COMPOSTING METHODS AND MATERIALS

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By

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PREFACE

The art and science of composting has received a great deal of attention in the past; however, the emphasis was either on composting methods for the farm or as a means of disposing of town refuse. The recommendations published on composting for the home gardener have been based on methods involving large amounts of material.

The ideal method of composting for the home gardener should be one that is neat, does not require too much attention, is rapid, economical, and simple in operation. The recommendations in the published articles, being based on large scale methods, did not fit the requirements of the home gardener.

Composting cabinets of various designs have been suggested for use both with and without special activating compounds. This method, if practical, would satisfy the requirements for an ideal home size composter.

It was decided that a study should also be made of compost activators to determine which were best for small scale composting.

The Stillwater, Oklahoma, Park Board requested recommendations on composting large amounts of plant refuse from the city parks. Certain European countries had reported success in composting large amounts of organic matter by mixing with sewage sludge.

This investigation was further extended in order to study whether this method was practicable under Oklahoma climatic conditions.

This thesis, then, is an account of three problems: (1) determining methods of composting on a small scale, (2) determining the best activating compound or inoculant for home composting, and (3) determining a method of composting large amounts of plant wastes using sewage sludge as the activator.

Introduction

Compost, or synthetic manure, may be described as the product obtained from the decomposition of plant residue through the action of certain fungi and bacteria under favorable conditions of aeration, moisture and temperature. This final product is usually dark and if correctly prepared resembles farm manure in appearance and composition. Farm manure is the result of the disintegration or breaking down of vegetable matter within the animal's body, whereas in the case of compost an artificial disintegration process is initiated outside the body, with the aid of an activator, usually animal manure containing the desired microorganisms for the breaking down process.

It is often impractical to incorporate plant residues directly into the soil since the organisms active in reducing them will at the same time tie up the available nutrients to such an extent that crop failure results. For this reason it is often desirable to compost the residues before they are applied to the soil unless such applications are made far in advance of the crop.

Composting is an age old practice employed by farmers all over the world and has been used with considerable success by European cities for the disposal of community garbage and other organic refuse.

The art of composting as practiced by farmers has certain drawbacks from the home gardener's standpoint, and a review of the literature indicates that there is a dearth of information relative to composting on a small scale. The usual recommendations for composting are based on ton lots of dry organic materials. It is doubtful that the ordinary city lot would produce over 1000 pounds of compostable material during the entire growing season. Though the scientific principles of composting relating to moisture, temperature, and innoculants are the same, regardless of volume, achieving them is much more difficult when a small amount of material is being used.

Oklahoma weather conditions are decidedly detrimental to the composting process due to the prevalance of dry periods followed by extremely wet conditions. During the summer months the hot-dry periods are usually accompanied by winds which quickly dry out the compost.

The purpose of this thesis is to discuss the conditions necessary for the decomposition of plant materials and methods of composting under Oklahoma conditions, and to present the results of some compost experiments designed to determine better methods of composting plant residues on a home garden scale.

One phase of this paper is devoted to the utilization of digested sewage sludge. Sewage sludge is used in great quantities as a fertilizer on the campus at Oklahoma A. & M. College. Under the warm humid conditions often encountered in the spring and early summer months, the sludge develops odors which are quite unpleasant. The experiments for more efficient (less malodorous) utilization of the sludge were designed to determine whether digested sewage sludge could be composted to remove by biological means the disagreeable odors usually associated with it, and to determine the effectiveness of digested sludge as an innoculant for composts.

REVIEW OF LITERATURE

Factors Affecting the Composting Process

Essential Requirements

In order that the composting of plant residues can proceed it is necessary that certain requirements be satisfied. The essential requirements are the proper moisture content, aeration, temperature, mineral elements, and the proper pH plus the presence of the organisms capable of reducing plant residues. Some of these will act as limiting factors before others; however, without the proper amounts of each the process will cease.

Moisture

The amount of moisture in the compost if of prime importance. Van Vuren (44) considered moisture so important that he has written, "This factor is so important as to be virtually a sine qua non to success." According to Bartholomew and Norman (6) the activities of the microorganisms are carried on within a water film. Increase in moisture content above the optimum has little effect until anaerobic conditions are developed. They further state that reducing the moisture content below the optimum has an immediate effect, that of decreasing the extent and rate of decomposition accomplished by the microorganisms and at low moisture contents the organisms are reduced to inactivity and may even die. McCool (27) found that under the conditions of his compost experiments the temperature of untreated straw rose more rapidly after watering and mixing than did the temperature of straw to which fertilizer salts had been added.

The amount of water to be used in a compost is quite important. When the decomposition is well underway, temperatures of 150°F. will be reached. According to Smith and Thornton (35), this is the critical time at which water should be applied. If water is withheld at these high temperatures the compost will dry rapidly and start "fire fanging." If too much water is supplied the compost will cool and the decomposition process slow down or even cease altogether.

Tenny and Waksman (39), studying the effects of anaerobic decomposition, were able to simulate the formation of peat moss by using such a large quantity of water that only anaerobic forms of organisms could survive.

Ashworth (5) found that compost at one third of its total water holding capacity decomposed at the most rapid rate. Mahoney, Bessey, and McDaniel (24) suggest that water should be added at the rate of 150 to 250 per cent on a dry weight basis. The criteria of optimum moisture content given by van Vuren (44) is that when a handful of compost is squeezed the hand is moistened but no moisture will come between the fingers. Van Vuren also states that under arid conditions the compost should be made in a pit in order to conserve moisture. Martin and Waksman (25) recommend making compost in a shed or in the shade of trees as an aid in preventing the excessive loss of water through evaporation.

Aeration

Aeration of the compost is as important as the moisture content. Factors affecting aeration are type of material, age of material, amount of packing and, most important, the amount of water present. Bartholomew and Norman (6) state that the optimum thickness of the water film in which the microorganisms live is 3 to 5 mm in thickness. When the water film gets thicker than this, the aerobes are unable to survive and the process becomes essentially anaerobic.

Tenny and Waksman (38,39) made an extensive study and comparison of aerobic and anaerobic composts. They found that digestion of materials is much more complete in the aerobic process. The anaerobic process produces large quantities of organic acids. The restricted digestion in the formation of peats is essentially an anaerobic process. They further report that the protein content is considerably higher in the material digested in the anaerobic process than in that digested by the aerobic process. The aerobic process, they report, results in a considerable loss of nitrogen through the liberation of ammonia. Smith (33) asserts that the addition of two pounds of powdered sulfur to 100 pounds of dry compost almost completely prevents this loss of nitrogen. This action is due to sulfofication rather than to the retarding of ammonification.

A layer of dry material over the compost will also prevent loss of nitrogen by causing the ammonia to condense.

Martin and Waksman (25) et al, suggest turning the compost occasionally. This serves to break up the compaction and allows air to penetrate the mass. Smith and Thornton (35) found that when a material that tended to pack easily was being composted, aeration could be secured by the use of porous tile pipe.

Temperature

Although temperature is not as limiting to the decomposition process as moisture and aeration, it is important since Waksman, et al (48) stated, "...in the preparation of artificial manures from plant residues the rapidity of evolution of heat and resulting rise in temperature are tantamount to rapidity of decomposition." They found that nitrogen was conserved in the compost only when immediate decomposition set in as this resulted in a rapid breakdown of the carbohydrates and the transformation of the soluble nitrogen into insoluble forms. Whenever decomposition was delayed either because of too high or too low temperatures, losses of the volatile forms of nitrogen occurred. This is at odds with a later paper by Waksman and Garretsen (49) in which they conclude that at lower temperatures nitrogen retention is increased, but the rate of decomposition is reduced considerably.

