Effect of Added Plant Material on Decomposition of Native Soil Organic Matter and on Organic Matter Distribution in Soil Aggregates.

Abdul Latif

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A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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by

Abdul Latif
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ABSTRACT

Decomposition of native soil organic matter as affected by added plant material labelled with carbon-14 was studied in several soils which varied in native soil organic matter content. The effect of adding tagged plant material (barley straw) which had been composted for different periods on soil aggregation, the contents of total carbon and carbon-14 in various size fractions of aggregates, and on the spatial distribution of total carbon and carbon-14 within soil aggregates was also studied.

Plant material added to the soil caused an apparent priming action in the decomposition of the native soil organic matter in all the soils studied. Priming action was greatest at the beginning of incubation and decreased as incubation proceeded. Priming action was relatively large immediately after the beginning of incubation in coarse textured soils poor in native organic matter than in fine textured soil high in organic matter. For the whole incubation period, however, the total priming action was greater in the fine textured soils. Maximum priming action in a Commerce silt loam occurred at a moisture content of 30 percent. At 5 and 40 percent moisture content slightly negative priming action occurred.

Organic matter addition to the soil resulted in increased total soil aggregation and an increase in the formation of aggregates of large diameter. Higher contents of total carbon and carbon-14 were observed in the smaller aggregates of 0.21 to 1.00 mm. diameter as
compared to both larger aggregates with diameters greater than 1.00 mm. or in soil material smaller than 0.21 mm. diameter. In the aggregates larger than 1.00 mm., no differences were observed in the distribution of total carbon and carbon-14. No apparent effect of time of composting of plant material on the distribution of total carbon and carbon-14 in different size fractions of soil aggregates was observed. Total carbon and carbon-14 contents were similar in aggregates separated by either dry sieving or wet sieving. No consistent differences were observed in the spatial distribution of total carbon within the abraded aggregate shells.
INTRODUCTION

Maintenance of soil organic matter at an optimum level in cultivated soils is generally recognized as one of the major problems of agriculture. The supply of carbonaceous material is limited and most organic materials are oxidized rapidly in the soil. Green manure crops and crop residues have been the chief means whereby this maintenance or increase has been attempted. Laboratory evidence supports the idea that these materials are valuable as organic matter builders but there is considerable controversy as to whether their use will increase or even maintain the organic matter content at high levels under field conditions. A number of studies indicate that the addition of green manure crops and crop residues will increase the amount of organic matter in the soil, the increase being proportional to the level of plant material addition. On the other hand, some investigators have interpreted their laboratory data to show that the addition of crop residues may result in a net loss of organic matter in mineral soils, especially when the levels added are low.

Newly added organic matter may stimulate or retard the decomposition of organic matter already present in the soil. A change in the decomposition rate caused by fresh organic additions is described as a priming action, and may be positive or negative. One approach to evaluate this so-called priming action is through the use of isotopes incorporated into the plant residue, which permits a partition of the evolved carbon into that coming from the plant and that coming from the soil organic matter.
Organic matter plays a dominant role in soil aggregation. Many investigators have concluded that the cementing action of organic matter is of prime importance in soil aggregation. Others have proposed that organic matter induces soil aggregation through coprecipitation or flocculation with inorganic colloids. Still others have suggested that the presence of organic matter merely stabilizes aggregates already formed by other processes. It is also believed that mucilaginous material produced by soil microorganisms during the decomposition of organic matter encapsulates soil aggregates, making them resistant to wetting. All of these effects of organic matter on soil aggregation operating singly or in combination are considered important.

The present study was undertaken to determine:

1. Decomposition of native and added organic matter in selected Louisiana soils.

2. Decomposition of native and added organic matter as influenced by different moisture contents and soil pH.

3. Effect of organic matter which had been decomposed previously to different degrees on (i) soil aggregation, (ii) content of total carbon and carbon-14 in different sizes of aggregates and (iii) spatial distribution of total carbon and carbon-14 within soil aggregates.
REVIEW OF LITERATURE

I. The Decomposition of Organic Matter in Soil

All soils contain organic matter but the amount and the type of organic matter which they contain varies widely. Organic matter has two distinct functions in the soil: that dependent on its actual presence in the soil, and that dependent on its decomposition. The former group of functions primarily affect the physical properties of the soil and the latter the nutrient supply of the plant.

As a component of soils, organic matter is a resultant of a number of complex formation processes characteristic of the organic material and the environment in which it is formed. Residues of the vegetative cover might be termed the parent material from which soil organic matter is formed. By means of two processes, both of which are chiefly due to the activities of microorganisms, the characteristic organic matter of a given soil is produced. The first of these processes is decomposition of plant residues with resultant modification of their chemical composition and properties; the second process is synthesis of new microbial cells which in turn die and are decomposed by other microorganisms. Thus organic matter turns into humus in the soil.

A characteristic of soil humus is the slowness with which it decomposes. Half or more of the carbon in fresh residues is lost as carbon dioxide within 2-6 months following addition of the residues to the soil. Thereafter, however, the rate of decomposition slackens.
The ultimate product, the soil humus, decomposes at a rate of approximately two percent per annum in temperate climates. This rate is subject to some acceleration.

1. Priming Effect Caused by the Fresh Organic Additions in the Soil

In addition to its function as a source of new soil organic matter, fresh organic additions can alter the decomposition rate of soil organic matter in a number of ways. Lohnis (1926) was among the first who observed that if green manures were incorporated into a soil not too poor in humus, a general acceleration of the activities of the microorganisms living in the soil takes place with the result that the nitrification of the green manure nitrogen is accompanied by an intensified mineralization of the humus nitrogen. Accordingly, more nitrogen may be found in the first crop following the addition than has become available from green manure.

Pieters and Mckee (1938) have concluded "That in the main the object of green manuring must be to maintain rather than to increase the quantity of organic matter in soils."

Allison et al (1949) pointed out that green manures would not build up soil organic matter when turned under very succulent because the quantity of added material is very small. However, they suggested that the main function of young crops would be to prevent erosion, leaching, improve the physical condition of the soil, supply active organic matter and available nitrogen over an extended period of time.

White (1931) found that manurial treatments which stimulate the growth of higher plants also encourage a more vigorous growth and
activity of soil microorganisms associated with the decay of soil vegetative matter.

Broadbent (1947) and Broadbent and Norman (1948) used a tracer to follow the pathway of decomposition of carbonaceous material in the soil. Using the isotope carbon-13 they found that the carbonaceous material added to the soil increased the rate of decomposition of native soil organic matter. They expressed the opinion that these additions might result in net losses of organic matter after a brief period of time.

Hallam and Bartholomew (1953) by using radioactive carbon observed that the addition of plant residues to soil generally resulted in a marked increase in the rate of decomposition of the native soil carbon. The magnitude of the increase varied with the soil, with the plant material added and with the rate of plant residue addition. The addition of plant residues had a greater stimulating influence on the decomposition of native soil organic matter in coarse texture soil than in fine textured soil. Corn stover and soybean straw had similar accelerating influence in a given soil on the decomposition of soil organic matter. Difference in the rate of application of the residue resulted in pronounced difference in the mineralization of native organic matter. The greatest total stimulation occurred when the high rates of plant residues, 10 and 15 tons per acre, were applied. However, per unit of residue added, the smallest (2.5 tons per acre) application was far more effective in stimulating organic matter breakdown than the large additions. They suggested that the influence of added residue on the rate of decomposition of native soil organic
matter is not of short duration but apparently continues as long as the residue constitutes an important part of the decomposition mass. As builder of soil organic matter, green manures have not been found useful except on soils initially low in organic carbon. In fact, on soils in the prairie regions, they may actually serve to accelerate the decomposition and exploitation of the carbon already there. Green manures serve the most useful purpose as immobilizers and conservers of plant nutrients, or if legume, as possible contributor of nitrogen.

Broadbent et al (1949) observed that the rate of decomposition at the higher rate of addition of straw cannot be explained on the basis of inadequate supplies of air or of deficiency of nitrogen and phosphorous. They found that in the decomposition of sudan grass enriched with carbon-13 neither the rate of decomposition of the added sudan grass nor of the soil organic matter was proportional to the quantity of sudan grass added.

Rates of decomposition have been relatively slow in some laboratory investigations and sizeable fractions of the plant residues have been remained undecomposed after long periods of time. Norman (1948) observed that after 833 days decomposition of variously treated straws in soil, appreciable fractions of the added carbon still remained. Even where dextrose was added, 2.75 per cent of the added carbon remained at the end of this period. Jenkinson (1963), while studying the decomposition of labelled plant material under controlled conditions at 25°C, showed that the amount of carbon lost was directly proportional to the amount added. Furthermore, he pointed out that this was also true in field incubation. In his field experiment, 24 percent of th...
added carbon remained in the soil after two years. He showed that non-linear relationships between amount added and amount decomposed were usually found when the soil supply of microbial nutrients was insufficient for maximum decomposition at high levels of additions. In an additional study he observed a non-linear relationship between carbon additions and losses for wheat straw (C:N ratio 87) incubated with soil. When nitrate was added, additions became directly proportional to losses. He further observed that even in such cases where nitrogen was limiting, on prolonged incubation the relationship gradually became linear.

Broadbent (1947) showed in decomposition experiment with sucrose and cellulose in soil that virtually all the added material was decomposed in a relatively short time. In one case a net loss in organic matter was obtained. Young sweet clover decomposing in the presence of mature corn stalks was found to accelerate the decomposition of the latter. Furthermore he found, in the decomposition of organic material enriched with nitrogen-15, that in the presence of available energy materials the mineralization of native soil organic matter was enhanced.

