DISTRIBUTION OF OXYGEN AND CARBON DIOXIDE IN MUSHROOM COMPOST HEAPS AS AFFECTING MICROBIAL THERMOGENESIS, ACIDITY, AND MOISTURE THEREIN [1]

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INTRODUCTION

At the present time stable manure is the medium almost universally used for cultivating the common mushroom (*Agaricus campestris* L.). Growers have learned from experience that a period of composting is necessary before the manure is suitable for making up into beds. A rapid fermentation during which comparatively high temperatures are generated is apparently desirable. In general the rate of decomposition of the manure and the suitability of the finished compost for mushroom growing seem to be largely dependent on the size and shape of the compost heap, its height and compactness, the quantity of water added during turning, the thoroughness of the mixing, and the number of days between turnings. These factors probably influence the condition of the finished compost primarily by establishing in the compost heaps conditions of aeration, moisture, and temperature, which in turn establish the trend of the development of the microbial and insect population of the heaps.

The studies described in this paper were undertaken in order to improve composting practice by learning something of the distribution and interaction of these physical and biological factors in typical mushroom compost heaps. At first the writers were concerned principally with recording the temperature, aeration, moisture content, and acidity in all parts of standard mushroom compost heaps. As the observations progressed it became apparent that conditions are radically different in different parts of compost heaps and that the factors of temperature, moisture, and acidity are dependent on aeration, presumably through its effect on microbial activity, in a roughly predictable manner. From these observations an attempt has been made to derive principles that will give the experimenter an approximate conception of the conditions of aeration, temperature, moisture, and acidity to be expected in all parts of stable manure composted as for mushroom culture in heaps of any size or shape.

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METHODS

Ordinary soil thermometers were used for taking temperatures in compost heaps. After the metal tips of these thermometers are heated the instruments may be removed from the compost and read before the mercury begins to fall. For readings at depths greater than 1 foot it was necessary to add extensions to the handles. Complete immersion of these thermometers seems to cause little difference in the readings, and this may be determined and a correction applied. The use of ordinary thermometers of any type is not desirable for three reasons: (1) The fall of the mercury is very rapid once the instruments have been removed from the manure and it is consequently very difficult to take accurate readings; (2) in drawing the thermometers from the bottom of the heaps through the warmer interior the readings change materially; and (3) it is necessary to punch holes in the heaps larger than the diameter of the thermometers in order to drop them in, thus admitting currents of air that frequently change the temperature.

In taking temperatures the thermometers were placed at horizontal and vertical intervals of 6 inches or 1 foot in the heap, depending on the time available and the accuracy desired. After each reading the thermometers were cooled to about 80° F., put into the same holes, and shoved down to the next level. The readings obtained were recorded on crosshatched paper, and the temperature contours were filled in later.

Samples of air from within the compost heaps were obtained by means of a metal tube having a sharply pointed end. Just behind the point four holes were bored for the air to enter. This tube was connected with rubber hose to an Orsat gas-analysis apparatus and could be thrust into the pile at any point for sampling. The air was removed from the tubing before each sample was taken. Samples from within the heap were passed first through a solution of potassium hydroxide to absorb the carbon dioxide and then through alkaline pyrogallol to absorb the oxygen. The probable error of the Orsat apparatus under these conditions seemed to be about 0.2 percent. At times the error of sampling was probably several times this figure. A possible source of error is recognized in the presence within the compost heaps of gases, other than carbon dioxide and oxygen, that might be soluble in potassium hydroxide or alkaline pyrogallol. But in all probability the presence of such gases in small quantities would have little bearing on the problem under consideration and would not affect the evidence or the conclusions in any way.

The hydrogen-ion concentration of samples from different parts of the compost heap was determined with a portable potentiometer by the quinhydrone method. The determinations were made in the field so that the samples were tested only a few minutes after they were removed from the compost heap. There is a tendency for the readings of manure samples to drift toward the alkaline side after the quinhydrone is added. To equalize this effect all samples were allowed an equal period (4 minutes) between the adding of the quinhydrone and the taking of the readings. Preliminary tests showed an average difference of only 0.05 between the pH values of aliquot samples of compost tested with the hydrogen electrode and those tested with the quinhydrone electrode.

TESTS FOR CARBON DIOXIDE AND OXYGEN

Samples of air were taken at first from typical mushroom compost heaps at the Arlington Experiment Farm, Rosslyn, Va., 3 or 4 feet high and without artificial ventilation. Later, aspirations were made from commercial storage heaps 5 to 6 feet high, and from heaps with artificial ventilation at the ground level. In all heaps without artificial ventilation the oxygen content of the air in the interstices of the compost decreased steadily as the bottom center of the heap was approached from the sides or from the top. Anaerobic conditions were usually found within 2 or 3 feet from the side of the heap and 1 foot from the upper surface. Carbon dioxide analyses of the same samples of air indicated a corresponding increase in carbon dioxide as the lower center of the heap was approached. These phenomena are presumably due to the presence of an actively respiring microbial flora.