Bartholomew and Norman (6) found that low temperatures have an effect similar to low moisture content. Waksman, Umbreit and Cordon (53) reported that isolations of microorganisms in composts and soils maintained at different temperatures proved that the organisms most active in decomposition of plant residues were those capable of surviving at higher temperatures. This is in agreement with Bartholomew and Norman (6), who stated that each species has an optimum moisture and temperature requirement and as these factors deviate from the optimum, the activities of the microorganisms are reduced.

The temperature of the composting material is closely related to composting organisms, fly control, odor, and mineral elements. These relationships will be discussed under the appropriate headings.

Composting Organisms

The optimum temperatures for the growth of the majority of microorganisms living in the soil in areas of moderate climate lie between 55 and 100°F. Certain species are able to grow normally or continue to exist at temperatures considerable in excess of the limits noted. These are usually designated as thermophillic forms.

During the composting period temperatures as high as 175°F. have been noted. According to Waksman, et al (48), "...an active evolution of heat accompanies the digestion of the readily decomposable constituents in the plant residues." As long as a considerable quantity of carbohydrates, namely hemicellulose and cellulose, remain in the compost, there is a potentiality for a rise in temperature, under favorable conditions of moisture, aeration, pH and nitrogen supply. Waksman and his co-workers also reported that analyses of field soils show that thermophillic actinomycetes are found in all soils at all seasons of the year. They further found that the actinomycetes were less obligate relative to thermophillic temperatures than bacteria.

In a later paper (53) by Waksman, et al, it was reported that, "There was a definite sequence of populations, which varied with the temperature." Thus at 122°C., fungi appeared first, followed by bacteria which attacked the fungous mycelium, then by actinomycetes, while at 149°F., no fungi developed, and the bacteria and actinomycetes were most important to the composting process.

Smith and Thornton (35) studied the total numbers of organisms in composts over a four month period. At the end of the first, second, and fourth months, molds per gram numbered 5,000, 25,000, and 300,000; the numbers of bacteria were 3,250,000, 2,300,000, and 76,000,000 respectively. Waksman, et al (48) at an earlier date insisted that counting organisms did not present a true picture of what was taking place in a compost unless thermophillic temperatures were used in culturing the organisms present. According to them, the presence of an organism in the compost heap is not evidence that it is responsible for the particular condition of the material.

In order to conserve nitrogen it is essential that a rapid initial rise in temperature be created (49, 30). The organisms most active in the decomposition process are chiefly aerobic forms. A compost in which anaerobic conditions develop will not have the rapid initial rise in temperature nor will it ever achieve the extreme temperatures reported for aerobic composts. Tenny and Waksman (39) showed that aerobic organisms active in composting were much more complete in the destruction of plant constituents than the anaerobic forms active in the formation of peats. If, therefore, conditions for the most efficient decomposition are high temperatures and aeration, the organisms most active would be the thermophillic aerobes. Later it will be noted that these forms are found in soils and manures.

Proper Reaction

The proper reaction or pH is essential to a rapid decomposition of plant residues. It is a well known fact that if silage does not develop sufficient acid it will react as a compost, and decompose. An acid reaction is so important to the silage process that it is often advised that certain acids be added as preservatives.

Tenny and Waksman (39) found that the amount of air and moisture present affected the pH. They reported that the anaerobic process produces large quantities of organic acids. They assert that peat moss has an acid reaction primarily because of the conditions under which it was formed.

There have been a number of articles expressing the need of adding lime and the reasons for doing so (5, 8, 18, 25, 30). Lime does not serve as a nutrient for the decomposition organisms. Its presence serves only to alter the pH. Bodily (8) states that the addition of lime retards fungal development through increased bacterial activity rather than as a direct result of pH level. This is not in accord with Norman (30) who states that pH has an effect directly on the microorganisms inasmuch as a slightly alkaline condition directly hinders development of fungi. He further states that fungi are most active in "degrading" cellulose and that the decomposition process is delayed in a compost which becomes too alkaline.

Ashworth (5) found that a pH of 6.5 caused the most rapid decomposition.

Waksman and Cordon (47) reported that the presence of calcium carbonate was essential for the rapid decomposition of plant materials as a whole and especially of cellulose by the active thermophillic fungi. They did not report on the pH.

Norman (30) investigated the effect of pH level on decomposition of plant residues and recommends the use of calcium carbonate. "Manure and compost heaps undergoing natural aerobic decomposition generally remain fairly alkaline or neutral, so that maximum immobilization of nitrogen occurs. The practice of adding calcium carbonate to ensure this has much to recommend it, particularly in the case of composts to which ammonium sulfate has been added."

Norman also indicates that the pH level may be dependent on circumstances other than the amount of lime added or the minerals used. He states, "However, it sometimes happens that through packing or waterlogging anaerobic or partially anaerobic conditions occur in which circumstances organic acids are produced and the heap becomes definitely acid." Tenny and Waksman (39) agree.

Waksman, et al (52), studying the effect of calcium carbonate on decomposition, found that it had no effect on decomposition unless nutrients were added. In order of rapidity of decomposition they found: 1(CaCo3 + nutrients) 2(nutrients) 3(CaCo3) 4(water). The difference between lime only and water only was slight, while the difference between lime + nutrients, and nutrients only, was considerable.

McCool (27) found that composts of oak leaves, sugar maple leaves, and pine needles when applied to the soil reduced the pH for a short time. After standing, the compost treated soil had a higher pH than the untreated.

<u>Mineral Elements</u>

Possibly no other phase of composting has had as much investigation as the addition of nutrients in the form of mineral salts. That the addition of mineral salts would cause the decomposition process to proceed rapidly was reported prior to 1922 by Hutchinson and Richards of Rothemsted. A bulletin from the Missouri Experiment Station (2) reported on a method similar to the process devised by Hutchinson and Richards and subsequently they instituted a lawsuit against E. M. Pierot of Missouri for patent infringement. Hutchinson and Richards had patented a material and process under the name Adco, an abbreviation of Agricultural Development Company. They felt that Pierot in using mineral salts to make artificial manure on his farm had infringed on their patents (Adco patents 1471979 and 1619679). According to Albrecht (1), when the plaintiff was confronted with, "...the evidence behind the fact that the carbon-nitrogen ratio of microbial diet to speed or delay decomposition is a natural principle, long known before the days of the Adco patent," the lawsuit was withdrawn.

Collison and Conn (10) gave a comprehensive review of the cause of injury to plants when straw is applied to the soil. They found that the cause of injury was primarily due to a nitrogen deficiency as a result of microorganisms in the soil competing with the plant for the available nitrogen. The secondary cause was through the production of toxic substances within the straw. Decomposed straw did not have a deleterious effect on plants.

Extensive experimentation in England demonstrated clearly that straw could be rotted down to artificial manure in three to four months with the aid of added minerals and that the resulting product compared very favorably with good cow manure, both in chemical composition and effect on the growth of field and garden crops.

The Europeans were aware of the importance to the soil of organic matter long before the Americans; therefore, they devoted much more time and attention to composting. It had been noted for a great many years that the addition of animal manure and urine speeded up the composting process and that the resulting product did not have the depressing effect of raw plant residues on crops. It had also been noted that when straw was applied in such quantity as to cause unfavorable response of the crop, the addition of manure or nitrogen fertilizers would restore the crop to normal health.

According to Collison and Conn (10), the theory on competition between plant and soil organisms for nitrogen was first established in 1899 by Kruger and Schneiderwind of Germany. Later workers brought out further proof, until the evidence in its favor was regarded as conclusive.

Approximately the same thing occurs in compost as in the soil with the exception that the microorganisms compete with each other for nitrogen to the extent that the total number of organisms is held down so that the process proceeds very slowly unless some form of soluble nitrogen is added.