Sorensen (1963) added carbon-14 labelled barley straw to the soil and allowed it to decompose. A small stimulation in the decomposition of native soil organic matter was observed as a result of additions of barley straw.

Bingerman et al. (1953) investigated the decomposition of carbon-14 labelled glucose and alfalfa in an organic soil. The amount of carbon in the soil at the end of the experiment was always less when incubated alone than when incubated with organic additions. With
glucose there was a negative priming action in the first few days, followed by a positive one, for the remaining period of incubation. With alfalfa the effect was reversed, an initial positive priming action being followed by a negative one. However, in these experiments the alfalfa used as a composite sample, partly being uniformly labelled and partly being unlabelled. Supplementary experiments showed that the labelled and unlabelled alfalfa decomposed at slightly different rates so that it was difficult to interpret the priming action measured quantitatively.

Jenkinson (1963) observed positive priming action in soils having different quantities of native organic matter. He took two samples of soil at different times from the same experimental plot and incubated with uniformly labelled ryegrass. One sample was taken after a year's bare fallow and the second six weeks after 34 metric tons of farmyard manure per hectare, plus the stubble from the proceeding wheat crop, had been ploughed in. In both soils adding ryegrass increased the rate of decomposition of the organic matter already in the soil.

Jansson (1960) found an increase in mineralization of native soil organic carbon resulting from stimulation of the microflora by the added glucose in two arable top soils, one neutral and one acid. In the very beginning of the experiment, the priming action was slightly negative, especially in the neutral soil but then it turned positive and the resulting effect after 16 weeks of incubation was clearly positive in both soils.
Goswami and Datta (1961), using plant material labelled by a short exposure (24 hours) to active carbon dioxide, found both positive and negative priming action when their materials were incubated with a mineral soil.

Mann (1959) observed a greater increase in carbon and nitrogen on plots receiving green manures than in the corresponding plots not receiving them. In an earlier study Crowther and Mann (1933) concluded that a green manuring-wheat rotation caused a more rapid loss of organic matter than continuous wheat.

Smith (1963), while investigating some interrelationship between decomposition of various plant residues and loss of soil organic matter as measured by carbon-14 labelling concluded "that fresh plant residue frequently has a protective effect on indigenous organic matter and that this is not directly related to the maturity or nitrogen content of the plant tissue. The strong suppression of decomposition by root residues of wheat and corn suggests that some toxic compound is involved."

Rovia and Greacen (1957) showed in the laboratory experiments that mechanical disturbance of soil increased the rate of decomposition of soil organic matter. They suggested that additional soil disturbance caused by preparing a seedbed, sowing and plowing in a green manure may well increase the decomposition rate of native soil organic matter over that in a soil allowed to rest undisturbed between cultivations. However, they pointed out that mechanical disturbance in the laboratory may be more thorough than ever achieved in field
cultivation, so that the effect of a few cultivations per year is unlikely to be very great.

It is apparent that there are conflicting views regarding the priming action. Some investigators have come up with explanations which can, either wholly or in part, explain how the addition of labelled plant material can alter or appear to alter, the amount of carbon dioxide evolved from the native soil organic matter during incubation. Garrett (1956) suggested that the observed intensification of decomposition of resistant materials in the presence of fresh materials is due to the initial growth energy supplied to the microbes involved in order to enable them to attack the resistant materials. Park (1956) was of the opinion that humus decomposition slakens because there accumulates in soil inhibitory substances or antibiotics. Once developed, these materials decrease the rate of decomposition to a level lower than that which would otherwise occur. Addition of fresh residues counteracts this biostasis and thereby accelerates decomposition of native humus.

Jenkinson (1963) has put forward the following possible explanations for the priming action:

a. Systems which can give rise to apparent priming action.

In a soil containing unlabelled calcium carbonate to which carbon-14 labelled material is added the labelled carbon dioxide evolved by decomposition of the plant material can exchange with carbonate via bicarbonate in the soil solution. During incubation each molecule of labelled carbon dioxide exchanged would be replaced by an unlabelled one, thus increasing the evolution of unlabelled carbon
dioxide at the expense of the labelled carbon dioxide and causing an apparent priming action.

b. Priming actions caused by errors in relating the amount of carbon-14 evolved to the amount of plant carbon decomposed. The amount of plant carbon decomposed in a given time is obtained by measuring the carbon-14 activity of the evolved carbon dioxide and then using a factor to convert it to plant carbon decomposed. If isotopic fractionation occurs, or if the plant carbon is not uniformly labelled, or if a large fraction of the evolved carbon dioxide is re-absorbed by soil organisms, an apparent priming action can result.

c. Priming action caused by differences between the microbial environments in soil incubated with and without organic matter.

d. Mechanisms by which organic additions can directly increase the decomposition rate of the native organic matter. Soils containing microbial spores which will germinate on adding fresh organic matter may exhibit positive priming action. It is also possible that some of the products of decomposition may either solubilize or displace some of the native soil organic matter, rendering it more decomposable. Priming action may also be due to an increase in the concentration of exocellular microbial enzymes following the organic addition.

Clark (1967) has suggested "that the priming effect is largely illusory. This implies no challenge of the accuracy of the isotope measurements for evolved carbon dioxide or mineralized nitrogen, but it does imply doubt as to whether these measurements should be accepted as face value."
A review of the literature indicates that there is a controversy on the influence of fresh organic additions in the soil on the decomposition of soil organic matter. Probably the main cause of the controversy is due to the fact that changes in soil organic matter resulting from green manuring are usually small relative to the total amount of organic matter in the soil.

Hallam and Bartholomew (1953) suggested that green manuring "may actually serve to accelerate the decomposition and exploitation of the carbon already there" and that priming action is partly responsible for this. On the other hand Pinck and Allison (1951) concluded "that the effect of green manures on the soil organic matter is of only minor practical importance." Jenkinson (1963) has concluded that there is no new evidence to modify the conclusions of Pinck and Allison so far as the priming action is concerned.

2. Decomposition of Soil Organic Matter as Influenced by Soil Drying and Rewetting

Lehedjantzev (1924) showed that soil drying and rewetting are closely related to humus decomposition and thus with soil fertility. He observed that millet yields in a soil that had been air-dried and remoistened were on an average 45 percent greater than those in a soil which had not been dried out but was otherwise identical. Yield increases of up to 125 percent were recorded in extreme instances and large yield increases were also found for other crops. The effect of drying on yield was found to be greatest with uncultivated soil, less with soils under perennial grass and still less with soils subjected to ordinary methods of tillage. The application of manure and
phosphoric acid was found to increase the effect of drying. When yield increases due to drying were expressed as a percentage of the yielding capacity of the moist soil, it was found that the less fertile soils responded better to drying. Lehedjantzev concluded that during the process of drying chemical changes take place in the soil causing an increase in the solubility of organic substances and an enrichment with nitrogen and phosphorus. In addition to dehydration temperature was also considered to be an operative factor in these changes.

Steenhamp (1928) studied the effect of dehydration of soils on their colloidal constituents. He considered that the drying of a soil is a natural factor in transforming plant nutrient substances from a potential to an active form and that flocculation of the colloids (through drying) also leads to increased fertility due to improved physical conditions. He stated that an increase in nitrogen and phosphorus on soil drying is well established and concluded that the older a soil becomes the less it will respond to drying for the purpose of soil fertility. For the recovery of such soils he advocated a rest with as much moisture as possible.

Beaumont, cited by Birch (1937), studied the effect of drying on soil colloids and his results show an interesting parallel to the effects of drying on other soil properties. He showed that drying a soil one time produced as much effect on the colloidal material as repeated drying and rewetting. Similarly Lehedjantzer (1924) observed that a single drying and wetting was almost as effective as repeated drying and wetting in increasing yield. Birch (1937) found that a
single drying and rewetting was as effective as several drying and rewettings as regards the subsequent magnitude of decomposition.

Beaumont (1919) observed that the hygroscopicity of the soil decreased with air drying and oven drying. He also pointed out that drying increased the amount of water-soluble humus on rewetting. He concluded that drying a soil indirectly affects the reversability of the colloidal properties through biological and chemical action.

Patrick and Wyatt (1964) found that 15 to 20 percent of the total soil nitrogen was lost by repeated submergence and drying of a rice soil. Most of the losses occurred during the first three cycles of submersences and drying. They also observed that soil oxidation-reduction potential decreased rapidly after the initial submergence. They pointed out that the more times the soil had been submerged and dried, the slower the oxidation-reduction potential decreased when the soil was again submerged. They also noted that carbon and nitrogen were lost in approximately the same ratio that they occurred in the soil.

In laboratory studies on soil nitrification Cooke and Cunning (1958) found that air dry soils after moistening and incubation produced average increase in nitrate nitrogen approximately three times as great as the corresponding increase given by incubating fresh soils.

Harpstead and Brage (1958) found a pronounced increase in the nitrifying ability of soils on drying and storage for periods of one year. This was thought to be due to a change during drying in the relative numbers of various microorganisms which populate the soil.
The enhanced decomposition and nitrification following the moistening of a dry soil has so far been resolved into two processes. First, drying increases the amount of organic matter that goes into solution on moistening and this rapidly decomposes without producing mineral nitrogen. Secondly and simultaneously, nitrification of organic material occurs at the humus surface; the rate of decomposition and nitrification rapidly declines. These two processes are believed to be due to the same cause, namely an enhanced exposure of the organic surface to solution and microbial process as a result of changes in the colloids on drying and ageing, these changes being reversible on moistening with a consequent decrease in surface area and decline in the rate of decomposition.