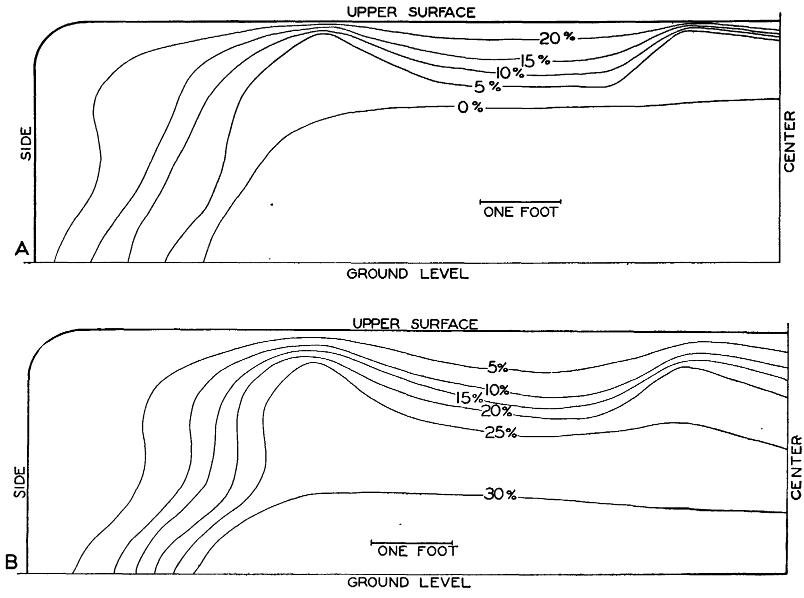

FIGURE 1.—Cross section of a mushroom compost heap from side to center, 12 feet from the end, showing the concentrations of oxygen (*A*) and carbon dioxide (*B*).

Contours showing the concentration of oxygen and carbon dioxide in a typical unventilated heap 3 feet deep are given in figure 1. The dip in the contour lines which appear 5 feet from the side of the heap suggests convection currents.

In most samples in which the oxygen content was more than 1 percent, the sum of the oxygen and carbon dioxide percentages was approximately 21 percent. This, of course, is roughly the percentage of oxygen in the ordinary outside atmosphere, and the constant recurrence of this figure may be taken to indicate that the average respiratory ratio $\left(\frac{ccCO_2}{ccO_2}\right)$ of the heterogeneous microbial population of the compost heap approximates unity under aerobic conditions.

The increase in concentration of carbon dioxide seems to reach a limit at approximately 30 percent. The fact that manure decomposition is arrested in this section is easily observed while the compost heap is being turned, especially during the second turning. At that time the manure in a mound-shaped region in the lower central part of the heap is distinctly "greener" than the remainder of the heap. No attempt was made to determine whether the 30 percent carbon dioxide content is responsible for this retarded fermentation; nor were analyses made of the remaining 70 percent for combustible gases, such as hydrogen and methane, which are known to be generated under similar conditions.

Tests were made to determine the rapidity with which the concentration of carbon dioxide builds up after the manure is turned. As shown in figure 2, it was found that the carbon dioxide content begins to increase rapidly immediately after turning. In 7 hours the carbon dioxide concentration had reached approximately 20 percent, and no oxygen could be detected.

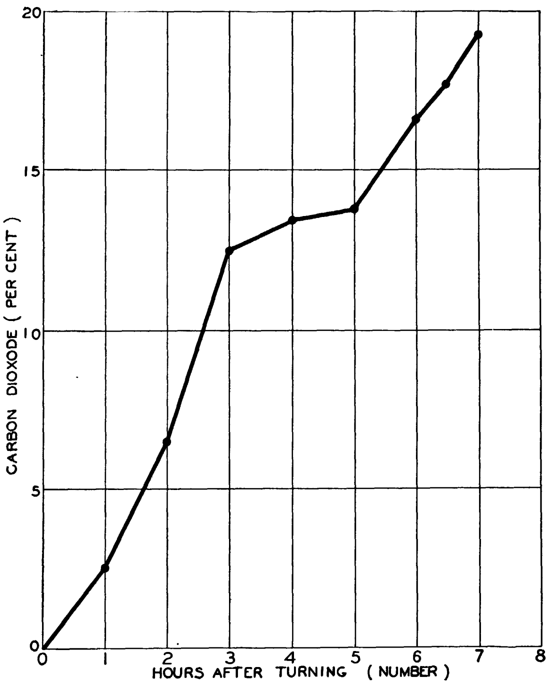

FIGURE 2.—Rate of accumulation of carbon dioxide in center of mushroom compost heap after turning.

For several years a few commercial mushroom growers have been placing ventilating tunnels of lattice work under the center of their compost heaps to speed up decomposition. To determine the effect of ventilation of this kind, bench tile was laid on the ground across an experimental compost heap and aspirations were made at different levels above the tile and at different lateral distances from the tiled area. The results of carbon dioxide analyses from these aspirations are given in figures 3 and 4. It should be noted that there is no anaerobic region in any part of the heap above the ventilation tile. Unlike the conditions in ordinary heaps the percentage of oxygen is higher at the bottom than at 1 or 2 feet from the top. The data in figure 4 indicate that the lateral extension of the effect of ventilation tile on aeration is rather limited. In the heap studied anaerobic conditions prevailed at a lateral distance of 2 feet from the tiled area.