It was further shown by the earliest workers that the addition of highly carbonaceous materials to the soil resulted in great increases in the total number of microorganisms which utilized these materials for energy, and that the resulting lack of nitrogen for the plants was caused by the organisms using it in the building of proteinaceous materials within their bodies.

Adco was the first patented material placed on the market as an aid to composting. It has since been discovered that other preparations will work equally as well, and in some instances better with reference to the rapidity of the process and the amount of nitrogen retained in the composted material.

That manure and urine would serve as nitrogen sources has been known for centuries, and this method of supplying nitrogen is still being used in many European and Oriental countries. In the Oriental countries and India, the practice of using night soil as a source of nitrogen in composts is quite prevalent.

Waksman and Reneger (50) have shown that no nutrients need be added provided part of the material used is high in nitrogen. Mixtures of 40% alfalfa and 60% straw, or 70% straw and 30% tobacco stems resulted in a high quality compost after a decomposition period of only 44 days.

Ancient history records that "green manure" crops were beneficial to the crops that followed them. In green manuring the crop failure or deficiency signs, like those when mature crops were turned under, were not noted. As the biological processes are essentially the same in compost as they are in the soil as concerns utilization of carbonaceous material, it would appear that the competition for nitrogen is not present when green crops are turned under. Martin and Waksman (25) state that only young green materials and leguminous plants contain sufficient nitrogen to decompose without additional nitrogen being added.

Tenny and Waksman (39) agree that nitrogen is not a limiting factor in the decomposition of young plants or legumes, and they further maintain that adding nitrogen to composts of such materials may have the effect of slowing the process by permeating the compost with ammonia, which is toxic to many organisms.

Although the investigators agree that additional nitrogen is essential to all composts except those having materials already high in nitrogen, there is some disagreement as to whether phosphorus is essential. Albrecht (2) states that phosphorus is not essential to the process, but because most soils require it, it might as well be added with the compost. Martin and Waksman (25) state that the microorganisms active in reducing plant material will compete for phosphorus, so recommend that it be used with all composts except those containing young green materials or leguminous plants.

Smith and Thornton (35) maintain that because phosphorus is a constituent of every living cell, it must be added to composts or it will become a limiting factor in the decomposition process.

With potassium, too, there is some disagreement as to whether it is essential. Smith and Thornton (35) state that potassium is required by many microorganisms and should be added for that reason. On the other hand, Kucinski (20) suggests that potassium is generally added only to make the finished compost similar to natural manure. As many of the formulas for adding nutrients do not include potash, it would seem that Kucinski is correct.

There are several recommended formulas listing the amounts of minerals to be added to plant residues for the making of compost. Each of these have, under the conditions of the various experiments, given good results.

Collison and Conn (10) at Geneva, New York, used:

ammonium sulfate	60 pounds	one ton of straw
super phosphate	30 pounds	
calcium carbonate	50 pounds	

Albrecht (2), Missouri, recommends:

ammonium sulfate	$67\frac{1}{2}$ pounds	one ton of dry wheat straw
ground limestone	60 pounds	
super phosphate	$22\frac{1}{2}$ pounds	

Halverson and Torgerson (18), Oregon, state that only two materials need be added:

ammonium sulfate	47.6 pounds	one ton of dry plant residue
lime	100 pounds	

Smith and Thornton (35) received best results from a mixture containing:

cyanamid	75 pounds	
muriate of potash	10 pounds	one ton of dry plant residue
super phosphate or rock phosphate	15 pounds / 65 pounds	

Ashworth (5), England, expressed in per cent the minerals to be added:

nitrogen	2.5 %	
phosphorus as P_2O_5	1.0 %	
potassium	2.0 %	dry plant residue
magnesium as MgO_2	1.0 %	

lime to bring pH to approximately 6.5

Turk (41), Michigan, made up a mixture containing:

ammonium sulfate	45 parts
superphosphate	15 parts
lime	40 parts

This mixture was applied at the rate of 150 pounds per ton of dry straw.

Smith, Stevenson, and Brown (34), Iowa, duplicated the work of Ames (3), Ohio, and found less loss of nitrogen from Adco than from ammonium sulfate instead of more loss as reported by Ames. In each of these experiments, the following amounts of materials were used:

Adco	150 pounds
compared to	
ammonium sulfate	65 pounds
calcium carbonate	150 pounds

According to Collison and Conn (11), Adco contains the less soluble forms of nitrogen and phosphorus. Lambert (21) states that Adco adds about .75 pounds of nitrogen to every 100 pounds of dry plant residues.

The preceding formulas have been established chiefly for making compost in great quantities using materials with a wide nitrogen-carbon ratio. As has been indicated, few articles have been written on composting with the home gardener in mind. Martin and Waksman (25) recommend using any standard complete fertilizer such as 4-12-4 or 5-10-5 at the rate of 200 pounds per ton of dry material. This seems extravagant when compared to Kucinski's (20) recommendation which is 100 pounds of 6-8-6 or 5-8-5 per 125 cubic feet of dry material. Expressed on a pound basis, the dry materials would weigh well over a ton.

Other important considerations

Certain factors are not considered essential; however, to compost successfully, they must be observed. They are commercial preparations, materials which may be composted, the finished product, weed seeds and pathogens, fly control, benefits of compost, and methods of composting.

Commercial preparations

Many different kinds of innoculants and other preparations for use in making compost are found on the market. Manufacturers of such preparations claim that much better and quicker results are obtained when they are added to the compost heap. Martin and Waksman (25) say no mystical preparations are needed to obtain good manure as crop wastes naturally contain all the microbes that are needed in the decomposition process. They state that the addition of manure, good garden soil, or material from a completed compost will give better results than using a commercial preparation.

Waksman (45), Stevens (36) and Newman (29) have found that by supplying optimum conditions for decomposition there will be a far greater increase in biological numbers than can be accomplished simply by adding them.

The majority of workers doing research on the biological and chemical aspects of compost have used liquid innoculations of soil or manure to start the decomposition process. Ashworth (5) prepared an innoculum with two pounds of rich garden soil to four gallons of water. The mixture was agitated, allowed to settle for an hour, and the liquid used at the rate of one gallon per 100 cubic feet of straw.

Halverson and Torgerson (18) found that spontaneous fermentation took place so rapidly that attempts to accelerate decomposition by using enrichments of decay organisms from successive fermentations (decompositions) generally gave no better results.

Some of the producers of activating compounds claim to have isolated certain organisms which are highly effective in reducing organic matter. Waksman, Cordon, and Umbreit (53) state that no single organism was as effective in reducing plant residues as mixed populations. These workers have further indicated that the only way they could keep the most active of their pure cultures alive was through maintaining them on culture plates at specific temperatures. It does not seem possible that commercial preparations could be sent through the mails and arrive in condition to become active in a compost unless special precautions were taken as to moisture and temperature.

The Adco product does not furnish organisms which are active in the decomposition of plant residues, nor has this been claimed. Adco simply furnishes the nutrients necessary for the organisms that are already present.

<u>Materials which may be composted</u>

Nearly everything that is derived from plant or animal tissue can be composted. There are many factors, however, that contibute to the speed at which any given material will compost.

Waksman and Tenny (51) found that certain substances in plants will retard decomposition. These are tannins, waxes and fats.

The age of the plant has a considerable effect on speed of composting. The younger the plant and less mature its tissues are, the faster it will compost, since young immature plants have a much narrower c/n ratio than mature plants. It is seldom necessary to add nitrogen to composts of young immature plants.

Tree trimmings and woody materials should not be mixed with other plant refuse in the preparation of ordinary composts because of the slowness with which they decompose. Such products, according to Martin and Waksman (25), should be built into a separate compost and allowed to decompose for several years.