II. Soil Aggregate Formation

Aggregates are the structural elements of soil. Aggregates are formed by the cohesion of clay, silt and sand. They consist of an intimate grouping of a number of soil grains into clusters. The mechanisms by which the soil particles are caused to aggregate and the forces which keep them aggregated are not very clear and are often contradictory. It is generally agreed, however, that organic matter plays a dominant role in soil aggregation in most soils.

The important cementing agents functioning in aggregate formation are clay, iron and aluminum hydroxides, organic matter and substances produced by soil microorganisms. Peterson (1947) also suggested an organic-inorganic linkage of calcium and polyuronides with clay serving as a cementing agent. Although there is no doubt
of their importance, clay and iron and aluminum hydroxides cementing agents will not be discussed in this review as they are not directly related to the present study.

1. Effect of Organic Matter on Soil Aggregation

It is generally agreed that organic matter in some way has a favorable effect on the formation of aggregates in the soil. It has also been observed that the beneficial influence of organic matter is more or less directly related to the amount and character of the organic matter applied to the soil.

Ensminger and Gieseking (1939) and Martin (1943) studied the effect of composts and compost materials upon the aggregation of soil particles. They found that aggregating effects of compost materials varied with the type of plant material involved. In general, the greater the percentage of readily decomposable constituents the organic material contained, the greater was its effect on soil aggregation. After composting, the aggregating influence of organic material decreased and the time required for maximum aggregation to occur was lengthened.

Browning and Milan (1942) studied the effect of varying amounts of organic matter such as alfalfa, rye, vetch, sucrose and wheat straw on aggregation in Gilpin silty clay loam soil. They found that there was a significant increase in aggregation for each unit increase in organic matter. Sucrose was much more effective than the other materials. They observed that organic materials that readily decomposed increased aggregation within a few days after they were incorporated and then gradually lost their effectiveness with time. Materials
that were slower to decompose required a longer time to exert their binding effect, but continued to be effective over a longer period.

Vilensky (1940) and Stuckling (1950) observed that the application of large quantities of fresh organic matter in the form of barnyard manure, crop residues, mulches or other substances usually produced a rapid increase in aggregation in soils immediately following the application. McCalla (1946) observed that the quality as well as quantity of organic matter are important in soil aggregation. He suggested that, unless the initial application of organic matter was sufficiently large to produce a continuous supply of dissolved substances to the soil or was supplemented by additional applications at latter dates, this initial increase in aggregate formation soon reached a climax, subsequently the number of aggregates in the soil underwent a steady decline.

Chapek and Sakun (1944), while studying the effect of organic additions on soil aggregation, observed that a single application of 12 tons of manure per acre increased the number of aggregates in the soil. In a few weeks, however, this initial rapid change in the aggregation of these soils was followed by a decline in the number of aggregates present. They pointed out that this increase due to the addition of manure was related to the biological activity in the soil. They also concluded that the improved physical condition of the soil was due to the combined transitory and stable effects of the byproducts of decomposition and to the large amount of cells and other materials synthesized by the microorganisms.
Geltzer (1943) found that decomposing organic matter conferred a good structure on the soil and the more rapid the decomposition, the better the structure. He suggested that some substance, which only has temporary existence in the soil, was formed as a byproduct during decomposition.

Havis (1943) observed that Wooster silt loam soil reached a relatively high state of aggregation under straw mulch. Tyulin (1938) found this condition was reached more quickly where unleached wheat straw and alfalfa were used than where leached materials were used. Bluegrass sod increased and maintained a high percentage of aggregates of the larger sizes but was not as effective as mulch. Stauffer (1946) showed that mulch and sod were more effective in aggregate formation in the top soil than in the sub-soil or B horizon. Mulch favored the formation of large aggregates. Boller and Stephenson (1946) observed that aggregation under a ten-year straw mulch was much greater than that under five-year mulch.

Alderfer (1946) observed that the addition of large amounts of manure to sandy soils over a period of 28 years did not bring about a high degree of aggregation. He observed that the portion of the surface soil which was free from the effects of mechanical dispersion due to rainfall, machinery or animals and where moisture content and aeration were sufficient for maximum biological activity possessed the greatest aggregation.

Sideri (1936) found that sucrose, unleached wheat straw and alfalfa produced a sharp increase in aggregate formation when added to Wooster silt loam surface soil. He concluded that the increase in
aggregate formation was not due to the physical effects of organic matter but to soluble substances including carbohydrates.

Kroth and Page (1945) showed that the concentration and nature of water-soluble binding substances in the organic materials varied, depending on their source. In some instances, very small amounts were capable of bringing about considerable aggregation. Organic amendments increased the microaggregation in the soil, even on a light coastal plain soil which contained very little clay.

Baver (1959) observed that organic matter aided in the formation of relatively larger stable aggregates. He found a positive correlation \( r=0.758 \) between organic matter and aggregation, in soils containing less than 25 percent clay. For clay contents above 35 percent, the correlation between organic matter and aggregation was 0.663. He concluded that organic matter not only caused a high degree of aggregation of clay particles but also produced large aggregates.

Patrick et al. (1964) found that the correlation coefficient between aggregation and organic matter in a soil that was relatively low in clay content was highly significant, but at a relatively high clay content the correlation was nonsignificant. They also found nonsignificant correlation between aggregation and clay when the organic matter content of the soil was relatively high.

Sideri (1936) and Myers (1937) suggested that humus was adsorbed by clay particles by the orientation of polar organic molecules on the particle surface and that this adsorption was irreversible upon dehydration.
Martin and Waksman (1941) contended that in the well aggregated and most productive agricultural soils of the world a considerable portion of the binding materials is organic in nature and is formed as a result of the activities of soil microorganisms. McCalla (1945) observed that when a suspension of colloidal organic matter was mixed with soil material a water stable structure was obtained. Moreover, he found that soil aggregation was proportional to the number and activities of microorganisms in the soil.

McHenry (1945) stated that organic substances vary widely in their ability to granulate the soil, and their effectiveness in this respect depends on the state of decomposition. He pointed out that some organic constituents, such as sugars, do not stabilize soil granules directly. However, once transformed into microbial tissues and decomposition products, sugar becomes highly effective as a soil stabilizer. He suggested that fungal filaments and certain decomposition products of bacteria, such as fats, waxes, lignin, oils, proteins, and resins have a direct stabilizing effect.

2. Microorganisms and Soil Aggregation

It has been conclusively shown that mucus and other substances produced by soil microorganisms are effective binding agents in the formation of water-stable soil aggregates. The organic binding forces may be divided into three groups. The first group is made up of colloids consisting of the decomposition products of plant residues, probably of the hyphoellic and similar types. The second group consists of microorganisms and their secretory products, such as mucus, slime or gum,
produced during growth and resembling colloids and gels in their physical state. The third group consists of materials such as polysaccharides, synthesized by certain soil microorganisms.

Kanivet z and Koreneeve (1937) observed an increase in percentage of water-stable aggregates in soils incubated with Azotobacter and Trichoderma. Straw that had been incubated with Trichoderma lignorum and added to the soil caused a six-fold increase in the number of water-stable aggregates. Waksman and Martin (1939) observed that a marked increase occurred in the percentage of bound materials when sand-bentonite mixtures containing sucrose or cellulose were incubated with pure cultures of bacteria and fungi. McCalla (1945) also obtained similar results by using sand-clay mixtures. The binding of fungi was attributed to the extensive mycelium and that of Azotobacter indicum to the slimy substance produced by the organism. They suggested that microbial groups vary widely in their ability to aggregate soil.

Peele and Beale (1940) observed that aggregation in Cecil sandy loam was greatly improved through the activity of certain fungi and bacteria. Inoculation of nonsterile Cecil sandy loam in pots with certain cultures of bacteria and fungi, following addition to the soil of sucrose or ground oat straw, resulted in marked increase in aggregation over soil receiving similar organic matter treatments without inoculations.

Gilmour et al (1948) found that the addition of oat straw and especially alfalfa in the presence of molds increased aggregation. Inoculated soils to which neither oat straw nor alfalfa was added underwent only a slight to moderate degree of aggregation. Myer and
McCalla (1941) stated that soil organisms and their metabolic products were active in the formation and stabilization of soil structure, though they played a greater role in the stabilization than in formation. Alderfer (1941) revealed that beneficial organisms break down plant and animal residues, liberate plant nutrients and produce soil structure stabilizing substances. Reaggregation of soil is aided by the biological effect of added organic matter.

Martin (1946) observed that high aggregation is brought about largely by microbial cells, decomposition products or organic residues, and synthesized substances, some of which are polysaccharides. These active materials, although synthesized by some microorganisms, may be slowly destroyed by others, and as a result aggregation may decrease. Geoghegan and Brain (1948) pointed out that polysaccharides are normal metabolic products of microorganisms. Numerous species of bacteria, fungi and actinomycetes are capable of producing a wide variety of complex polysaccharides as cell constituents or as extracellular products. Hence it is reasonable to expect that under natural conditions the diverse flora of the soil may synthesize many polysaccharides from the constituents of vegetable material and these substances may be of considerable importance in the formation of crumb structure in soil.

Stallings (1952) indicated that, in general, the bacterial polysaccharides were better aggregating substances than was casein or lignin. When combined with casein and lignin, the polysaccharides, with minor exceptions, were as effective as when used alone.

Although the exact nature of the organic matter effect on aggregation is not completely understood, most of the evidence points to some
type of oriented adsorption or complex linkage of organic molecules
with clay particles that is stabilized by subsequent dehydration.