TESTS FOR TEMPERATURE

Two or three days after the compost was mixed the contours of temperatures were found to be substantially the same in all the flat heaps studied. Typical contours are shown in figures 5 to 8. In general the exterior 3 or 4 inches of the compost heaps varies from slightly above air temperature to above 100° F., depending on the moisture content and the tightness with which the manure is packed. Consistent temperatures begin to be found at a depth of about 6 inches. At the ground level temperatures are relatively low, usually

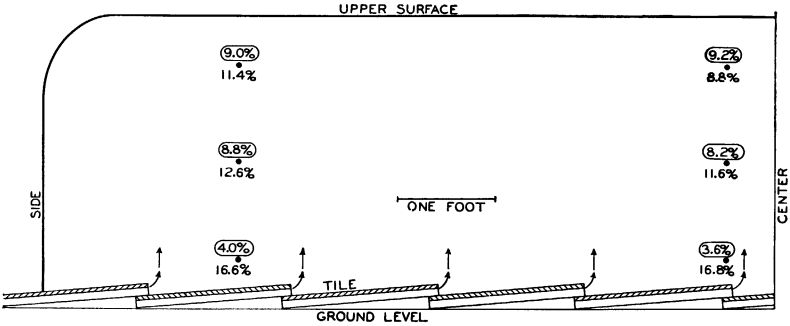

FIGURE 3.—Cross section of one half of compost heap ventilated with greenhouse bench tiles at ground level. Numbers encircled represent concentrations of carbon dioxide; other numbers represent concentrations of oxygen, at points indicated by dots. Arrows indicate currents of air.

from 110° to 120° at points within the heap 2 to 4 feet from the side, then dropping as the center of the heap is approached until temperatures of less than 100° may be encountered. Above the ground there is a similar temperature range. The low-temperature region forms a low mound in the center of the pile roughly corresponding

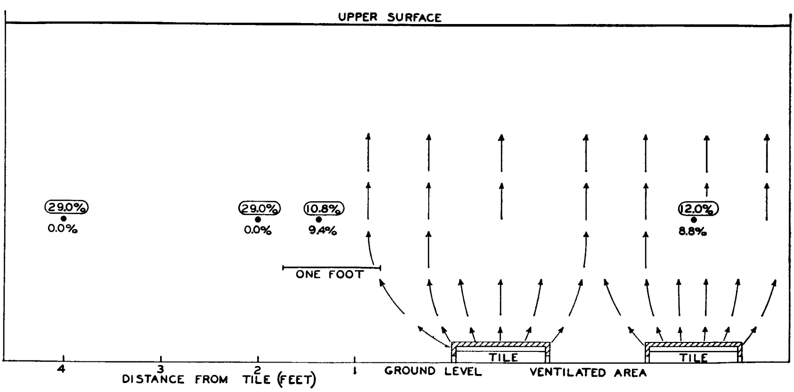

FIGURE 4.—Longitudinal section of portion of compost heap ventilated with greenhouse bench tiles. Section taken across tiles to show percentages of oxygen and carbon dioxide immediately above, and at different lateral distances from source of air. Numbers encircled represent percentages of carbon dioxide; other numbers represent percentages of oxygen, taken at points indicated by dots. Arrows represent currents of air.

to the anaerobic region. Above this the layers of successively higher temperatures rise in more or less regular strata, following the outlines of the mound. The hottest portion of the heap occupies the space between the sides of the heap and the central anaerobic mound. It usually extends from 6 inches to 2 feet down from the top and from 1 to 4 feet in from the sides. Though usually somewhat oval, it varies in shape and may contain from 2 to 5 square feet in cross section. In this region, forming a ring like a huge elongated doughnut about the center of the pile, the temperature is usually in the neighborhood of 170°, although 182° was recorded on one occasion.

In view of the work of numerous investigators on microbial thermogenesis (*6*, *7*, *8*),[2] there can be little doubt that this distribution

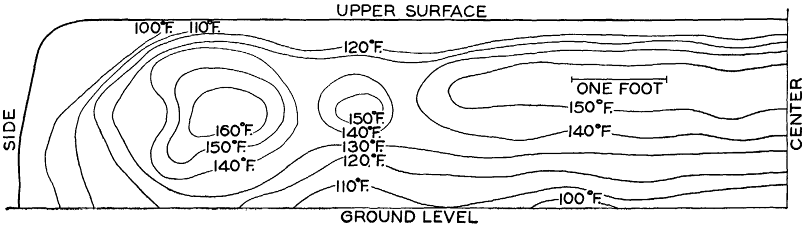

FIGURE 5.—Cross section 6 feet from end of compost heap 2 feet high, showing temperature contours.

