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ARTIFICIAL MANURE FROM STRAW

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ARTIFICIAL MANURE FROM STRAW

R. C. COLLISON AND H. J. CONN

ABSTRACT

For some years investigations have been under way at this Station concerning the injury to plants caused by the presence of cereal straw in the soil or other medium in which the plants are growing. The most recent work has been concerned with methods of treating straw to overcome this injurious effect.

While these investigations were in progress, an English method was announced which, it was claimed, would rot straw quickly to an artificial manure.

This method, together with a simple fertilizer mixture which had already been used for the same purpose, was used to rot straw in these experiments.

Both methods, in about three months, rotted the straw to a point where no injurious straw effect was noted on the growth of plants.

The investigations indicated, however, that the labor involved, the large water supply necessary, and the cost made it questionable if the method would be practical under average farm conditions, at least in New York. Where the necessary requirements mentioned can be met, the method is worth a trial.

Cutting down labor and water supply by depending on natural rainfall was not successful in producing a good grade of "artificial manure" within a reasonable time.

INTRODUCTION

During the last decade there has been a remarkable development in methods of producing synthetic fertilizers, especially in Europe. By no means, however, has the same attention been paid to organic manures. Altho mineral fertilizers are fundamentally necessary in agricultural production, they do not supply in any appreciable amount what is probably an equally important ingredient of soils, namely, organic matter. Neither farm practice nor soil research in the United
States has yet ultimately proved that mineral fertilizers, even when used with crop residues characteristic of the best rotations, can entirely replace organic manures.

In England, the results at Rothamsted covering from 70 to 80 years show that when "artificials" replaced organic manures soil deterioration was observed eventually, altho not evident over short periods of time. Organic manures, however, have maintained production at a higher and more uniform level over this long period, and practically no soil deterioration is evident. Further, farm manure proved to possess other valuable properties, evidently not associated directly with its content of minerals.

These facts are of prime importance in soils used for gardening and special cropping systems in which definite rotations providing green manures can not be or are not followed.

Agriculture in Europe is more keenly alive to this need of organic matter than it is in this country. More attention has been paid there to methods of handling, preserving, and storing farm manures and also to the utilization of organic refuse of various kinds.

Within the last few years considerable attention has been paid in England to methods designed to produce quickly from high carbon plant residues, especially straw, valuable organic "artificial manure." This has finally been accomplished in the so-called "Adco" process concerning which there has been considerable inquiry and comment in this country.

**EXPERIMENTAL**

In 1925, this Station reported¹ the results of some investigations on the injurious effects of fresh cereal straw on the growth of plants. It was shown at that time that the effect is apparently due in part to a cause already reported on by a number of other workers, namely, the competition for nitrates which takes place between the plant and the soil micro-organisms which decompose the carbon compounds present in the straw. Some effort had already been made before the above date to rot down straw in such a way as to eliminate its injurious effect while retaining some of the value of its organic matter.

Some preliminary work of this kind was done in 1921 and 1922 on a laboratory scale. In 1923 further work on this point was carried out

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in the greenhouse in 25 gallon stone jars. In the last-mentioned work
fresh straw, chopped and unchopped, was saturated with four dif-
ferent materials, *viz.*, (1) water only; (2) sodium nitrate solution;
(3) ammonium sulfate solution with added calcium carbonate; (4) a
nutrient solution containing sodium nitrate, mono-calcium phosphate,
and potassium sulfate.

The effective decomposition has been judged in three ways—the
general appearance of the mass as a whole, the appearance of the fiber,
and especially the effect of the decomposed straw on the growth of
barley or other plants.

The 1923 work can be summarized as follows:

1. The amount of water used and the degree of aeration are im-
portant factors in the decomposition. A deep vessel closed at the bot-
tom did not permit of proper aeration. Since fresh straw is very difficult
to wet thoroughly at best, some of the solution added tends to collect in
the bottom of the container and thus provides partially anaerobic con-
ditions.

2. Chopping the straw into smaller fragments slowed down the rate
decomposition. This was probably due to better aeration in the
unchopped straw.

3. Solutions containing phosphate and potassium in addition to
nitrogen were more effective than nitrogen alone in causing rapid rotting
down of unchopped straw.