Oftentimes nurseries and greenhouses or poultry producers accumulate large amounts of used peat moss. Special precautions must be used in composting this material as it has in its formation already undergone decomposition. It has been suggested (5, 12, 26) that peat moss be added to composts of other materials. McCool (26) found that by adding wet peat to straw, no additional water was needed and the compost was fairly rapid. Ashworth (5) suggests using peat whenever possible "more on account of its physico-chemical properties, e.g., ammonia absorbtion, and not because of any expected contribution to the changes called composting." Conn and Collison (12) also state that by adding peat, nitrogen is conserved in composts.

Singh and Singh (32) analysed 50 species of weeds for their chemical content and found that they could be grouped according to the preponderance of certain minerals which they accumulate. The high point of accumulation is at the preflowering stage. Fletcher (15) determined the N.P. and K. in an extensive list of materials suitable for composting.

During World War II, nitrogen containing fertilizers were on short supply due to their use in explosives. Prince and Bear (31) suggest that many organic materials, if they can be had cheaply enough, would serve as sources of nitrogen for farmers and gardeners. They analysed four groups of materials suitable for composting: (1) manures, (2) humus like materials, (3) crop materials, and (4) miscellaneous waste.

Anderson (4) suggests the use of many products, chiefly those that are wastes from various manufacturing and processing industries, which might be composted.

The finished product

Contrary to general belief, it is not necessary that organic material decompose until it resembles humus before it may be used safely on growing plants.

Pot tests have been made using composts at varying degrees of decomposition, and there is a constancy of agreement among the workers that compost is ready for use when the material composted has lost its usual strength and breaks or crumbles easily.

When straw is the chief material decomposed, McCool (27) and Albrecht (2) agree that the finished product will resemble in all respects the strawy manure found in barnyards where straw is liberally used as bedding and becomes tramped down in the manure.

Results vary slightly as to the weight of the finished product. As a rule, a ton of dry material will yield three tons of moist compost.

The finished compost, like manure, will lose its mineral content if it is not stored properly. Smith (33) reported that the addition of two pounds of sulfur to 100 pounds of compost (dry weight) almost completely prevented the loss of nitrogen.

Recommendations for storing manure can be applied to compost. Covering the finished compost with soil will prevent loss of ammonia. It is best if the compost be stored under cover in bins. If it is to be stored outside, precautions should be taken to prevent the leaching of soluble nutrients.

<u>Weed seeds and pathogens</u>

According to Buchanan (9), the maximum temperature for most pathogenic bacteria lies between 104 and 122°F. As the temperatures in an active compost will far exceed these figures, it can be assumed that none would survive the composting process. Buchanan was speaking of animal pathogens; however, as Martin and Waksman (25) have pointed out, most plant pathogen and even weed seeds would not be able to survive the hot-moist conditions within the compost heap. It is suggested that when the compost is turned, the outside should be worked well into the middle to subject it to the sterilizing effect within the heap.

DeFrance (14) found that through the proper use of aero-cyanamid a 100% weed free compost could be produced. In order to utilize the method recommended by DeFrance, it is first necessary to have a completed compost. This compost is first screened through a quarter inch mesh, and 13 pounds of granulated "aero" cyanamid is mixed thoroughly with each cubic yard of material. The mixture of compost and cyanamid is then put into wooden bins and the sterilization process begins. Four to six weeks are required to kill all of the weed seeds. DeFrance emphasizes the fact that little heat is generated during the process, and that the cyanamid produces a substance toxic to seeds.

As the temperatures created in small compost heaps do not always reach the extremes encountered in large compost heaps, it is sometimes recommended that diseased plant material be burned rather than composted.

Fly Control

Van Vuren (44), Union of South Africa, suggests using fly traps to reduce the number of flies around decomposing material. It was noted that fly larva would move to the outside of a compost heap to escape the heat generated in the interior, so small canals were erected around the base of the cabinet into which the larva would fall and drown. Extremely offensive materials were being composted, such as abettior waste.

In the United States, where such materials would seldom be composted, the fly problem would not be so great. Stucky and Smith (37) found that by adding sulfur to compost, not only was nitrogen conserved but the smell of ammonia that attracts flies was also prevented. The average person, however, would have difficulty following their recommendation, which was based on the amount of nitrogen present in the compost. They recommended using one pound of sulfur for each pound of nitrogen in the compost.

Benefits of Compost

The chief purpose in the use of compost in this country is to supply organic matter to the soil. In many foreign countries it is the mineral content of compost that is most prized. Thompson (40), van Vuren (44), and Anderson (4) summarize the benefits secured from additions of compost to the soil.

One interesting benefit which compost has on soil is the reduction of plant nematodes. Linford, Yap, and Oliveira (2) found that adding organic matter to soils brought about a large build-up of total nematodes which in turn caused a build-up of organisms destructive to them so as to result in a greatly decreased number of nematodes. Cordner and Romshe (13) found that the nematode populations on plots receiving annual applications of 10 tons of farmyard manure for eight years were decidedly lower than those on adjacent plots which did not receive the manure treatment.

The writer feels that this benefit should receive more emphasis from experiment stations.

Methods of Composting

An extensive list could be compiled of methods of making compost or artificial manure. As has been indicated, there is a dearth of articles designed to aid the home gardeners with compost problems. Agriculturists in Europe and in the Oriental countries have been especially cognizant of the importance of maintaining the organic matter in their soils, and as a result, much of the literature on methods of composting comes from workers in these countries. Most of the articles of foreign origin deal with composting as a means of disposing of municipal wastes.

A technical bulletin (7) from the University of California contains annotations of 610 articles on municipal composting problems and related studies.

Van Vuren (44) suggests that townspeople might prefer, for social reasons, having an underground pit for making compost; "What the eye doth not see, the heart doth not grieve over." The dimensions of the suggested pits are 3 feet deep, 6 feet wide, and 9 feet long. The New Zealand compost box, also described by van Vuren (44) would be more acceptable to people in the United States. This box is constructed without top or bottom and with a removable front. The dimensions are 4 feet deep, 4 feet wide, and 8 feet long. A divider is placed through the middle so as to form two sections each 4 x 4 x 4 feet. Plant residues are composted in one section and transferred to the other to ripen. It is suggested that the different constituents be mixed before placing them in the first section. This method will furnish about four tons of compost per year.

Kucinski (20) recommends using a pile for composting. The pile should be built in layers, with a few handfuls of 6-8-6 fertilizer scattered on each new supply of organic material as it is added. A sprinkling of soil to each layer will furnish the necessary microorganisms. The pile should be kept moist. It is recommended that the pile be turned at least three times during the season. This method is essentially like that of van Vuren's (44) except that no cabinet is used.

Martin and Waksman (25) believe that the lack of a large supply of material should not be a deterrent to composting. The heap can be started with whatever material is available and additional material added from time to time. After one layer has been completed, it is sprinkled with a small quantity of any complete fertilizer, moistened with water, and covered with a thin layer of soil. Additional layers are added in a similar manner. Three or four weeks after the last layer is added, the pile should be turned. One turning is usually sufficient.

Sewage Sludge

Sewage sludge is a by-product derived from the treatment of new sewage. Two types of sewage sludge are produced: digested sludge and activated sludge. Hayes (19) states that there are 212 sewage disposal plants in Oklahoma, and of these, two produce activated sludge while all of the others produce digested sludge.

In the activated sludge process (19), the raw sewage is seeded with activated sludge and air is passed through the mixture. An extensive growth of organisms occurs which take up some of the dissolved material in the sewage. The organisms adhere to the suspended solids, and cause them to settle. The sludge consists partly of solid organic material from the sewage and partly of bodies of the organisms which produce the clarification and take up some of the constituents of the sewage.