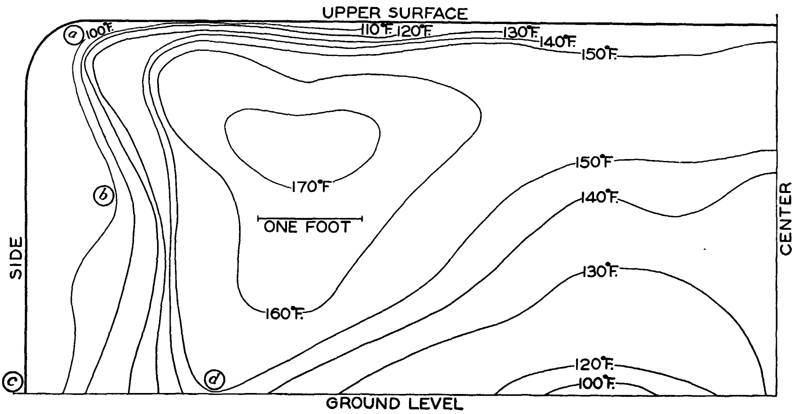

FIGURE 6.—Cross section through compost heap 4 feet high, showing temperature contours. Letters in circles designate points referred to in the text.

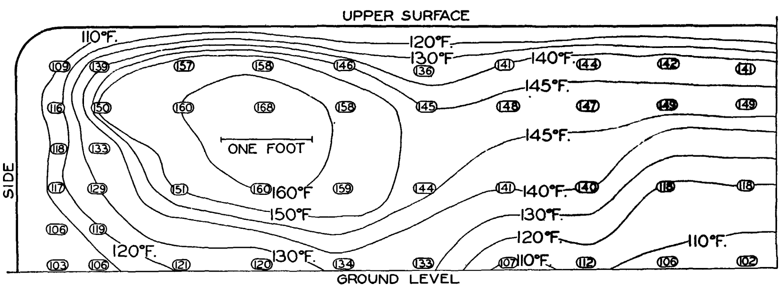

FIGURE 7.—Cross section 6 feet from end of compost heap 3 feet high, showing temperature contours. Ellipses indicate points at which temperatures were taken. Small figures encircled represent temperatures at those points.

of temperature is due largely to the thermogenic activities of an active microbial population.

The warm region apparently is favorable for the accumulation of heat because it is well insulated from outside temperatures and at the same time is comparatively well supplied with oxygen. The outer

[2] Reference is made by number (italic) to Literature Cited, pp. 600 ,601.

layers are cooler because of the lack of insulation from the outside; and the lower central region is cooler because the lack of oxygen retards the microbial activity. The slight extension of the high-temperature region into the adjacent anaerobic region is probably due to the conduction of heat from the aerobic region.

Although moderate aeration seems to be necessary for the production of high temperatures, an excessive current of air through decomposing material may have a cooling effect. This was especially noticeable in heaps of artificial manure made at the Arlington Experiment Farm in the fall of 1930. In these experiments some heaps were made with straw as it came from the straw stack; whereas other heaps were made with the same weight of straw and chemicals, but the straw used had been chopped by means of a corn cutter into 3-inch lengths. There were 12 pairs of these comparable heaps, and in every case during the early part of the composting period the heaps made with short straw were from 40° to 80° F. warmer than those made with long straw. After a few weeks of composting, when the long straw had lost much of its stiffness, the difference was not so noticeable.

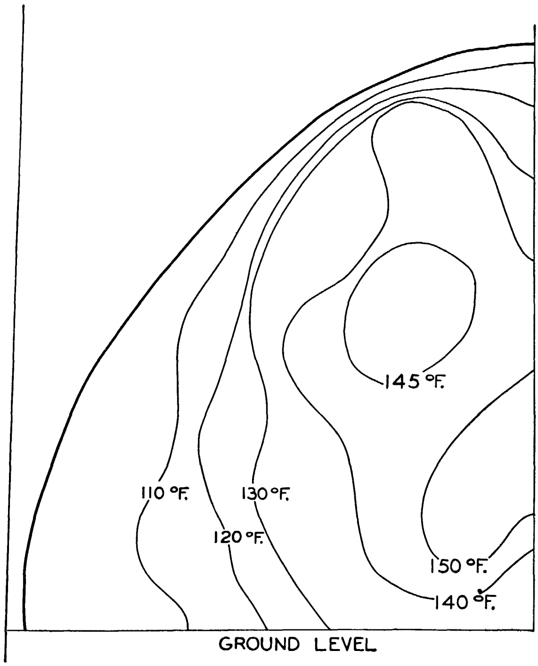

FIGURE 8.—One half of cross section through center of conical compost heap, showing temperature contours.

Irregularities in the exterior contours of the heaps illustrated in figures 5 and 6 may also have been caused by excessive aeration due to convection currents. In hand-turned piles there is usually more or less "flaking", or stratification, on oblique lines from the center, and the air passes into the heap along these strata. This is probably the cause of the convex contour in figure 6, the warm air rising at *a*, drawing in cool air at *c*, and causing the convexity at *b*. The extension of the hotter regions toward *d* is probably due to oxygen brought in by this fresh air, which is available for the heating of the manure beyond the point where the cooling effect of the excessive aeration is felt. In more uniformly turned piles the contours would be expected to be more regular, as in figure 7.