After 13 weeks in the containers at greenhouse winter temperatures
the different lots were examined and comparable amounts of each used
for the growth of barley in sand cultures. A complete nutrient solution
including nitrate was added to all straw cultures as well as to the con-
trols receiving no straw.

The following dry weights (Table 1) of barley tops give some indi-
cation of the effect of the variously treated straw on the growth of the
plants. Each weight is an average of closely agreeing duplicate cul-
tures.

The chopped straw composted for 13 weeks with water only was as
injurious to barley as fresh straw. The unchopped straw similarly
treated was somewhat less injurious. The straw treated with sodium
nitrate was much less injurious to the barley plants, while that treated
with ammonium sulfate and calcium carbonate was still less so. The
unchopped straw treated with a three-salt nutrient solution carrying
nitrogen, phosphorus, and potassium gave as good growth of barley as
Table 1.—Effect of Wheat Straw, Variously Treated, on the Growth of Barley in the Greenhouse.

<table>
<thead>
<tr>
<th>Treatment of straw</th>
<th>Dry weight of barley tops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chopped + water only</td>
<td>6.2</td>
</tr>
<tr>
<td>Chopped + NaNO₃</td>
<td>38.4</td>
</tr>
<tr>
<td>Chopped + (NH₄)₂SO₄ + CaCO₃</td>
<td>44.2</td>
</tr>
<tr>
<td>Chopped + 3-salt solution</td>
<td>37.2</td>
</tr>
<tr>
<td>Unchopped + water only</td>
<td>13.5</td>
</tr>
<tr>
<td>Unchopped + NaNO₃</td>
<td>39.2</td>
</tr>
<tr>
<td>Unchopped + (NH₄)₂SO₄ + CaCO₃</td>
<td>43.1</td>
</tr>
<tr>
<td>Unchopped + 3-salt solution</td>
<td>47.4</td>
</tr>
<tr>
<td>No straw, control</td>
<td>47.3</td>
</tr>
<tr>
<td>Fresh straw at time of planting barley</td>
<td>6.1</td>
</tr>
</tbody>
</table>

the controls. This does not mean, however, that the injurious effect of the fresh straw on barley was completely overcome by 13 weeks' treatment with the nutrient solution. The barley plants in these cultures should and undoubtedly did benefit, as did some of the others, from the nutrients added in the treated straw and, therefore, should have made better growth than the controls, if all injurious straw effect had been eliminated. This fact simply indicates that more of the available carbon compounds had been decomposed in this treatment than in those with nitrogen alone.

From 1924 on the investigations on straw rotting were carried out on a somewhat different and larger scale, owing to the fact that some time before this there had been placed on the American market a commercial patented material which was claimed to rot straw in three or four months to a material closely resembling rotted farm manure.

THE "ADCO" PROCESS

Prior to 1922, H. B. Hutchinson and E. H. Richards at Rothamsted, England, had been working on a method of making artificial manure from straw. It seems that in England much more attention has been paid to the utilization of refuse materials for manurai purposes than in this country. Probably in Europe generally this is more or less true. Thus, H. J. Page² mentions that in Italy the Beccari process of fermentation of organic refuse in a closed chamber is used to produce organic manures. This general subject awakened much interest in England and stimulated investigation.

In 1922, Hutchinson and Richards considered their process suffi-

ciently well developed to place it on a commercial basis, which was done by the organization of a so-called Agricultural Development Company. The object of this company was to develop this process of making artificial manure on a commercial basis. Between 1922 and 1924 there were many demonstration experiments carried out in various parts of England, testing out the Hutchinson and Richards process, or what is now known as the “Adco” process. These experiments seemed to demonstrate clearly that straw can be rotted down to artificial manure by the process in three or four months and that the resulting product compares very favorably, both in chemical composition and effect on the growth of field and garden crops, with good cow or bullock manure.

In 1924, the process was improved by some changes in the character of the ingredients. Less soluble forms of nitrogen and phosphate were substituted in order to cut down the loss of the nutrient materials by leaching thru to the bottom of the pile. The process in both its forms is covered by patents. The method in brief is as follows.