In the digested sludge process, the material resulting from the activated sludge process is returned to the digester for further reduction. The digested sludge or filter cake, as it is often called, consists largely of material which has resisted the action of the decomposition organisms. It is much lower in fertilizing value, as the digestion process converts the materials resulting from the activation process into gases and more soluble forms.

According to Fraps (16), dried, digested sludge closely resembles farmyard manure in composition. It has sufficient available plant nutrients to justify its use in a manner similar to that of ordinary farm manure. Digested sludge may be utilized as fertilizer in areas near to sewage disposal plants if the cost of hauling is not too great.

Dried activated sludge contains more soluble plant nutrients than digested sludge. Activated sludge is produced only in large cities that can realize some revenue from it. It is sold under such trade names as Milorganite, Huactinite, Rapid-Gro, and San Diegoite. A manual published by the Federation of Sewage Works Association (43) lists several other trade names and the cities producing the product.

Digested sludge is produced by the smaller communities because the sewage is most thoroughly reduced by this process. Expensive drying equipment and a ready market for the product is required to produce activated sludge. If no drying equipment is used, a much larger drying site is required by the activated process as compared to the digested process.

According to the manual (43), in 1946 the demand for heat dried activated sludge was much greater than the supply.

In this review, only the problems concerning utilization of digested sludge as an inoculant for composts will be discussed.

According to the Manual of Practice No. 2 (43) Ransom in England successfully composted surplus straw and sewage sludge. Ransom used both air dried sludge and liquid sludge (settled primary sludge with about 6% solids). With dried sludge, heaps nine feet wide, length not specified, were built to a height of 6 feet with alternate layers of 18 inches of water soaked straw, and 2 inches of sludge. The straw was well rotted in three months. Four tons of dry straw and eight tons of sludge produced 24 tons of compost.

Ransom used liquid sludge by spraying it on successive 18 inch layers of straw. The dimensions of the heaps are not expressed; however, 1,440 U. S. gallons were applied per ton of straw.

Ulrich and Smith (42) substituted sawdust for sand on the drying beds at the Austin, Texas, disposal plant. They reported that after a six week period the sawdust was well rotted and that instead of the characteristic musty odor of sludge the finished product had a clean, earthy smell and appeared to be of the same consistancy as a loam soil.

Graves (17) believed that wet digested sludge should compost materials much faster than dry digested sludge because of the greater numbers of organisms present in the wet material and the soluble nutrients in the liquid which would narrow the c/n ratio.

The danger of organisms in sludge that may be pathogenic to human beings is always present; however, just how dangerous they can be is still a matter of much discussion.

Waksman (46) states that few of the bacteria and other microorganisms that cause human and animal diseases survive long in the soil. Once introduced, they are inhibited or killed by antagonistic organisms, which produce active chemical substances known as antibiotics.

Whether pathogenic organisms will survive the digestive process is still not clear. The manual (43) contains reviews of articles on the hygienic aspects of sludge utilization. Reviewed are articles on Eberthella and Bacterium typhosium, Vibrio cholerae, Mycobacterium tuberculosis, Virus of poliomyelitis, Entamoeba hystolytica (ameobic dysentery), and some intestinal parasites such as hook worm, Trichuris, and the helminths.

Most of the above named pathogens, with the exceptions of intestinal parasites and ameobic dysentery, could not be isolated from this sludge after a digestion period of 10 days.

The manual concludes "...that no case is known of sickness traceable to the use of digested or activated sludge." Most of the state health departments advise that sludge should not, unless heat dried, be used for crops which are consumed raw.

They further recommend that liquid sludge from the digesters should be used with care as it may contain pathogenic organisms depending on its age. It is not as safe to use as air dried sludge.

Fraps (16) states that digested sludge is free from weed seeds but often contains great numbers of tomato and melon seeds. The writer has also observed this in digested sludge from the Stillwater, Oklahoma, disposal plant.

In the use of sewage sludge, some odor may occur but its intensity and duration depend on circumstances. It is pointed out in the manual (43) that working the sludge into the soil will banish the odors. According to the manual, Wigley developed a process at Atlantic City which removed the odor from moist sewage sludge. In this process, the sludge is dried to 30% moisture content and ground. It is then stored in a dark place where molds develop rapidly. In three or four days the sludge is deodorized.

The work by Rudolfs has been reviewed in the manual (43). Rudolfs is reported as noting that sludge produces acidic conditions on aerobic decomposition in the soil and recommends the addition of lime to prevent burning, especially when the sludge is used in the greenhouse. The pH of digested sludge is reported to vary from 6.8 to 8.0.

METHODS AND MATERIALS

Cabinets

Three above ground types of cabinets were used: (1) Upright cabinet with grate bottom of the type designed by T. A. Loveland, New York City, New York, and designated by him as the "Activated Compost Frame," (2) Compost bin "Lehigh Type" manufactured by the Keston Organic Products Company, Haddon Heights, New Jersey, and (3) New Zealand compost box of the type described by van Vuren (44).

Pit Compost

One pit type composter was used.

Description of Cabinets

1. "Activated Compost Frame" (See figures 1 and 2). Six of these cabinets were used. The inside dimensions are 31 x 31 inches, 35 inches deep. The corner posts are of 4 x 4's, 54 inches long, slotted diagonally at 2 inch spaces in such a manner that the side pieces (slats) form louvered vents (like a venetian blind open half way). Outside bracing is secured with 2 x 2's, at the top and also at a distance of 17 inches from the base of the corner posts so as to form the bottom part of the cabinet where the composting takes place. Six 2 x 3 boards 44 inches long are placed on the bottom braces and loosely bolted to the outside brace at one end. The other ends of these pieces are left loose and extend over the front lower brace about 12 inches. These pieces swivel from the bolted ends and serve as a means of shaking the finished compost out of the cabinet much as the grates on a wood stove.

Solid sides of sheet metal were used to protect the material being composted from excessive drying. The solid sides were fastened to the corner posts with turn buttons for easy removal.

Figure 2. An Activated Compost Frame With The Solid Sides Removed to Show Details of Construction.

Figure 2. An Activated Compost Frame With Solid Sides in Place.

The materials cost a total of $18.00, and with all materials on hand and cut to size, the assembly time was four hours.

2. The "Lehigh type" compost bin (see figure 3) is constructed of 2 x 2's 48 inches long. Two bins of this type were used. Each bin was made up of 48 pieces, 12 to a side. A 5/8 inch hole is bored in each end of these pieces through which a metal rod is passed. In assembling, the pieces are held together with the rods so that each side has 12 pieces and 12 spaces. The dimensions of the bins are 4 x 4 x 4 feet. The cost for the two bins was $24.00.

3. The New Zealand compost box (see figures 4 and 5) was constructed of scrap 2 inch lumber. One of these boxes was used. The box was constructed without a top or bottom and with a removable front. The dimensions were 4 x 8 feet and 3 feet deep. A divider was placed through the middle to form two sections, each 4 x 4 x 3 feet deep. One inch lumber was used for the removable front panels. The cost of new materials needed to construct this box was approximately $20.00.

Description of pit used for composting

A concrete walled cold frame 6 feet wide and 18 feet long (see figure 6) was used. The soil in the cold frame was removed to a depth of 2 feet. Three inches of pea-sized gravel was placed in the pit for drainage.

Materials composted

1. Straw
2. Garbage
3. Greenhouse waste
4. Sawdust
5. Weeds
6. Castor bean hulls

Description of Materials composted

1. Wheat straw. This material was taken from an old stack. Some natural decomposition and "fire fanging" had taken place. These areas were avoided so that the straw composted would not serve as a source of

Figure 4. Front View of A New Zealand Compost Box Showing Details of Removable Front Panels.