In heaps of the same area, but 2 feet in depth, the contour pattern is practically the same on a vertically compressed scale as in the higher heaps, except that the cool central mound tends to occupy a slightly greater proportion of the heap than is the case in the higher heaps (fig. 6).

A fairly typical contour pattern for conical heaps is shown in figure 8. In this type of heap the cool central region at ground level is relatively small, but the cooling effect of outside air being drawn in at the lower sides influences a relatively far greater region.

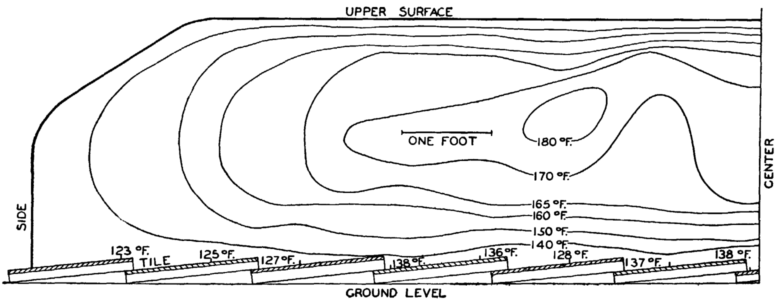

FIGURE 9.—Cross section of compost heap ventilated with greenhouse bench tiles, taken parallel to tiles. Note that whole bottom layer is above 120° F.

In large heaps of the "ridged" type, used in some places, the cross section resembles that of the conical heap, except that the sides are perpendicular to a height of 3 or 4 feet and taper thence to a truncate ridge. These piles are 50 to 60 feet long. In these heaps it would be expected that the contours in cross section would resemble those in figure 8 more or less closely. Because the currents of air have access

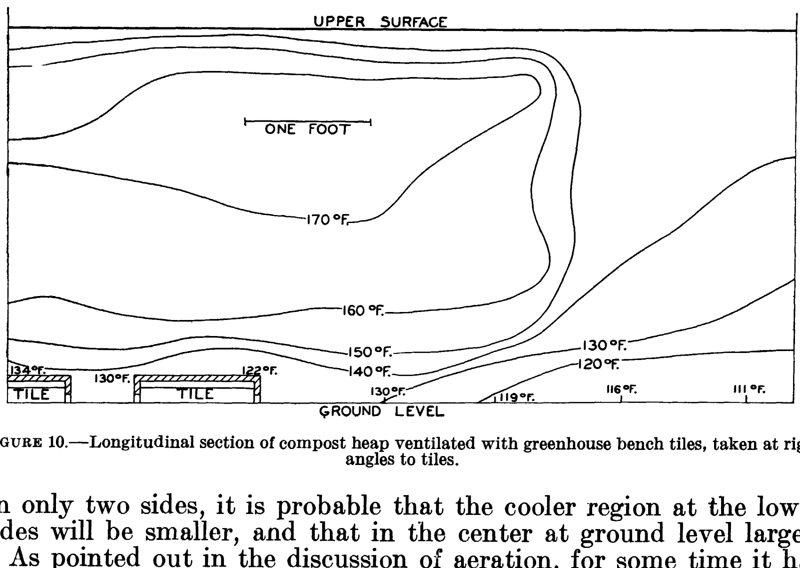

FIGURE 10.—Longitudinal section of compost heap ventilated with greenhouse bench tiles, taken at right angles to tiles.

on only two sides, it is probable that the cooler region at the lower sides will be smaller, and that in the center at ground level larger.

As pointed out in the discussion of aeration, for some time it has been the practice of a few growers to place beneath the composting heaps heavy lattice troughs, or other means of admitting air to the bottom. The effect of this procedure on the temperature contours is shown in figures 9 and 10. It will be seen that the temperature at the ground level is raised uniformly to above 120° F. In the upper strata the high-temperature areas coalesce, so that the temperature contours are flattened out and the temperature of the whole heap is raised and made more nearly uniform. Undoubtedly this is due to the comparatively uniform distribution of oxygen that was present over the ventilation tiles. When temperatures were taken in a plane at right angles to the tiles, it was found that the parts of the heap more than a foot away from the tiles at ground level were not much affected. As would be expected, a foot or so above the tile the heat of the manure extends laterally for a somewhat greater distance. From the data at hand, however, it would seem that the lateral extension of the effect of aerating devices is rather limited.