3. Concept of Aggregate Formation

Stallings (1952) suggested that under some conditions clay may act
directly as a binding agent in forming aggregates, but that in most
cases aggregate formation in soils is associated with adequate supplies
of biologically active organic matter and those substances produced or
synthesized by microorganisms. He emphasized that the humate fraction
of the organic colloids produced in the course of decomposition of
organic matter by soil microorganisms appears to be one of the important,
if not the main, factors contributing to the formation of soil aggregates. These substances are adsorbed onto colloidal clay particles,
perhaps by electrochemical union with inorganic colloids. Apparently
they are bound through the carbon linkage "bridge" between reactive
groups on the polymer. The presence of small amounts of sodium,
calcium, magnesium and other cations increases the aggregating effect
with low concentration of humate fractions. Locked to the soil
particles, the humate fraction or hydrophylic colloids act like bridges
between them, keeping them from separating yet at the same time holding
them apart so that they will not pack down tight.

Stalling (1952) further pointed out that since certain groups of
soil microorganisms break down these organic colloids as they are
formed, it is necessary to maintain a continuous supply of fresh
organic matter in the soil if a high rate of aggregation is to continue.

Russell (1934) theorized that the mechanism for aggregate forma-
tion proceeds as follows: (a) orientation of water molecules between
soil particles and hydrated cations, (b) the formation of chains of oriented dipole molecules in the vicinity of soil particles and (c) linking together of these chains upon dehydration.

Sideri (1936) suggested that the basis for stable aggregate formation lies in the near irreversible nature of the oriented adsorption of dish shaped clay particles on sand surfaces upon dehydration.

Page (1954) proposed that soil aggregates are formed either as a result of consolidation of disperse primary particles or as the result of the breakdown of coherent masses of soil. He postulated the following three mechanisms for consolidation of dispersed primary particles: (a) binding of soil particles by living bacteria and fungi, (b) encapsulation of primary particles by gelatinous organic materials such as gums, resin or waxes and (c) cohesion between clay particles or between clays and larger particles. The breakdown of large clods into soil aggregates may result from (a) action of small animals, particularly earthworms, (b) tillage, (c) pressure and differential drying caused by freezing, (d) compression due to roots, and (e) localized shrinkage caused by removal of water by plant roots or evaporation.

Emerson (1959) proposed a model of a soil crumb in which the crumb consisted of domains of oriented clay and quartz particles. He defined a clay domain as a group of clay crystals which were oriented and sufficiently close together to behave in water as a single unit. Dehydration is one process by which clay particles may be brought sufficiently close to form a domain. Emerson felt that dehydration by root action contributed to the genesis of clay domain. He hypothesized that organic matter and soil conditioners stabilize soil crumbs by increasing the
strength of quartz-clay bond. According to this concept, the possible arrangements of domains, organic matter and quartz in a soil crumb could be thought the following type of bonds:

(a) Quartz - organic matter - clay domain
(b) Clay domain - organic matter - clay domain
(c) Clay domain - clay domain, edge-face

4. Spatial Composition of Soil Aggregates

Very little work has been done concerning the composition and spatial distribution of components of soil aggregates. Kroth and Page (1947) studied the nitrogen content of shells and centers of soil aggregates. They observed that aggregate shells had slightly more nitrogen than aggregate centers though the differences were not statistically significant. They concluded that organic matter was uniformly distributed throughout the aggregates, with the possible exception of aggregate centers.

Waring and Bremner (1964) studied the effect of soil mesh size on the estimation of mineralization of nitrogen in soils. They found that a decrease in mesh size resulted in a marked increase in the amount of nitrogen mineralized under aerobic or anaerobic conditions. They concluded that much of the organic matter within soil aggregates was not susceptible to decomposition because of the inability of the microorganisms to deeply penetrate the aggregates. When the aggregates were reduced in size the organic matter becomes more accessible to microorganisms.

Holt and Timmons (1967), while studying the chemical heterogeneity of soil material within natural aggregates, found that there was a
higher concentration of water soluble elements in the exterior soil material, whereas the interior material contained about equal or slightly greater amounts of extractable elements than the exterior material. Also, it has been reported that interior of aggregates may be anaerobic and contain more organic matter than the exterior which is more likely to be aerobic (1966).

In summary, it may be said that little work has been done concerning the composition and spatial distribution of components of natural soil aggregates from which inferences regarding the role of organic matter on soil aggregate formation and behavior can be made.
MATERIALS AND METHODS

I. Soils Used

Five Louisiana soils were used in this study. All the soil samples were taken from the plow layer of cultivated fields, air dried, mixed and passed through a 40 mesh sieve. Information on the treatments and cropping system in the field from which some of the samples were collected and a list of soils and some of their properties are given in Table I. Loring silt loam soil samples were obtained from a field experiment at Winnsboro which had been designed to study the effect of lime and sulfur application on soil pH.

II. Incubation Technique

Barley straw which had been uniformly labelled with carbon-14 at an activity of 80 uCi per gram of carbon was used in this study. Soil samples with and without the addition of plant material were incubated under a controlled environment. Carbon dioxide which resulted from decomposition of native and applied organic matter was absorbed in standard sodium hydroxide solution and precipitated as BaCO$_3$ by the addition of BaCl$_2$. Carbon dioxide production was determined at various time intervals and in some cases only at the end of entire incubation period. The use of isotopes incorporated into the plant material permitted the separation of the carbon lost as CO$_2$ into two fractions, (1) that arising from the decomposition of added plant material, and (2) that coming from the decomposition of the soil organic
Table 1. Soils, treatments and cropping systems of the field from which samples were collected.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Texture</th>
<th>Treatment or Cropping System</th>
<th>pH</th>
<th>Organic Carbon %</th>
<th>Nitrogen %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Commerce No. 1</td>
<td>Silt loam</td>
<td>-</td>
<td>6.1</td>
<td>0.45</td>
<td>0.06</td>
</tr>
<tr>
<td>2</td>
<td>Commerce No. 2</td>
<td>Silt loam</td>
<td>Commerce No. 1 + 200 PPM N added as NH(4)NO(_3)</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Commerce No. 3</td>
<td>Silt loam</td>
<td>Commerce No. 1 incubated for 2 weeks with 1% ground rice straw at 20% moisture</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Mhoon No. 1</td>
<td>Silty Clay loam</td>
<td>3 years sugar cane - one year summer fallow - 3 years sugar cane (cane trash burned)</td>
<td>5.5</td>
<td>1.02</td>
<td>0.12</td>
</tr>
<tr>
<td>5</td>
<td>Mhoon No. 2</td>
<td>Silty Clay loam</td>
<td>3 years white clover - one year grass sod - 3 years sugar cane (cane trash chopped and turned under)</td>
<td>6.0</td>
<td>1.36</td>
<td>0.14</td>
</tr>
<tr>
<td>6</td>
<td>Crowley</td>
<td>Silt loam</td>
<td>-</td>
<td>6.3</td>
<td>0.89</td>
<td>0.11</td>
</tr>
</tbody>
</table>
matter. A comparison of the latter with the carbon lost from untreated soil indicated the existence and magnitude of the priming action.

Ground tagged plant material was thoroughly mixed with soil and sufficient water was added to bring the moisture content of the soil to 20 percent. The moist soil was placed in 100 ml. glass tubes of 3 cm. diameter and the tubes were placed in large jars containing standard sodium hydroxide solution. The concentration and amount of the sodium hydroxide solution was such that amount of sodium hydroxide was about two equivalents of the CO$_2$ estimated to be produced. Stopcock grease was applied to the lip of the jar and the jar was sealed. The jar containing the sample was placed in an incubator at 30°C. The glass tube containing the sample was transferred every few days to new jars containing fresh sodium hydroxide solution. Since the sample was being transferred to new jars every few days, oxygen was not limited in the jars. The oxygen content of the air in the jars was frequently measured to insure that adequate oxygen was present. In experiments where the carbon determination was made only at the end of the entire incubation period, the oxygen content of the jars was measured frequently and occasionally oxygen was supplied to the jars.

III. Analytical Procedures

1. Determination of Total Carbon

After incubating for a certain period of time, the glass tube containing the sample was removed from the jar and transferred to another jar containing sodium hydroxide solution. The jar from which the soil was removed was sealed immediately and set aside for total
carbon and carbon-14 analysis. Twenty-five ml. aliquots of \( \text{NaOH-Na}_2\text{CO}_3 \) solution were withdrawn from the jar into 250 ml. Erlenmeyer flasks and an excess of \( \text{BaCl}_2 \) solution was added to precipitate the carbonate as \( \text{BaCO}_3 \). The unreacted \( \text{NaOH} \) was back titrated with standard HCl, using phenolphthalein as an indicator. Similarly, carbon dioxide absorber (\( \text{NaOH} \)) from the control jar containing no soil was back titrated concomittantly with those from the treatment jars, thereby minimizing the chance of any error that could be caused due to atmospheric carbon dioxide interference during handling of the entire experiment. The following relationship was employed to calculate from titrimetric data the amount of carbon dioxide evolved:

\[
\text{Milligram carbon} = (B-V)NE
\]

where \( V \) = volume (ml.) of acid to titrate the alkali in the solution to the end point,

\( B \) = volume (ml.) of acid to titrate the alkali in CO\(_2\) collector from control to the end point.

\( N \) = normality of acid,

\( E \) = equivalent weight of carbon in the reaction = 6.

2. Determination of Radioactive Carbon in Evolved CO\(_2\)

Ten ml. of \( \text{NaOH-Na}_2\text{CO}_3 \) solution from the jar was pipetted into an 8 oz. wide mouth bottle. A vial containing 10 ml. of 1:1 solution of methyl cellosolve and ethanolamine was placed in the bottle. A small amount of stopcock grease was applied to the lip of the bottle. \( ^{14}\text{CO}_2 \) was liberated from the solution by the addition of an excess of lactic acid (which was added rapidly) followed by immediate sealing of the bottle with the screw cap lid. After gentle mixing, the bottle
was left standing for 72 hours at room temperature. At the end of this period, the vial was removed from the bottle, shaken and 1 ml. of the solution transferred to a liquid scintillation counting vial which already contained 15 ml. of the scintillation solution (66.3% toluene, 33.1% methyl cellosolve and 0.6% 2,5-Diphenyloxazole). Carbon-14 activity was determined on a Tri-Carb Liquid Scintillation Counter.