Figure 5. Rear View of A New Zealand Compost Box.

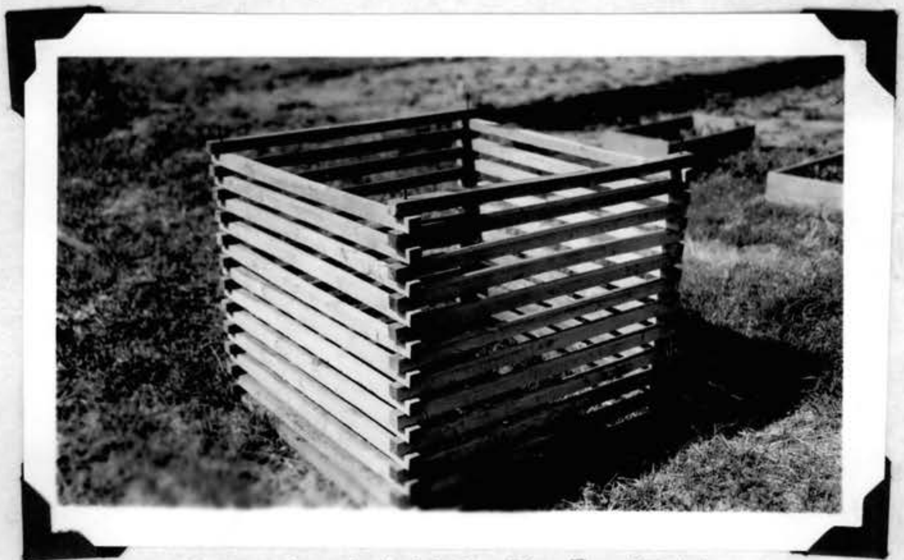

Figure 3. A Lehigh Bin Emptied to Show Details in Construction.

Figure 6. The Cold Frame Used in Pit Composting.

decomposition organisms.

2. Garbage. The garbage was obtained from the college Student Union kitchen, and was of two types: (1) vegetable waste only, e.g., lettuce leaves, citrus rinds, potato peelings, and so forth, and (2) a composite of all the waste from the kitchen, bones, table scrapings, vegetable wastes, and so forth.

3. Greenhouse waste. All waste from the College Greenhouse of a vegetative origin was used. The major part of this material was the stems and leaves of snap dragon, tomato, and sweet potato plants.

4. Sawdust. Coarse, hard wood sawdust.

5. Weeds. Bermuda grass stems, runners and a mixture of rank growing weeds was used.

6. Castor bean hulls. Castor bean hulls are the hard woody outer covering of the seed left after the seed is threshed.

Inoculants

Two groups of inoculants were used:

1. Non-commercial

Top soil	Completed compost
Cow manure	Liquid from top soil
Digested sewage sludge	

2. Commercial

Activo	BCA
Loveland's Formula	Enz Bac
QR	Soil Booster

Fertilizers

Adco

Complete Fertilizer

Description of Inoculants

Top soil: The top soil used was taken from the student garden area located west of the college greenhouse. Fresh soil was taken each time it was to be used.

Cow manure: Fresh cow manure was secured at the college milking barns. As the floors in the milking barn are concrete, the manure was pure (droppings and urine only).

Digested sewage sludge: Two types of sludge were used: (1) air dried, and (2) liquid sludge direct from the digesters.

Completed compost: The finished compost from the bins used for inoculation and comparison tests.

Liquid from top soil: Approximately one cubic foot of soil was added to 40 gallons of water. The misture was agitated for several minutes, allowed to settle for 15 minutes, and the liquid used as the inoculant.

Commercial Inoculants

With the exception of the Soil Booster, these products are advertized in popular magazines as "preparations which will reduce organic matter in a short time to a light, fluffy compost." Some of these products are quite expensive. The cost of the activator per ton of completed compost for these materials follows:

Activo	3 ton unit	$7.00	Benson-MacLean	Bridgeton, Indiana
Loveland	3 ton unit	$26.80	T. A. Loveland	New York, New York
QR	4 ton unit	$1.00	Waldor Greenhouses	Clifton, Mass.
BCA	1 ton unit	$1.20	Organic Products	Newark, New Jersey
Enz Bac	1 ton unit	$2.00	Organic Implements	Haddon Heights, N.J.

Soil Booster is a heat dried digested sludge produced in Oklahoma City. It was included in the test to see what effect the heating had on the decomposition organisms.

Description of Fertilizers

Adco: Adco is a patented fertilizer especially formulated to hasten the composting process. It does not contain any composting organisms.

Complete fertilizer: Any fertilizer containing N., P. and K., usually a total of 20 units, such as 5-10-5.

Methods and Materials used in filling cabinets

Cabinets: The cabinets were used to compare inoculants and to determine methods of re-activating composts in which decomposition had stopped.

Experiment 1. Comparison of liquid sludge and dried sludge as inoculants on wheat straw. The cabinets were loaded August 21, 1950, at the Stillwater Sewage Disposal Plant, moved to a location adjacent to the College Greenhouse for convenience in handling on May 24, 1951, and were emptied for comparison on June 5, 1951.

Dried sludge: A 6 inch layer of wheat straw was placed in the bottom of the cabinet, then a 4 inch layer of sludge. Additional layers were added in a similar manner. Each layer of straw was well moistened.

Liquid sludge: Alternating layers of wheat straw and sludge. The sludge was poured over each layer of straw till it was thoroughly moistened before adding the next layer.

Experiment 2. Comparison of Activo and Adco on various plant residues. The cabinets were loaded August 21, 1950. These were located west of Q9-W on the campus.

Top soil, bermuda grass, and Activo or Adco: The cabinets were filled by layers, a 2 inch layer of soil, 5 inch layer of bermuda grass, and a liberal sprinkling of Activo or Adco. The layers were repeated in that order till the cabinets were filled.

<u>Experiment 3.</u> Comparison of top soil plus 5-10-5 and cow manure as inoculants on various plant residues. The cabinets were filled on May 24, 1951. They were located adjacent to the College Greenhouse.

The top soil plus 5-10-5 cabinet was filled like the Activo and Adco cabinets except that 5-10-5 was substituted for the activators.

The cow manure cabinet was filled like the liquid sludge cabinet. The manure was poured over alternate layers of greenhouse waste.

<u>Experiment 4.</u> To determine if the odor could be removed from sewage sludge by composting it with soil. This experiment was completed in two months, from June 5, 1951, to August 7, 1951.

Two inch layers of soil and 5 inch layers of sludge were alternated till the cabinet was filled.

<u>Experiment 5.</u> To simulate composting conditions encountered by the home gardener. This experiment was started on June 5, 1951.

Partially filled with greenhouse waste using Loveland's activating compounds between the layers. At short intervals garbage (type 1) and more greenhouse waste was added according to Loveland's (23) recommendations.

<u>Experiment 6.</u> A cabinet was taken to H. L. Ransom's residence at 516 Ramsey, Stillwater, Oklahoma, on August 7, 1951, to be used by Mr. Ransom in order to get a more adequate check on the home gardener's use of this type of composter.

<u>Re-inoculation Tests</u>

On May 25, 1951, after severe cold weather, the Adco cabinet had apparently stopped working, so 30 gallons of liquid top soil was poured over the material and into holes punched into the center.

On April 11, 1952, the Activo, cow manure, and top soil cabinets were re-inoculated with liquid top soil.

Lehigh Bins

The Lehigh Bins were used to compare top soil and cow manure compost as activators.

On June 8, 1951, garbage (composite 1 and 2), weeds, greenhouse waste, commercial fertilizers, lime, and inoculant were the materials used.