In order to ascertain how long it would take compost to attain its maximum heat after turning, with its attendant aeration, the bulbs of recording thermometers were placed in various portions of the 4-foot heaps. In the heaps without tile the temperatures usually reached their maximum in from 18 to 24 hours in the portions of the pile well off the ground but at points at or near ground level continued

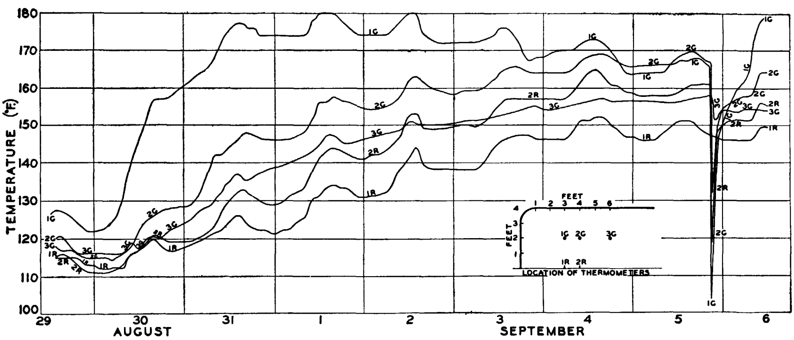

FIGURE 11.—Record of temperatures in different parts of mushroom compost heap after the second turning. The small diagram indicates the positions of recording thermometers by dots and by the symbols 1-G, 2-G, 1-R, 2-R, etc.

climbing for 144 to 168 hours or more, as shown in figure 11. In these piles the difference in temperature between the lowest and highest points at the end of a week or 10 days may be as much as 40° F. and was usually in the neighborhood of 20°. By this time the temperatures are usually running along fairly evenly or dropping slightly. The influence of external weather conditions is very evident. There is a sharp rise in temperature, even at the bottom of the pile, at about noon on warm days, and a corresponding drop at night. Rain causes a sharp drop and a nearly equally sharp rise in temperature, affecting the upper portions of the heaps more than those lower down.

In ventilated compost heaps the temperatures rise more slowly, attaining their maximums in from 48 to 72 hours, the lower portion of the heap being the slowest to warm up. After the maximum temperature has been reached and held for 24 hours or so the temperature slowly drops until the next turning, descending perhaps 25°, as shown in figure 12. The difference between points in the lower and upper portions of the heaps is, as has been pointed out, much less, being only about 8°. The influence of external weather conditions is seen in these piles but is very much less evident than in the unventilated ones.

HYDROGEN-ION CONCENTRATIONS

There is a considerable difference in the opinion of different workers on the question of the acidity of the compost. Duggar (*4*) in 1905 stated that manure which has undergone fermentation for a few weeks is usually slightly acid in reaction. This statement was accepted for 20 years and substantiated by Bechman (*2*), who found a reaction of pH 6.4 in manure that had fermented 21 days. On

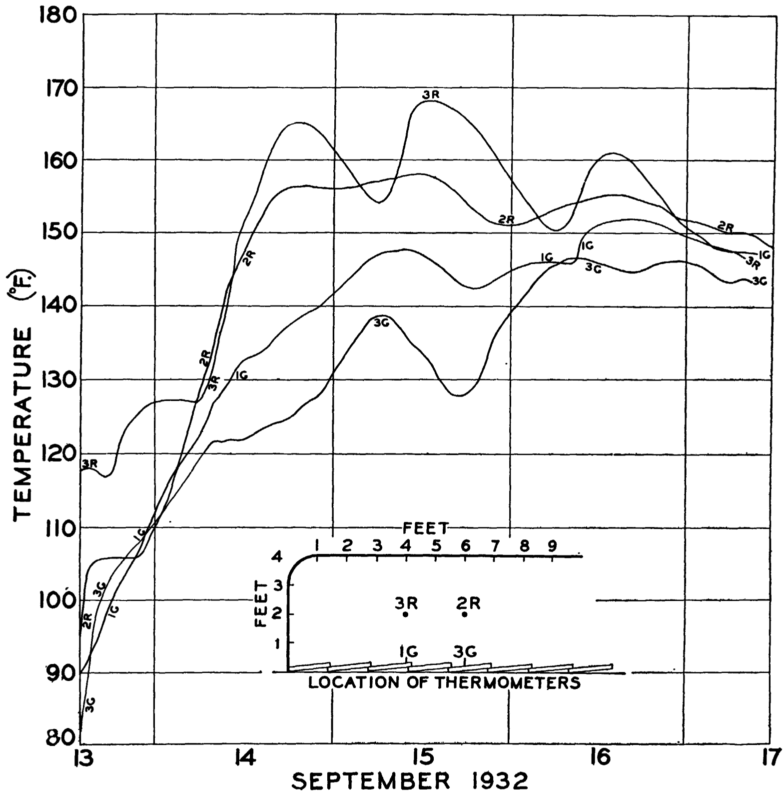

FIGURE 12.—Record of temperatures over tiled portion of mushroom compost heap. The small diagram indicates positions of recording thermometers by dots and by the symbols, 1-G, 3-G, 2-R, and 3-R.

the other hand, Beach (*1*) and Lambert (*9*) found an alkaline reaction in numerous samples of mushroom compost from commercial establishments in eastern Pennsylvania. The pH values recorded in the present study indicate an alkaline condition in well-aerated compost and an acid condition in the parts of the heap composting under anaerobic conditions. It is possible that the discrepancies in the results of different workers can be explained on this basis.