3. Determination of Activity of Tagged Plant Material.

The activity of the tagged plant material was determined by the same method used to measure $^{14}\text{CO}_2$ evolved during the decomposition of the tagged plant material when incubated with soil. A half gram sample of tagged plant material was thoroughly mixed with 50 g. of Commerce soil and 2 g. samples from this mixture was taken to determine the activity of the plant material. By dry combustion procedure, the sample was burned for 15 minutes in a steam of purified oxygen and $^{14}\text{CO}_2$ in the effluent gas stream was trapped in standard sodium hydroxide solution placed in two gas wash bottles connected in series. The concentration of sodium hydroxide solution was selected such that the amount of sodium hydroxide was about two equivalents of the carbon dioxide estimated to be produced. The NaOH-Na$_2$CO$_3$ solution of the two gas wash bottles was mixed together thoroughly and 0, 5, 10, 25 and 50 ml. aliquots of the solution were transferred by pipette to 8 oz. wide mouth bottles and the solution was prepared for counting as described in section 2 above. The counts per minute were plotted against the amount of NaOH-Na$_2^{14}$CO$_3$ solution taken to find the activity of the carbon-14 absorbed in NaOH solution. A linear relation between counts per minute
and amount of NaOH-Na$_2$CO$_3$ solution was observed up to 25 ml. of NaOH-Na$_2$CO$_3$. Above this concentration a curvilinear relationship, probably as a result of quenching, was obtained. The relationship obtained is shown in Figure 1. To minimize quenching, 10 ml. of the NaOH-Na$_2$CO$_3$ solution was used for $^{14}$CO$_2$ counting throughout this study.

IV. Description of Experiments


   a. In this experiment the rate of decomposition of native and added tagged organic matter was studied in six Louisiana soils. The soils were selected (or prepared) to provide a wide range in organic matter content and other properties, the details of which are given in Table 1. Six soils with and without tagged organic matter were incubated in this study. Each treatment was duplicated.

   Ground tagged plant material was thoroughly mixed in 0.1 gm. amount to 50 gm. samples of Commerce No. 1, 2, 3, Mhoon No. 1, 2 and Crowley soils, respectively. Sufficient water was added to each sample to bring the moisture content to 20 percent. The moist soil was transferred to glass tubes and incubated at 30°C in one liter jars containing 100 ml. of 0.0975N NaOH solution as described above. After 2, 6, 12, 20, 36, 48, 88 and 130 days of incubation the glass tubes containing the samples were transferred to new jars containing 100 ml. of 0.0975N NaOH solution. After transferring the glass tubes to new jars, the old jars were sealed immediately and set aside for total carbon and carbon-14 analysis by the method already described under
Figure 1. Net counts per minute for various amounts of NaOH-Na$_2^{14}$CO$_3$ solution taken to determine the activity of the carbon-14 absorbed in the NaOH solution.
analytical procedures. Exactly the same procedure was used for the incubation of soils without tagged organic matter.

b. A supplementary experiment was conducted in which the decomposition of native and added organic matter was studied in three Louisiana soils (Commerce No. 1, Crowley and Mhoon No. 1). Three soils with and without tagged organic matter were incubated with each treatment duplicated.

One-tenth gram ground tagged plant material was thoroughly mixed with 50 gm. Commerce No. 1, Crowley and Mhoon No. 1 soils, respectively. Sufficient water was added to each sample to bring the moisture content to 30 percent. The moist soils were transferred to glass tubes and incubated at 30°C in one liter jars containing 100 ml. of 0.3050N NaOH solution as described above. Occasionally fresh oxygen was supplied to the jars to maintain aerobic conditions. Total carbon and carbon-14 determinations were made only at the end of the entire incubation period (130 days). The soil samples without tagged plant material were incubated in the same way.

2. The Decomposition of Native and Added Organic Matter in Soils as Influenced by Different Moisture Contents and Different Soil pH Values.

a. In this experiment, the decomposition of native organic matter and added tagged plant material at different moisture contents was studied. The Commerce No. 1 soil was used for this experiment. Eight moisture levels, 5, 10, 15, 20, 25, 30, 35 and 40 percent, were studied. Soil samples both with and without tagged organic matter were incubated at 30°C. Each treatment was duplicated.
One-tenth gram of ground tagged plant material was mixed thoroughly with eight 50 gm. portions of soil. Sufficient water was added to the eight samples to bring the moisture content to 5, 10, 15, 20, 25, 30, 35, and 40 percent, respectively. The moist soil samples were transferred to glass tubes and the tubes placed in 1 liter jars containing 100 ml. of 0.1000N NaOH solution. Total carbon and carbon-14 determinations were made at the end of the incubation period (96 days).

b. Effect of soil pH on the rate and decomposition of native and added organic matter in soil. Soil samples were obtained from an experiment at Winnsboro which had been designed to study the effect of lime and sulfur application on soil pH. Nine soils with and without tagged plant material were used and each treatment was duplicated. Ground tagged plant material in the amount of 0.5 gm. was mixed with 100 gm. samples of each of the nine soils. Sufficient water was added to each sample to bring the moisture content to 20 percent. The moist samples were transferred to glass tubes and the glass tubes were placed in 3 liter jars containing 250 ml. of 0.3040N NaOH solution and incubated at room temperature for 164 days. Total carbon and carbon-14 determinations were made at the end of the incubation period. Incubation procedure and methods for total carbon and carbon-14 analysis were the same as described above.

3. Effect of Organic Matter Which Had Been Decomposed Previously to Different Degrees on (i) Soil Aggregation, (ii) Content of Total Carbon and Carbon-14 in Different Sizes of Aggregates and (iii) Spatial Distribution of Total Carbon and Carbon-14 Within Soil Aggregates.

In this experiment a study was made of the effect of added
organic matter, decomposed previously to different degrees, on soil aggregation, distribution of total carbon and carbon-14 in different sizes of aggregates, and spatial distribution of total carbon and carbon-14 within large soil aggregates.

a. Preincubation of organic matter. One gram of ground tagged plant material was thoroughly mixed with nine grams of ground rice straw for each of the incubation treatments and placed in 100 ml. glass tubes of 3 cm. diameter. Ten ml. of soil extract was added to each of the samples and then water was added to bring the moisture content of each sample to 300 percent. Three glass tubes containing the samples were placed in incubating flasks connected to an aspiration apparatus. The various samples were incubated at 30°C for 1, 3, 6 or 12 weeks, respectively. During the incubation period moist air was drawn through the incubating flask and the CO$_2$ evolved was trapped in NaOH solution to avoid contamination by radioactive carbon. At the end of each incubation period, the composted sample was removed from the glass tube, air dried and stored until all the samples were ready for mixing with the soil.

b. Mixing of composted organic matter with soil. Each of the air dried composted organic matter samples was thoroughly mixed with 1000 gm. portions of Commerce No. 1 soil which had been forced through a 40 mesh sieve, and incubated along with a 1000 gm. samples of Commerce No. 1 soil to which no composted organic matter was added. Sufficient water was added to the soil to bring its moisture content to 20 percent. The moist soil samples were placed in glass jars through which moist air was drawn and a CO$_2$ trap was placed between the
incubating jars and the vacuum source. The samples were allowed to incubate at 30°C for 195 days. At the end of this period, soil samples were removed, passed through 8 mm. sieve and air dried. Each of the 1000 gm. samples was divided into two portions of 500 gm. each and subjected to either dry or wet sieving to separate the soil aggregate.

c. Separation of dry aggregates. Aggregates of different sizes were separated on the 500 gm. sample by hand sieving with a nest of 8 sieves, (3 inches in diameter, 1 inch high) of the following sizes in order of opening: 4.76 mm., 4.5 mm., 4.0 mm., 3.0 mm., 2.5 mm., 2.0 mm., 1.0 mm., and 0.21 mm., respectively. The various size fractions were collected on screens of successively smaller sizes and the amount at each fraction was determined by weighing. The sieving process was repeated ten times to accommodate 500 gm. sample since only 50 gm. sample was passed through the nest of sieves in one operation. The aggregates thus separated at each size fraction from each of the treatment were pooled together and weighed.

d. Separation of wet aggregates. The method involves wetting of the sample prior to separating aggregates into various size fractions by sieving the sample through a nest of 4 sieves, 8 inches in diameter, 2 inches high, immersed in water. The sieves were arranged in the following order of opening: 4.76 mm., 2.0 mm., 1.0 mm. and 0.21 mm. This nest of sieves was moved up and down with a frequency of 30 cycles per minute and a stroke of 1.5 inch in tap water at room temperature. The level of water was adjusted so that the uppermost screen was just covered with water in its highest position. A total of 500 gm. of soil was used with 50 gm. at a time being spread evenly over the top sieve
before starting the sieving process. Sieving was done for 5 minutes after which the screens were removed from the water, placed in pans and put in a draft oven for drying to constant weight at 70°C. The oven dry weight of each sieve separate was determined. Aggregates of different sizes that were separated by dry and wet sieving were subjected to total carbon and carbon-14 analyses by procedures described in the section on analytical technique.

e. Abrasion of aggregate to remove successive shells. The purpose of this study was to see the distribution of carbon throughout the entire aggregates, i.e., whether natural soil aggregates are homogeneous with regard to both native and added carbon content or if a difference exists between their exterior and interior portions. Aggregates for this study were obtained from the experiment in which organic matter which had been composted for 1, 3, 6 or 12 weeks was mixed with the soil and then incubated for 195 days. One sample of untreated soil was also used to serve as a control. Aggregates separated by dry sieving, having the diameter 4.5-4.76 mm. from each of the treatments were selected for this study.

