Abdul H. Wahab, Noel Singh, "Agricultural Research in Jamaica", February 1981

No. V - 5 P. Aitken-Soux, A.H. Wahab, I.E. Johnson, "Country Level Action Plan (CLAP)", May 1981

No. V - 6 P. Aitken-Soux, A.H. Wahab, I.E. Johnson, "Overview of Agricultural Development in Jamaica", May 1981

No. V - 7 Samuel Thompson, I.E. Johnson, P. Aitken-Soux, Abdul Wahab, "The Land Development & Utilization Act 1966", July 1981

No. V - 8 Abdul Wahab, Percy Aitken-Soux, Irving Johnson, Bo-Myeong Woo, Howard Murray, Joseph Dehaney, "The Experiences of Jamaica in the Management of Agricultural Production on Hillsides", July 1981

No. V - 9 Dave Hutton, Abdul Wahab, Howard Murray, "Yield Response of Yellow Yam (Dioscorea Cayenensis) After Disinfesting Planting Material of Pratylenchus Coffeae", July 1981

No. V - 10 Elaine Montague-Gordon, Abdul H. Wahab, Joseph Dehaney and Audrey Wright, "Performance of Eleven Varieties of Dry Beans (Phaseolus vulgaris) Over Two Successive Seasons on the Hillside of Jamaica", August 1981

No. V - 11 Dave G. Hutton, Abdul H. Wahab, "Position Paper on Root Crops in Jamaica", August 1981

No. V - 12 Percy Aitken-Soux, Abdul H. Wahab, Irving E. Johnson, "Technical Assistance for the English Speaking Caribbean (Considerations for an IICA Strategy)" (Internal Document of Work), September 1981

No. V - 13 Bo-Myeong Woo, Abdul H. Wahab, Joseph Dehaney, "Crop Production on Hillsides using non-Bench Terracing Alternative Measures for Soil Conservation (first year's results of the Olive River Soil Conservation studies)", September 1981

No. V - 14 Abdul H. Wahab, Percy Aitken-Soux, Irving E. Johnson, Bo-Myeong Woo, Howard Murray and Joseph Dehaney, "Agricultural Production on Hillsides - the Allsides Project Case Study", September 1981

No. V - 15 D.G. Hutton, A.H. Wahab and J. Dehaney, "Investigating Critical Levels of Dry Rotting of Yellow Yam (Dioscorea Cayenensis) Planting Material, the Benefits of Disinfesting the Heads of Pratylenchus Coffeae and of After-Planting Nematicide Treatments", September 1981

No. V - 16 D.G. Hutton, A.H. Wahab, H. Murray and J. Dehaney, "Critical Levels of Dry Rotting of Yellow Yam (Dioscorea Cayenensis) Planting Material and Yield Responses After Disinfesting Heads of Pratylenchus Coffeae and After Post-Plant Nematicide Applications", September 1981

No. V - 17 E. Ayer and J. Reyes, "Seminar on Mediterranean Fruit Fly", September 30, 1981

No. V - 18 Bo-Myeong Woo, "Erosion Control Works in Korea", October 1981

No. V - 19 Irving E. Johnson and Percy Aitken-Soux, "Country Level Action Plan (CLAP)" (Third Revision - Internal Document of Work), October 1981

No. V - 20 Humberto Pizarro, "Programme of Work to Establish Guidelines for the Effective Administration, Operation and Maintenance of the Irrigation and Drainage District in the BRUMDEC Project", November 1981

No. V - 21 Humberto Pizarro, "The Operation of the Drainage System in the Black River Upper Morass Project" November 1981

No. V - 22 Humberto Pizarro, "Recommendations for Land Use and Irrigation Needs in the BRUMDEC Project", November 1981

No. VI - 15 Michael Wiles, "Freshwater Prawn (Shrimp) Culture for Jamaica - An Exploratory Report", June 1982

No. VI - 16 Norma Munguia, Byron Lawrence, "Goat Revolving Scheme Project Model", Rural Women Project, July 1982

No. VI - 17 Franklin E. Rosales, Ministry of Agriculture et al "Experimental Designs for Cassava-Peanut Production Systems", July 1982

No. VI - 18 IICA/Jamaica, Samuel B. Bandara, "Institutions in the Agricultural Sector of Jamaica", (A Catalogue) Preliminary version, July 1982

No. VI - 19 Charles Percy Kennard, "Vegetable Production Programme - BRUMDEC Third Quarterly Report", Period March 19th

No. VI - 20 Swarna Bandara, "Mushroom Prod-ction" An Annotated B Bibliography of Literature Available in Jamaica", September 1982

No. VI - 21 Charles Percy Kennard, Final Report "Adaptive Production Oriented Research Programme on Vegetables - BRUMDEC", September 1982

No. VI - 22 Bo-Myeong Woo, Franklin E. Rosales, "Making Compost" Guide for Agricultural Personnel, September, 1982

FECHA DE DEVOLUCION