The results of a series of tests of the pH value in different parts of a compost heap are given in figure 13. It is apparent that the outside layer of this heap was largely alkaline or neutral (pH 8.5 to 7.1), whereas the anaerobic mound at the bottom of the heap was predominantly slightly acid (pH 6.6 to 5.1). The general trend from an alkaline reaction in the outside layers toward a slightly acid reaction in the lower central portion is unmistakable, although there are several notable exceptions. Manure subject to firefang was neutral or alkaline in reaction, and manure over tile ventilation as a rule was more alkaline than manure taken from the bottom of unventilated heaps.

MOISTURE CONTENT

Moisture is one of the most variable factors in a compost heap. In general, mushroom growers attempt to maintain approximately 150 percent of water in the compost on a dry-weight basis. Water is usually added during the process of turning the compost, and in many cases soil is added to the manure to help conserve the moisture. As a result of these practices a moderate moisture content is maintained in most of the compost. On the other hand, there is always a tendency for the compost to dry out excessively on the sides of the heap. This is undoubtedly due to the taking up of moisture by cur-

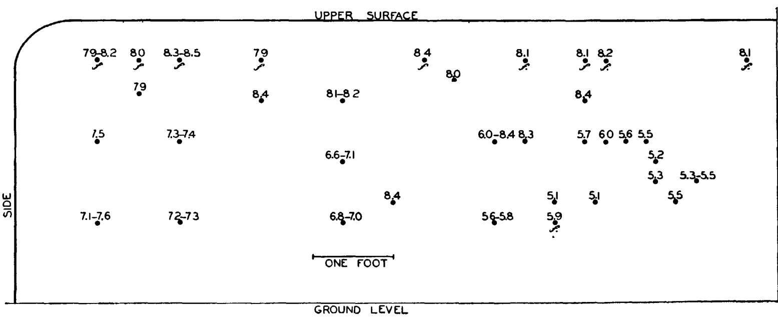

FIGURE 13.—Cross section of compost heap, showing pH values of composting manure, 7 days after second turning, taken at points indicated by dots. The surface layer is alkaline (pH 8.0 to 8.5). The aerated layers on the sides of the heap range from pH 7.1 to 7.6. The wet layer on the bottom center is usually acid (pH 5.1 to 6.6), with occasional alkaline spots (pH 8.0 to 8.4). The firefanged manure (*f*) is aklaline as a rule.

rents of air which are warmed upon entering the heap. A tendency to dry out is noticeable also in the layer of manure in contact with ground-level ventilators. A converse condition is noticeable in the upper 6 inches of the heap. Here the warm air from the lower regions rises to the surface saturated with moisture that condenses when the air reaches the cool outer shell. As a result there is usually a wet layer over the surface of the heap. Toward the end of the composting period there is usually less tendency for the compost to dry out than in the beginning when the straw in the manure is still stiff.

DISCUSSION AND CONCLUSIONS

It is evident from the data presented that there are markedly different conditions of aeration, temperature, acidity, moisture, and rate of decomposition in different parts of ordinary flat mushroom compost heaps and that these conditions are distributed in a regular manner that is fairly consistent for heaps of similar size and shape. Perhaps it would be well to point out here the changes in these conditions to be expected from changes in the size and shape of the heap and some of the implications of these phenomena in the general problem of improving the composting practice for mushroom culture.

Considering aeration first, it has been shown that there is a progressive reduction in oxygen accompanied by an increase in carbon dioxide in the interstices of the manure as the center of a compost heap is approached from the outside, and that 8 hours after turning, anaerobic conditions prevail in regions deeper than 1 foot from the top of the heap and more than 3 feet within the side of the heap. Likewise, it is apparent that when ventilators are run under the center of the heap along the ground the anaerobic condition, high in carbon dioxide, in the lower central part of the heap, is changed to a fairly well aerated one. Vertically this change extends from the ventilators to the top of the heap, but laterally the aeration does not seem to extend more than 2 feet. It is evident from these observations that increases in the height or the width of unventilated compost heaps tend to increase the proportion of manure subject to anaerobic conditions over that subject to aerobic conditions. On the other band, anaerobic conditions can be entirely eliminated by the use of closely spaced ground ventilators.

The distribution of temperature in the compost heap seems to be dependent on three factors, namely, aeration, conduction, and convection. The highest temperatures (160° to 180° F.) are usually confined to a region 2 to 4 feet within the sides of the heap and 1 to 3 feet from the top. The outer layers are cooler because of the lack of insulation from the outside and the lower central region is cooler because the lack of oxygen retards microbial thermogenesis. Since thermogenesis is retarded by a lack of oxygen, changes in the height or width of the heap can be expected to affect the average temperature in much the same way as aeration is changed. Increases in the height or width of the heap reduce the average temperature by increasing the size of the cool central region, and complementary ventilators placed at the ground level materially raise the average temperature of the heap.