To determine the distribution of carbon in the entire aggregate, arbitrary successive shells from these selected aggregates were obtained by mechanical abrasion. Aggregates were abraded until the diameter was reduced to predetermined value. This was done by the use of a special type of abrasion assembly and a set of sieves with diameter 4.76 mm., 4.5 mm., 4.0 mm., 3.5 mm., 3.0 mm., 2.5 mm., and 2.0 mm., respectively. The detailed procedure is described below.
Fifty gram samples of aggregates with diameter of 4.5-4.76 mm. were placed in a round wide-mouth, screw cap bottle which had No. 2747 sand paper glued to the inside wall of the bottle. This bottle containing the aggregates was put on a roller mixer for two minutes. The fine material removed from the aggregates as well as the aggregates were then placed on a 4.5 mm. diameter sieve. The fine material and those aggregates whose diameter was reduced to 4.5 mm. passed through the sieve. Any aggregate which did not pass the 4.5 mm. sieve, was returned for additional abrasion. This process was repeated until all the aggregates passed through the 4.5 mm. sieve. The fine material was then separated from the 4.5 mm. spheres by using a 0.5 mm. sieve. In this manner six aggregate shells whose dimensions are given in Table 2 were obtained. The spheres which passed the smallest sieve, i.e. 2 mm. diameter, were considered to be the aggregate centers. The total carbon content of the shells and aggregate centers were determined by the dry combustion method and carbon-14 by the method described under analytical procedures.
Table 2. Description and thickness of successive aggregate shells removed by abrasion of aggregates.

<table>
<thead>
<tr>
<th>Aggregate diameter (mm)</th>
<th>Aggregate shell removed (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before abrasion</td>
<td>After abrasion</td>
</tr>
<tr>
<td>4.76</td>
<td>4.5</td>
</tr>
<tr>
<td>4.5</td>
<td>4.0</td>
</tr>
<tr>
<td>4.0</td>
<td>3.5</td>
</tr>
<tr>
<td>3.5</td>
<td>3.0</td>
</tr>
<tr>
<td>3.0</td>
<td>2.5</td>
</tr>
<tr>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Aggregate less than 2 mm. diameter</td>
<td>Aggregate centers</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION


a. Carbon lost as CO$_2$ from various sources of organic matter in the soils is shown in Figures 2-7 for the loss per day and in Figures 8-13 for the cumulative loss. The rate of loss of carbon from the soil organic matter of the untreated soil is represented by the area below the bottom line in the graphs. The area below the top line of the figures indicates the loss of carbon from the soil plus the loss from the added plant material. The area between the top and middle line represents the loss of carbon from the added plant material as determined by the carbon-14 evolved. The area between the bottom line and the middle line represents the priming action of the added organic matter or the stimulation of decomposition of native soil organic matter caused by the added organic matter.

On the basis of the data presented in Figures 2-13, it is evident that the addition of plant material to soil resulted in a marked increase in the rate of decomposition of the native soil organic matter. The nature and magnitude of this increase varied considerably with the soil and the treatment. A rapid loss of carbon from both the soil and added plant material was observed at early stages of incubation which was then followed by a rapid decline in rate of decomposition such that, in about 20 days, the flush of decomposition was over in most of the soils. Thereafter, a somewhat constant, low rate was observed. It may be noted, however, that soils comparatively high in
Figure 2. Evolution of labelled and unlabelled CO₂ carbon from soil incubated for 130 days at 30°C with and without labelled plant material.
Figure 3. Evolution of labelled and unlabelled $\text{CO}_2$ carbon from soil incubated for 130 days at $30^\circ \text{C}$ with and without labelled plant material.
Figure 4. Evolution of labelled and unlabelled CO$_2$ carbon from soil incubated for 130 days at 30$^\circ$C with and without labelled plant material.
Figure 5. Evolution of labelled and unlabelled CO$_2$ carbon from soil incubated for 130 days at 30°C with and without labelled plant material.
Figure 6. Evolution of labelled and unlabelled CO$_2$ carbon from soil incubated for 130 days at 30°C with and without plant material.
Figure 7. Evolution of labelled and unlabelled CO$_2$ carbon from soil incubated for 130 days at 30°C with and without labelled plant material.
Figure 8. Evolution of labelled and unlabelled CO$_2$ carbon from soil incubated for 130 days at 30°C with and without labelled plant material.
Figure 9. Evolution of labelled and unlabelled CO$_2$ carbon from soil incubated for 130 days at 30°C with and without labelled plant material.
Figure 10. Evolution of labelled and unlabelled CO$_2$ carbon from soil incubated for 130 days at 30°C with and without labelled plant material.
Figure 11. Evolution of labelled and unlabelled CO$_2$ carbon from soil incubated for 130 days at 30°C with and without labelled plant material.
Figure 12. Evolution of labelled and unlabelled CO₂ carbon from soil incubated for 130 days at 30°C with and without labelled plant material.
Figure 13. Evolution of labelled and unlabelled CO$_2$ carbon from soil incubated for 130 days at 30°C with and without labelled plant material.
organic matter (Commerce No. 3, Mhoon No. 2), continued to produce considerably higher amounts of CO$_2$, both with and without added plant material, for about 50 days. The priming action was marked at initial stages of incubation and declined rapidly thereafter. In most of the soils maximum priming action was over after about 12 days of incubation, although a considerable amount of priming action was apparent even up to 20 days of incubation. As the incubation was continued to 130 days priming action was negligible.

The total carbon lost from the various sources for the entire incubation period of 130 days is indicated in Figure 14. It is evident that total priming action in 130 days was highest (18 mg. carbon) for Commerce No. 3 with a high content of organic matter compared to the other soils. Notwithstanding this fact, the priming action when observed on a daily basis, especially just after incubation began, was higher in the coarse textured soils with a relatively low supply of native organic matter than in fine textures soils high in organic matter. Similar results were obtained by Hallam and Bartholomew (1953). They observed that the addition of plant residues to the soil resulted in a marked increase in the rate of decomposition of the native soil carbon. Further, they observed that the plant residue addition had a greater stimulating influence on the decomposition of native soil organic matter in coarse textured soil than in fine textured soil.

b. In this experiment, which is similar to the one just described except that evolved carbon was determined at the end of incubation only, three soils (Commerce No. 1, Crowley and Mhoon No. 1) were incubated with and without the addition of plant material. Carbon evolved as
Figure 14. Evolution of labelled and unlabelled CO$_2$ carbon from different soils incubated for 130 days at 30°C with and without labelled plant material.

Soils used:
1. Commerce No. 1
2. Commerce No. 2
3. Commerce No. 3
4. Mhoon No. 1
5. Mhoon No. 2
6. Crowley
\[ \text{CO}_2 \] from untreated soil, treated soil, and plant material during the entire course of incubation is shown in Figure 15. The data indicate that, as was the case in the previous experiment, the addition of plant material resulted in an increase in the rate of decomposition of native soil organic matter as a result of the addition of plant material to the soil. The magnitude of this increase varied with the nature of the soil used but in no case was it as high as in the previous experiment. Commerce No. 1, a soil low in native organic matter content, showed the smallest priming action while Mhoon No. 1, comparatively rich in native organic matter, showed the highest priming action. The Crowley soil, which was intermediate in native organic matter content, showed a moderate amount of priming action. No explanation is offered for the lower priming action exhibited in the second experiment as compared to the first. There was good agreement between replicates of all the treatments, indicating that the difference in priming action between the two experiments was real. A possible explanation may be due to the difference in oxygen concentration in the incubation jars. In the second experiment, in which the soils were maintained in the same incubation jars throughout the experiment, oxygen at a higher concentration than exists in air was frequently added to the jars in order to insure aerobic conditions. A higher oxygen content may have resulted in a lower priming action.

2. Decomposition of Native and Added Organic Matter in Soil at Different Moisture Contents and at Different Soil pH Values

   a. Decomposition of native and added plant material was studied in Commerce No. 1 soil which was maintained at different moisture
Figure 15. Evolution of labelled and unlabelled CO$_2$ carbon from different soils incubated for 130 days at 30°C with and without labelled plant material.
contents. The data obtained are represented graphically in Figure 16. It is evident that the rate of decomposition of soil organic matter increased progressively with an increase in moisture content, reaching a maximum at 30 percent moisture and then declined rapidly with an increase in moisture to 35 percent. A further increase in moisture above this level resulted in a rapid decline of the decomposition of soil organic matter. On the basis of the carbon-14 analysis, there was little effect of moisture content on the decomposition of added organic matter, this loss being about the same at all moisture contents. Even though the decomposition of added plant material was little affected by moisture content, adding the plant material had an accelerating effect on the decomposition of native soil organic matter in the range 10 to 35 percent moisture. The magnitude of this priming action varied considerably with moisture levels. Maximum priming action was observed at 30 percent moisture and decreased rapidly at 35 percent, resulting in a slight negative priming action with a further increase in moisture to 40 percent. A gradual decrease in priming action was also observed as the moisture content was decreased from 30 to 10 percent. With a further decrease to 5 percent a negative priming action occurred. This means that the addition of added plant material retarded the breakdown of native soil organic matter.