The bins were filled in alternate layers: garbage 4 inches, sprinkle of inoculant, weeds 6 inches, and repeated until filled. Fourteen pounds of ammonium nitrate, 10 pounds of superphosphate, and 16 pounds of lime were used in each bin. The dry weight of the plant wastes was approximately 640 pounds.

Lime was added as needed for odor control, and DDT and Isotox 10 were applied for fly control.

Cold Frame

The cold frame was loaded June 17, 1951, with wheat straw and liquid digested sludge (direct from digester).

The straw was placed in the cold frame in six inch layers. Approximately 30 gallons of the sludge were poured over each layer. The sludge caused the straw to compost so that it was possible to put six layers in the two foot deep frame.

The only moisture the straw received was that in the sludge. Two hundred gallons of sludge and 1,200 pounds of straw were used.

Inoculant Test

On January 22, 1952, eleven two-gallon crocks, each with 2500 grams of fresh tomato stems and leaves, were inoculated. A different inoculant was used in each crock. Another crock was set up as check and received no inoculant.

A cylinder formed from window screen was placed over the hole in the bottom of the crock. These tubes were long enough to extend above the material being composted, and thus served to aerate the mass. The material in each crock was moistened; then all the crocks were placed in a constant temperature box with the thermostat set for 104°F. as recommended by McCool (28). Additional water was added as needed, all crocks receiving an equal amount. After five days the temperature was reduced to 80 degrees to determine whether any of the inoculants would sustain the temperature.

New Zealand Compost Box

On December 6, 1951, the box was filled with weeds, wheat straw, and greenhouse waste. Soil was used as the inoculant, and the nutrient source was 5-10-5.

In filling the box, a 6 inch layer of vegetative matter was followed by a sprinkle of soil and two pounds of 5-10-5. These layers were repeated in that order till the box was filled. Additional material was later added in the same manner to maintain the original volume. At two week intervals holes six inches apart were punched into the material to provide aeration.

Methods of watering

Early in the study it was noted that if a bucket was used to moisten the material being composted it served only to flood part of the compost while other parts remained dry.

The solid sides of the Activated Compost Frames were removed and water was sprinkled through the louvered slats.

The Lehigh Bins were sprayed with a rose nozzle attached to a hose.

No additional water was added to the Cold Frame and Compost Box.

Water was applied to the material in the Inoculant Test with a greenhouse syringe. In the cabinets, water was added only as it seemed necessary, i.e., when excessive heating was noted or if the material became quite dry to a depth of four inches.

Basis for Comparison

Cabinets: According to Waksman, et al (48) and Norman (30), the best critique for an efficient decomposition was a rapid initial rise in temperature, thus the temperature of the material was taken daily for the first week the cabinets were in operation and than at two or three week intervals. As in most instances no unusual temperature rise was noted, the comparisons were made on the basis of the extent of the decomposition of the materials or on the loss of volume.

Inoculants

When inoculants were being compared in the same kind of cabinet, the same basis of comparison was used as when cabinets were being compared.

In the inoculant test the constant temperature box was heating unevenly, so it was necessary to make the comparison on the basis of total decomposition.

PRESENTATION OF RESULTS

Experiment 1. A comparison of liquid sludge and dried sludge as inoculants on wheat straw with a ten month composting period started on August 21, 1950.

Dried sludge: During the composting period, the materials settled slightly, but apparently not through decomposition. There was no unusual heating noted. Watering after warm weather, started in the spring of 1951, did not cause any further settling. When the cabinet was emptied and the residues examined, some discoloration of the straw immediately adjacent to the sludge was noted; however, no decomposition had taken place.

Liquid sludge: Three days after this experiment was started, a slight upward rise in temperature was noted. Later, when the volume became reduced by half, the cabinet was again filled to the original volume using the same materials as at first. Temperatures slightly above air temperature were noted until January; then ice crystals formed in the material and action stopped. An attempt to reactivate the composting organism by applying water was not successful, so the cabinet was emptied. Examination of the residues showed that a moderate amount of decomposition had taken place before freezing weather stopped the process.

On the basis of the results from this experiment, the cold frame test was set up using liquid sludge rather than dry.

Experiment 2. A comparison of Activo and Adco on various plant residues with a 20 month composting period started August 21, 1951.

Activo: Top soil, Bermuda grass, and Activo were used in the original filling. Although no heating was observed in this cabinet, the volume continued to reduce throughout the fall and winter. The original volume was restored at intervals using the same procedure as in the original filling, but substituting greenhouse waste for the Bermuda grass.

On January 18, 1951, the volume was restored using a 4 inch layer of greenhouse waste, a 4 inch layer of sludge, then a sprinkling of Activo. This same procedure was used on March 3, 1951, and again on June 4, 1951.

In August of 1951, a mixture of straw, castor bean hulls, and sawdust was placed in the cabinet in 6 inch layers, using a sprinkle of Activo and 2 inches of soil between them.

No unusual heating has ever been noted in this cabinet. No freezing occurred during the winter of 1950-51; however, during the winter of 1951-52, ice crystals formed and the volume remained constant.

On April 11, 1952, this cabinet was re-inoculated with liquid top soil. The temperature within the cabinet remained equal to the air temperature, but there was a decided decrease in volume.

The mixture of straw, castor bean hulls, and sawdust is still in the cabinet and has decomposed only slightly.

A total of 10 cubic feet of composted materials has been removed from this cabinet.

Adco: This cabinet was treated throughout the composting period just as the Activo cabinet.

Immediately after filling, a slight heating was noted, which in turn caused more drying than was observed in the Activo cabinet.

Decrease in volume ceased after the winter of 1950-51 necessitating re-inoculation on May 25, 1951. Throughout the rest of the warm season the volume continued to reduce.

A total of eight cubic feet of composted material has been removed from this cabinet.

As in the Activo cabinet, the straw, castor bean hull, and sawdust mixture has only slightly decomposed. In both cabinets the slow rate of decomposition in this material seems to be caused by compaction and poor aeration.

Experiment 3. A comparison of top soil plus 5-10-5 and cow manure as inoculants on various plant residues with an 11 month composting period started on May 24, 1951.

Top soil plus 5-10-5: Temperatures ranging from 10 to 15 degrees above air temperature were noted in this cabinet for three weeks after the initial filling. The volume decreased considerably. When the cabinet was again filled, the temperature did not come up although the volume decreased. In August, 1951, a mixture of straw, sawdust, and castor bean hulls was placed in the cabinet in the same manner as in the Activo and Adco experiment. This material decomposed slightly. During operation for eleven months, approximately two cubic feet of finished compost has been shaken out.

This cabinet was re-inoculated April 11, 1952, and some decrease in volume occurred after this.

Cow manure: Temperatures up to 50 degrees above air temperature were noted within four days after original loading. The temperature gradually decreased. The finished material was used to inoculate fresh material being placed in the cabinet, but the high temperatures were never duplicated. This cabinet, too, froze out in the winter of 1951-52, and was re-inoculated in April. After re-inoculation, a decrease in volume was noted.

The mixture of straw, sawdust, and castor bean hulls has only slightly decomposed in this cabinet.

Approximately three cubic feet of finished compost has been shaken out of this cabinet in its eleven months of operation. Most of this has been returned to the cabinet for inoculation of fresh material.

Experiment 4. This test was designed to study the removal of the odors from sewage sludge by composting it with top soil. At the end of a two month composting period, there was a slight decrease in volume through settling and the sludge had only a slight trace of the musty odor usually associated with it.

Experiment 5. To simulate composting conditions encountered by the home gardener. This cabinet had an eleven month composting period. Loveland's (23) compounds and recommendations were used, and garbage (type 1), weeds and greenhouse waste were the materials composted.