A region containing compost having an acid reaction and having a comparatively slow rate of decomposition corresponds roughly with an anaerobic region, and the proportion of compost subject to these conditions is increased also with increases in the height and width of the heap.

It is a common observation that currents of air passing into the sides of compost heaps or through ventilators at the ground level have a tendency to dry out the compost at the sides of the heap and surrounding the ventilators. Therefore, reducing the width of a heap increases the tendency for it to dry out during composting, and the insertion of ventilators at the ground level has a similar tendency.

It would seem then that within reasonable limits decreasing the lateral dimensions of a compost heap, or reducing the width of the heap as compared to the length, tends to increase the proportion of aerated alkaline compost in the heap, to raise the average temperature, and to increase the tendency of the compost to dry out between turnings. The insertion of ventilators at the ground level has a similar effect. On the other hand, increasing the height of the compost heap, as is frequently done when manure is stored for several weeks, tends to increase the proportion of anaerobic acid compost in the heap, to decrease the average temperature, and to some extent to reduce the tendency toward drying out.

The foregoing considerations naturally raise the question, What composting conditions are likely to produce the most favorable medium for the growth and yield of mushrooms? At the present time this question cannot be answered in a categorical fashion in terms of size, shape, ventilation, and methods of turning the compost heap. Most commercial growers, when using manure of average texture, make up their heaps about 4 feet high, 20 feet wide, and 40 to 60 feet long. In these heaps about one half of the manure composts under anaerobic conditions; and if it were not for the thorough mixing obtained during the turning process, the lower central part of the heap would take 2 or 3 times as long to decompose as the outer portion. Preliminary experiments and the beneficial effect of the final fermentation in the beds suggest that an aerated condition in the compost heap is preferable to an anaerobic condition provided it can be attained without excessive heating or drying out. Theoretically aeration can be increased by making the heaps narrower or lower, by inserting ventilators at the ground level, or, perhaps preferably, by both increasing the height of the heap and inserting ground-level ventilators. Such changes seem worthy of experimental trial, but it should be recalled that they also may tend toward excessive drying out and overheating and that the beneficial effects of aeration are not well established. The problem can probably best be attacked by a series of semi-empirical yield experiments combined with a study of the microbial and insect population encouraged under different conditions. The large number of factors to be considered and the heterogeneity of stable manure, composting conditions, and conditions during the growth of the crop will make sure progress slow and expensive.

As a working hypothesis it may be assumed that composting conditions which produce a favorable medium for the development of mushrooms probably do so because they encourage the development of a microbial population that is best able to pave the way for the subsequent growth and fructification of mushrooms. Such a hypothesis must take full cognizance of the effect of the staling products of different groups of organisms on mushroom development as well as the action of these organisms in producing changes in the manure favorable to the nutrition of mushrooms under competitive conditions. Interesting facts pertinent to the latter question have been brought to light by the culture studies of Styer (*10, 11*) and Bechman (*2*) and the proximate chemical analyses of Hébert (*5*) and of Waksman and Niessen (*12*).

Raising the temperatures approximately 25° F. at the bottom of the heap by ground-level ventilation suggests interesting possibilities from the standpoint of reducing the introduction of pests into the mushroom houses with the composted manure. If all houses could be properly heated, fumigated during the peak of the heat, and protected thereafter, there would be much less trouble from insect and fungus pests; but at present this ideal is usually not attained, and it is important that the compost be taken into the house as nearly pest-free as possible. In the unventilated heaps a considerable portion of the bottom layer is below 100°, and a still greater proportion below

110°, temperatures that most mushroom pests can survive for some time. It is true that the high carbon dioxide concentration and the lack of oxygen might cause insect and fungus pests to cease activity, but they probably can survive for a long time under those conditions. Temperatures necessary to kill mushroom insects of various species in their various stages have not yet been determined with accuracy but are certainly below 130°. Chapman (*3*) gives 125.6° as the highest authentic record of temperature endured by any insect. In the case of fungus pests the benefits are more uncertain, because some fungus pests are known to withstand temperatures higher than 130°.

SUMMARY

Gas samples taken from all parts of mushroom compost heaps indicate an increase of carbon dioxide and decrease of oxygen toward the lower central part of the heap. In flat heaps 3 feet deep anaerobic conditions are usually found deeper than 1 foot and more than 3 feet from the sides of the heap. Compost in this portion of the heap tends to be acid, while that in well-aerated portions is alkaline or neutral. The highest temperatures (160° to 180° F.) are usually confined to a region 2 to 4 feet from the sides of the heap and 1 to 3 feet from the top. The outer layers are cooler because of the lack of insulation from the outside and the lower central region is cooler because the lack of oxygen retards the microbial activity. At ground level temperatures (100° to 120°) are usually lower than in the higher strata, presumably also because of lack of oxygen. A more uniform distribution of oxygen and wider distribution of the high-temperature region is induced by placing ventilating tiles at ground level. In all probability, conditions such as these influence the suitability of the finished compost for mushroom culture by establishing the trend of the microbial and insect population of the compost heap.

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