The negative priming action at 5 percent moisture content can be attributed to the competition of the added organic matter for the small amount of soil moisture, thereby decreasing the amount available to the soil organic matter. At 40 percent moisture content the excessive amount of water resulted in anaerobic or partially aerobic conditions.
Figure 16. Evolution of labelled and unlabelled CO$_2$ carbon from Commerce silt loam at different moisture contents incubated for 96 days at 30°C with and without labelled plant material.
As a result the microflora were probably dominated by anaerobic and facultative anaerobic bacteria. Since the anaerobic bacteria operate with a lower energy requirement, the process of decomposition is different under anaerobic conditions. Under such conditions the decomposition of the added plant material was not greatly affected, but the breakdown of the native soil organic matter was apparently retarded slightly, resulting in a negative priming action.

b. The effect of soil pH on the decomposition of native and added organic matter was studied on nine soil samples with a pH range of 4.0 to 6.0. The data obtained are given in Table 3.

Table 3. Carbon evolved as CO$_2$ from soil and plant material during incubation of 100 gram samples of amended and unamended soils of different pH.

<table>
<thead>
<tr>
<th>No.</th>
<th>Soil pH</th>
<th>Soil alone</th>
<th>Soil plus plant material</th>
<th>Plant material (calculated)</th>
<th>Priming action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.0</td>
<td>38.48</td>
<td>136.54</td>
<td>94.96</td>
<td>3.10</td>
</tr>
<tr>
<td>2</td>
<td>4.2</td>
<td>48.92</td>
<td>155.45</td>
<td>100.62</td>
<td>5.90</td>
</tr>
<tr>
<td>3</td>
<td>4.7</td>
<td>39.04</td>
<td>148.46</td>
<td>103.45</td>
<td>5.97</td>
</tr>
<tr>
<td>4</td>
<td>4.6</td>
<td>35.39</td>
<td>141.51</td>
<td>101.35</td>
<td>4.77</td>
</tr>
<tr>
<td>5</td>
<td>4.5</td>
<td>28.31</td>
<td>133.87</td>
<td>101.07</td>
<td>4.49</td>
</tr>
<tr>
<td>6</td>
<td>4.8</td>
<td>28.01</td>
<td>132.92</td>
<td>104.22</td>
<td>0.69</td>
</tr>
<tr>
<td>7</td>
<td>5.0</td>
<td>23.95</td>
<td>131.64</td>
<td>107.17</td>
<td>0.52</td>
</tr>
<tr>
<td>8</td>
<td>5.4</td>
<td>29.50</td>
<td>140.65</td>
<td>105.92</td>
<td>5.22</td>
</tr>
<tr>
<td>9</td>
<td>6.0</td>
<td>41.99</td>
<td>155.41</td>
<td>103.78</td>
<td>9.65</td>
</tr>
</tbody>
</table>
No definite and consistent effect of soil pH was observed on the decomposition of added and native soil organic matter in the entire pH range studied. The priming action was apparently highest at pH 6.0 but the significance of this effect should probably not be emphasized since no definite trend in priming action at different pH values was recorded.

The experiments reported in this investigation indicate that the application of highly available energy materials to the soil may accelerate the decomposition of native soil organic matter. This effect was always greatest during the first few days of incubation. The data confirm earlier findings of Lohnis (1926), White (1931), Broadbent (1947), Broadbent and Norman (1948), Hallam and Bartholomew (1953), Sorensen (1963), Bingerman (1953), Mann (1959), Jansson (1960, and Jenkinson (1963) that the addition of plant residues to soil generally resulted in a marked increase in the rate of decomposition of native soil organic matter. The magnitude of this increase varied with the soil, with the plant material added and with the rate of plant residue added. Broadbent and Norman (1948) observed that the addition of plant residue had a greater accelerating effect on the decomposition of native soil organic matter in coarse textured than in fine textured soils. Similarly, in the present study it was observed that coarse textured soil with relatively low native organic matter had a greater priming action on a daily basis than fine textured soils rich in native organic matter. However, the total CO₂ evolved due to the priming action was more in soils rich in native soil organic matter.
It seems difficult to explain why the presence of freshly added plant residue should accelerate the decomposition of the native soil organic matter. Birch (1959) is of the opinion that it is possible that the high rate of organic matter decomposition following the addition of fresh plant residue and the rapid decline in this rate thereafter, is due to the high microbial activity associated with the youthful phase of a developing microbial population, this activity declining as the microbial population ages. Garrett (1956) has suggested that the observed intensification of decomposition of resistant material in the presence of fresh material depends on the supply of initial growth energy to the microbes in order to enable them to attack the resistant material. Park (1956) has indicated that humus decomposition slows almost to a standstill because there accumulates in soil a miscellany of antibiotic or inhibitory substances. Once developed, these materials depress the rate of decomposition to a lower level than that which would otherwise occur. Addition of fresh plant residues, however, counteracts this biostasis and thereby accelerates the decomposition of native soil organic matter.

Jenkinson (1963) has suggested processes which can explain to some extent the existence of priming action. He pointed out that soils contain microbial spores, many of which will germinate on the addition of fresh organic matter. A resting spore respires more slowly than a germinated one so that, in this way, a positive priming action is produced by the accelerated CO\textsubscript{2} production of the spores. It is also possible that some of the products of decomposition may either solubilize or displace some of the native soil organic matter, rendering
it more decomposable. Another possible explanation of the apparent priming effect is that the effect is not real but is due to the greater breakdown of CH₂ groups on organic matter that are composed of carbon-12 as compared to carbon-14. The priming action may also be due to an increase in the concentration of exocellular microbial enzymes following the organic addition, resulting in more rapid breakdown of the native soil organic matter. This explanation is in line with the first explanation of priming action given by Broadbent and Norman (1948) in which the addition of fresh organic matter was linked with fanning of the bacterial fires. With one exception (1953) all of the published work on the priming action has shown that a soil incubated with plant material contains more carbon at the end of a period of incubation than the same soil incubated itself.

The stimulative effect of newly added organic matter on the rate of decomposition of native soil organic matter has an important agronomic implication. The plant material used in this investigation can be compared to green manure crops or crop residues and the results are in line with the failure of green manure crops to be helpful in building or maintaining at a high level the organic matter content of many soils. Furthermore, the influence of added plant material on the rate of decomposition of native soil organic matter may not be of short duration but may continue as long as the residue constitutes an important part of the decomposing mass. It may also explain the fact that green manuring, in most part of the world, has been applied more successfully to increasing the available nitrogen supply over a period of time rather than to increasing the humus content of the soil.
3. Effect of Organic Matter which had been Composted Previously for Various Times on (i) Soil Aggregation, (ii) Contents of Total Carbon and Carbon-14 in Different Sizes of Aggregates, and (iii) Spatial Distribution of Total Carbon and Carbon-14 within Soil Aggregates.

(i) A study was made of the effect of organic matter which had been composted for 1, 3, 6 or 12 weeks before being mixed with the soil on soil aggregation. As shown by the results depicted in Figure 17 it appears that addition of organic matter to the soil generally improved aggregate formation regardless of the initial degree of decomposition of the organic matter. The soil incubated without the addition of organic matter was not only aggregated to a lesser extent but also was dominated by aggregates of smaller sizes. The major effect of adding organic matter was in increasing the amount and extent of large aggregates (>4.6 mm.) and suppression of smaller aggregates (<0.6 mm.). The aggregates having average diameters between 1.0 mm. and 4.3 mm. were least affected by organic matter additions. This general observation is in agreement with the long established fact that the addition of organic matter to the soil improves aggregation. It further supports the earlier work of Baver (1959) which showed that organic matter addition to the soil not only caused a high degree of aggregation but also produced aggregates of large diameter.

No difference was observed in the effect of organic matter composted for various times on the degree and extent of soil aggregation. This infers that different degree of decomposition of organic matter had little or no effect on soil aggregation. Contrary to these results, Martin (1943) and Ensminger and Gieseking (1939), while studying the effect of composts and compost materials on soil aggregation, observed
Figure 17. Effect of organic matter composted for various lengths of time on aggregate distribution (Aggregates of various sizes were separated by dry sieving methods).
that, after composting, the aggregating influence of organic matter decreased and the time required for maximum aggregation to occur increased. They believed that the greater the percentage of readily decomposable constituents the organic material contained the greater was its effect on soil aggregation. The apparent lack of agreement of the work reported here with earlier published results may be due to the fact that the organic material composted for various times in the present study had a high carbon-nitrogen ratio (50:1). With such a low content of nitrogen the decomposition of organic material probably could not have occurred to the extent that it would cause any different effect on soil aggregation.