Approximately 36 cubic feet of garbage and 20 cubic feet of weeds and greenhouse waste were placed in the cabinet over a ten month period. During that time, no material was ever removed. Contrary to Loveland's findings, the material would not shake out. The garbage developed some bad odor, especially after holes were pushed into it to provide aeration. Lime was effective in reducing the odor.

Experiment 6. The cabinet at H. L. Ransom's residence. Composting period of nine months started August 7, 1951.

Mr. H. L. Ransom filled the cabinet according to the recommendations of T. A. Loveland. Soil to which manure had been added was used as the inoculant. In filling the cabinet, Ransom used dead annual flower plants, household garbage, grass clippings, and other materials to which the average home gardener would have access.

Mr. Ransom reported that he had difficulty keeping the material of optimum moisture content. There was considerable reduction in volume, but it appeared to be only through the material becoming more compacted and not through decomposition.

There was no further reduction in volume after the winter of 1951-52. No finished material has ever been removed from the box.

Re-inoculant test

Re-inoculating the "Activated Compost Frames" did not cause any unusual heating; however, in each cabinet that it was used, an appreciable decrease in volume was noted.

Lehigh Bins

It is often recommended that active compost be used as an inoculant for starting composts. However, material from an active compost would not be available to many home gardeners. This experiment was designed to determine whether material from a compost was more efficient than top soil in starting and carrying to completion the decomposition process. The total amount used in each bin was 34 cubic feet of garbage (composite of 1 and 2), and 32 cubic feet of weeds and sweet potato stems.

The two bins were loaded in the same way except for the inoculants. No unusual heating was observed in either cabinet. After four days of operation, the smell from the cabinets was sickening. There were a great many flies and maggots. Lime reduced the odor somewhat, but increased the number of flies.

Various concentrations of DDT were ineffective in reducing either the flies or the maggots. Isotox 10 was found to be effective in killing the larva when applied by dusting full strength over the material being composted and then covered with a thin layer of soil.

The material was turned at the end of four months. One month later, it was ready to be used. There was approximately sixteen cubic feet of finished compost in each bin.

Cold Frame

No heating was noted in the material being composted, although there was a rapid decrease in volume. When the material had decreased in volume from 216 cubic feet to 50 cubic feet, it was turned and repiled so that the material on the surface that had not composted was in the center of the heap.

One month after turning and repiling, the material was decomposed. The finished material was steam sterilized and is now being used for mixing potting soils in the greenhouse.

Inoculation test

Examination of the material in the two gallon crocks at the end of 30 days showed that there was little, if any, difference between the treatments. The check had decomposed as much as any of the treatments.

New Zealand compost box

There was a steady decrease in v olume throughout the winter, although no unusual heating was ever noted.

The material was turned once by putting it in the second section. The material was composted in five months.

Approximately 110 cubic feet of raw material yielded 36 cubic feet of compost.

DISCUSSION

Comparison of Methods

Cost: The initial cost of the "Activated Compost Frame" is more than that of the "Lehigh Bins" and the New Zealand compost box. In order to obtain the plans for the frame, it is necessary to buy a year's supply of the activating compounds sold by Loveland. The plans and a year's supply of the compounds cost $26.80. The factory built model is priced at $93.50.

The construction of the frames is quite complicated and it is assumed that few home gardeners could construct a frame without the services of a carpenter. The bin and the box, being simple, would not require skill in their construction.

On a volume basis, the New Zealand composter is the least expensive.

Ease of Handling:

Loading. The compost box was easiest to load, then the bin, and then the frame. The greatest difficulty in the frame was its excessive height.

Removal of the finished product. Unloading followed the same trend as loading.

Contrary to Loveland's (23) literature, the finished product could not drop through the grate. It could be made to pass through the grate when it was quite dry; however, in these experiments when the finished material became dry enough to shake out, the material being composted became so dry action stopped.

In order to remove the finished material from the bins, it was necessary to either dismantle them or tip them to one side.

Watering:

Less difficulty was experience in watering the box than the bins or frames.

As the frames were exposed to the air on all sides, the problem of providing a suitable amount of water was difficult. When the outside 4 to 6 inches became so dry decomposition had ceased, the inside remained too wet for decomposition. Watering the outside served to further aggravate the situation on the inside.

In the bins and the box the problem of drying was not so severe, and was further lessened by the ease with which the material could be turned.

Final product:

Amount. The compost box yielded more of the finished product than the frames or the bins.

Quality. The material from the frames was decomposed more than the material from the box; however, when quality is considered on a time basis, the box will still produce more of the final product.

Comparison of the innoculants

Efficiency: Under the conditions stated in this experiment, top soil was as efficient in making compost as any of the commercial compounds. All of the commercial compounds called for soil in the recommended usage so it would appear that the purchaser was paying for something he already had or at best, for low nitrogen compounds.

The liquid digested sludge, on the basis of speed and amount of finished compost, was the best inoculant, followed by top soil to which commercial fertilizer had been added. Wet cow manure was good, but it gave no better results than top soil even though the temperatures reached the highest peak where it was used.

Top soil and compost originally started with fresh cow manure gave equal results when used as inoculants in the bins.

Cold Frame Compost

This appears to be an efficient, low cost means of securing large amounts of compost.

When this experiment was completed, all of the material composted would pass through a quarter-inch mesh screen. The odor of the material was suggestive of top soil rather than sewage sludge.

Disposal plants with the problem of final disposal of sludge could well use this method if they had access to large quantities of straw or other plant wastes.

Total time for starting the compost and one turning was five hours.

Nursery and greenhousemen who would ordinarily have hot beds or cold frames empty during the summer months should find this method of producing compost practical.

The material is now being used in the College Greenhouse and has been reported to be more acceptable than barnyard manure.

SUMMARY AND CONCLUSIONS

1. Methods and materials for the home gardener were investigated.
2. The New Zealand compost box is the most favorable method of composting for the home gardener. Points in its favor are:
    1. Cost of construction.
    2. Ease in handling.
    3. Minimum of drying or freezing.
    4. Permanence and screenability.
    5. Most rapid return.
3. The "Lehigh Bins" require more space than the average home gardener would want to use. The fact that they must be moved makes them difficult to screen with plant materials.
4. The "Activated Compost Frame" was the least favorable method. It's height makes it difficult to load. The unloading process was much more difficult than the advertizer claimed, because in order for the material to shake through it had to be dry, achieving that point dried almost the entire cabinet, also the weight of the material pressing on the grates made it difficult to move them. Excessive drying was more pronounced in this method.
5. The most favorable materials for composting were green plant wastes which were not extremely succulent. i.e. Mature but not dry plants.
6. Dry woody material like castor bean hulls and sawdust should not be used in composts where a rapid return of finished material is expected.
7. Large amounts of material such as restaurant waste whould not be composted in small composters because of the resulting odors.
8. Using commercial inoculants did not give faster decomposition or

better compost. Fresh cow manure inoculants gave the best results, however, few home gardeners would have access to it. Liquid from soil or top soil are the best and most practical innoculants for home gardeners.

9. Liquid digested sludge is effective in furnishing the organisms for an efficient decomposition of straw.
10. Air dried digested sludge can be composted with soil to remove most of the odors ordinarily associated with it.
11. The pit method of composting using liquid digested sludge and plant wastes should find much favor among nurserymen, park superintendents and estate gardeners.
12. Ordinarily flies are a nuisance only when large quantities of garbage are being composted. Isotox 10 applied to the surface of the composted material was found to be effective in controlling the larva.
13. Lime incorporated in material such as garbage was found to reduce odors.
14. The extremes of temperature noted by other workers have never been noted in these small volume compost experiments. Under Oklahoma climatic conditions high temperatures in the cabinets increased the problem of excessive drying.

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