(ii) The results obtained from the study made on the effect of organic matter which had been composted previously for various times on the contents of total carbon and carbon-14 in various size fractions of aggregates is illustrated in Figures 18-21. Figures 18-19 represent data for various sizes of aggregates separated by dry sieving and Figures 20-21 represent data for wet sieved aggregates. It is evident that the addition of organic matter to the soil increased the carbon content of all the fractions of aggregates studied. In the untreated soil total carbon was relatively low but almost uniformly distributed in the various sizes of aggregates. However, total carbon and carbon-14 contents of various size fractions of aggregates from the treated soil varied considerably. The highest contents of total carbon and carbon-14 were observed in aggregates having 0.21 to 1.0 mm. diameter. Any increase or decrease in aggregate size from 0.21 to 1.0 mm. diameter caused a rapid decline in the carbon contents of
Figure 18. Distribution of total carbon in aggregates of Commerce silt loam separated by wet sieving.
Activity (Disintegrations per minute)

1 week Decomposed
3 weeks Decomposed
6 weeks Decomposed
12 weeks Decomposed

Aggregate Diameter—Millimeter

Figure 19. Distribution of carbon-14 in aggregates of Commerce silt loam separated by wet sieving.
Figure 20. Distribution of total carbon in aggregates of Commerce silt loam separated by dry sieving.
Figure 21. Distribution of carbon-14 in aggregates of Commerce silt loam separated by dry sieving.
aggregates. The content of total carbon and carbon-14 in the larger 
aggregates ranging from 1.0 mm. to 6.4 mm. size fraction was almost 
uniform. In quantitative terms it may be noted the aggregates with 
diameter 0.21 to 1.0 mm. had about 0.43 percent total carbon and an 
activity of about 5000 DPM (disintegrations per minute) of carbon-14. 
All aggregates with diameters more than 1.0 mm. contained about 0.35 
percent total carbon with an activity of about 3000 DPM of carbon-14. 
The data for total carbon and carbon-14 contents of various 
sizes of aggregates separated by wet sieving (Figures 20-21) confirm 
the observations made above for dry sieving. The total carbon and 
carbon-14 contents in different sizes of aggregates separated by wet 
sieving also varied to a great extent as was the case with aggregates 
separated by dry sieving. Aggregates separated by wet sieving were 
more water resistant and presumably more stable than aggregates 
separated by dry sieving. The highest amounts of total carbon and 
carbon-14 were observed in aggregates with diameter 0.21 to 1.00 mm. 
and the least in aggregates of diameter 2.00 to 4.76 mm., aggregates 
having diameter of 1.0 to 2.0 mm. being intermediate in total carbon 
and carbon-14 contents. There was apparently no effect of degree of 
precomposting or organic matter on the contents of total carbon and 
carbon-14 in the various size fractions of aggregates.

No satisfactory explanation can be offered for the higher carbon 
contents of the small size fractions of aggregates (0.21 to 1.00 mm.) 
as compared to the larger aggregates. However, it may be possible 
to explain this higher concentration of carbon in smaller size of
aggregates by a proposed mechanism of aggregate formation. Organic matter added to the soil is acted upon by microorganisms and fungal filaments, and certain decomposition products of bacteria like fats, waxes, oils, proteins, resins etc. are produced. These fungal filaments and decomposition products may serve as nuclei for aggregate formation around which individual soil particles may accumulate to form aggregates. As long as the amount of cementing material in the growing aggregate is sufficient, more and more soil particles will continue to accumulate around it and the soil aggregate will continue to grow. A stage is reached when all the cementing material in the aggregate center will be utilized and the aggregate will not grow further in size without the addition of additional cementing material. The low carbon content of the soil material smaller than 0.21 mm. was probably due to its low content of organic matter and consequently low degree of aggregation which enabled these particles to pass through the 0.21 mm. sieve.

(iii) To determine the spatial distribution of total carbon and carbon-14 within soil aggregates, arbitrary successive shells from aggregates of 4.5 to 4.76 mm. diameter were obtained. Total carbon and carbon-14 determination on aggregate shells and centers (diameter less than 2.00 mm.) were made. The data obtained are presented in Figures 22-23. It may be noted that the total carbon content of aggregate centers was slightly less than that of the outside of the aggregate. Although the difference was not pronounced, it appeared to be consistent. Likewise, a similar trend was noted in the distribution of carbon-14 (Figure 22) where a higher activity was observed in the outer layers
Figure 22. Distribution of total carbon within aggregates 4.50 to 4.76 mm. diameter successive layers removed by abrasion.
Figure 23. Distribution of carbon-14 within aggregates 4.50 to 4.76 mm diameter successive layers removed by abrasion.
of aggregates compared to that of the aggregate centers. The results here are in agreement with the earlier work of Kroth and Page (1947). These workers believed that the slightly higher concentration of carbon found in the outer shells may have been due to luxury accumulation and did not influence the aggregate stability to an appreciable extent.

Regarding the effects of degree of prior decomposition of organic matter on the carbon contents of aggregate shells and centers, the data (Figures 22-23) indicate that aggregate shells and centers from samples receiving organic matter composted for one week had the highest carbon content, that receiving organic matter composted for 12 weeks had the least and that receiving organic matter composted for 3 and 6 weeks were intermediate in their carbon content. These results suggest that soil protects the organic matter from severe decomposition as compared to decomposition of the plant material in the absence of soil.
SUMMARY AND CONCLUSION

A study was made with selected Louisiana soils; Commerce, Crowley, and Mhoon, to determine (1) decomposition of native and added organic matter in soil, (2) decomposition of native and added organic matter in soil as influenced by different moisture contents and different soil pH values, and (3) effect of organic matter which had been composted previously for various times on (I) soil aggregation, (II) contents of total carbon and carbon-14 in different sizes of aggregates, and (III) spatial distribution of total carbon and carbon-14 within soil aggregates.

Barley straw which had been uniformly labelled with carbon-14 was used in this study. Soil samples with and without the addition of plant material were incubated under controlled temperature and moisture conditions. Carbon dioxide which resulted from decomposition of native and applied organic matter was absorbed in standard sodium hydroxide solution and precipitated as BaCO₃ by the addition of BaCl₂. Carbon dioxide production was determined at various time intervals and in some cases only at the end of entire incubation period. The use of an isotope incorporated into the plant material permitted the separation of the carbon lost as CO₂ into two fractions, (1) that coming from the decomposition of the soil organic matter and (2) that arising from the decomposition of added plant material. A comparison of the former with the carbon lost from the untreated soil indicated the existence, nature and magnitude of the priming action.
Addition of plant material to the soil resulted in an apparent marked increase in the rate of decomposition of native soil organic matter. A rapid increase of loss of carbon from the soil and added plant material was observed at early stages of incubation which then was followed by a rapid decrease. The priming action was also marked at the initial stage of incubation and declined rapidly thereafter. Priming action, when observed on a daily basis, especially just after incubation, was higher in coarse textured soil with a relatively low supply of native organic matter than in fine textured soils high in organic matter. The total priming action was higher in soils rich in organic matter than in those poorly supplied with organic matter.

The rate of decomposition of soil organic matter increased progressively with an increase in moisture content, reaching a maximum at 30 percent moisture and declined with further increase in moisture. There was little effect of moisture content on the decomposition of added organic matter. Added plant material had an accelerating effect on the decomposition of native soil organic matter in the moisture range from 10 to 35 percent. However, maximum priming effect was observed at 30 percent moisture and any increase or decrease from this moisture level caused a decline in priming action. At 5 and 40 percent soil moisture content a negative priming action was observed.

No definite and consistent effect of soil pH was observed on the decomposition of added and native soil organic matter in the pH range (4.0-6.0) studied.

Regarding the effect of organic matter on different aspects of soil aggregation, it was observed that the addition of organic matter
to the soil not only increased natural soil aggregation but also produced aggregates of large diameter. The major effect of added organic matter was in increasing the amount and extent of large aggregates (> 4.6 mm.) at the expense of smaller aggregates (< 0.6 mm.). The composting of organic matter for various times before mixing with the soil had little or no effect on soil aggregation.

Total carbon and carbon-14 contents of various size fractions of aggregates varied considerably. The highest contents of total carbon and carbon-14 were observed in aggregates of 0.21 to 1.00 mm. diameter. Any increase or decrease in aggregate size from this value caused a rapid decline in the carbon contents of aggregates. No effect of time of precomposting of organic matter on the contents of total carbon and carbon-14 in various size fractions of aggregates was observed.

It was observed that total carbon and carbon-14 contents of large abraded aggregate shells was slightly higher than the aggregate centers. Although the difference was not pronounced, it appeared to be consistent.

Although some of the results of this study are not conclusive, the evidence gained in these experiments appears definite enough to make the following generalizations.

1. Freshly added plant material stimulated the decomposition of the native soil organic matter in all the soils studied.

2. Priming action was greatest at the beginning of incubation and decreased as incubation proceeded.

3. The rate of priming action, when considered on a daily basis and particularly immediately after incubation, was relatively higher
in coarse textured soils poorly supplied with organic matter than in fine textured soils higher in native organic matter. By contrast, the total priming action over the entire incubation period was higher in fine textured soils rich in organic matter.

4. The maximum priming action was observed at 30 percent soil moisture content; any increase or decrease in this moisture level caused a decline in priming action.

5. When the moisture content of the incubated soil was too low (5 percent), or too high (40 percent), a slight negative priming action was observed.

6. Organic matter addition to the soil not only increased natural soil aggregation but also produced aggregates of large diameter.

7. Considerable variation was observed in the distribution of total carbon and carbon-14 in the different sizes of natural soil aggregates. Relatively higher contents of total carbon and carbon-14 were observed in the small aggregates of 0.21 to 1.00 mm. diameter as compared to larger aggregates with diameter greater than 1.0 mm. or in soil material smaller than 0.21 mm. diameter.

8. No differences were observed in the distribution of total carbon and carbon-14 in the natural aggregates of different sizes ranging from 1.0 to 6.4 mm. diameter.

9. No apparent effect of various time of composting of organic matter on the distribution of total carbon and carbon-14 in different size fractions of natural soil aggregates was observed.

10. Organic matter treated soil showed relatively high carbon content of aggregates as compared to the untreated soil throughout the size range of natural aggregates studied.
11. Total carbon and carbon-14 contents determined in natural soil aggregates were similar in aggregates separated by dry sieving and wet sieving.

12. No differences were observed in the spatial distribution of total carbon and carbon-14 within the abraded aggregate shells with the possible exception of aggregate centers. The carbon contents of aggregate centers were slightly less than the abraded outer shells.
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VITA

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Major Field: Agronomy (Soils)


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Major Professor and Chairman

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Dean of the Graduate School

EXAMINING COMMITTEE:

[Signature]

[Signature]

[Signature]

[Signature]

Date of Examination:

July 18, 1968