The straw or other refuse organic matter is spread out in a pile, layer by layer. Each layer consisting of about 6 inches of compacted straw is sprinkled with “Adco” reagent at the rate of 150 pounds per ton of dry straw. It is then washed in by thoror wetting with water. Each successive layer is treated in this way until the pile is about 4 feet high. The pile should be left flat on top. Fermentation soon starts and the temperature rises. The temperature is kept down by frequent additions of water until sufficient decomposition has taken place to lower the temperature permanently. Less frequent watering is then required. It is well after considerable rotting has taken place to fork over the top some in order to get the material on top underneath. After some three months, depending on conditions, the straw will be rotted to a mass resembling in general appearance rotted farm manure. It is then ready for use. It is claimed that 1 ton of fresh straw will make from 2 to 3 tons of rotted manure, requiring from 100 to 150 pounds of “Adco”. It should be made clear that this process does not furnish the organisms which decompose the straw, nor has this ever been claimed. It simply furnishes the necessary nutrient medium in which the organisms already present on the straw can more quickly and efficiently do their work.
FURTHER EXPERIMENTAL WORK

The work of 1923 already described indicated that straw could be rotted down by micro-organisms when provided with a proper nutrient medium to such a degree that it was practically non-injurious to the growth of plants. In 1925 further work was done on a larger scale out of doors. Two lots of 500 pounds each of a mixture of oat and wheat straw were separately treated as follows:

One lot was built into a pile by the "Adco" process, using the "Adco" material and following as explicitly as possible the "Adco" directions.

The other lot was built up in approximately the same way, but instead of the "Adco" material a mixture of nutrient salts based on the work of 1923 was used. Since sulfate of ammonia with calcium carbonate had proved more effective than nitrate of soda, it was substituted for the latter. To make the work still more practical commercial acid phosphate and muriate of potash were substituted for the pure salts used in the smaller scale work. They were used in the following quantities per ton of dry straw: Sulfate of ammonia, 60 pounds; ground limestone, 50 pounds; superphosphate, 30 pounds; and muriate of potash, 25 pounds. These were mixed and used according to directions already given.

Since this mixture contains three soluble salts, each layer of straw was partly wet down before the salts were applied so as to prevent too much leaching out.

The two piles rotted in much the same way, the only difference noted was that the temperature went higher in the pile receiving the nutrient salts mixture. The work was begun in July. Three months later both lots seemed to be effectively rotted down to artificial manure, very little difference being noted in the superficial character of the two. The decomposition had possibly gone slightly further in the "Adco" lot which also contained slightly more water. The straw in both lots had completely lost its original character, the material working up in the hands to a pasty mass very similar to rotted manure or wet humus.

VEGETATION WORK WITH THE TWO PRODUCTS

Equivalent amounts of the two lots were used as almost the sole source of nitrogen in sand cultures of barley, rape, and peas, the last being both inoculated and uninoculated. The work was done in the greenhouse in 3-gallon glazed stone jars. Two series of cultures were prepared. One series, in which all three crops were included, was fur-
nished with a complete nutrient solution very low in nitrogen to ins
erse an ample supply of the necessary nutrient ions. To each jar in
this series a standard amount of 300 grams of the artificial manure was
added. The other series of cultures, in which barley was the only crop
employed, was given no nutrients except those in the artificial manure.
In this series three different quantities of artificial manure (200, 300,
and 500 grams, respectively, per jar) were employed in order to de-
termine if the compost still contained enough undecomposed straw to
give an injurious effect.

Each jar contained 25 pounds of sand. The same number of uni-
form plants were grown in each jar and the optimum moisture main-
tained in the usual manner. At the same time cultures with the same
nutrients without manure and others with fresh straw were used as
controls. All treatments were in duplicate. The crops were harvested
after nine weeks and green weights taken.

Table 2 gives these weights, the figures being the mean of duplicate
cultures.

The low yields of the controls were due of course to the low content
of nitrate of the nutrient solution. This is reflected in the weight of
the cultures of inoculated peas which is nearly double the weight of
those uninoculated.

Fresh straw, as usual, was exceedingly detrimental to barley and rape,
killing the plants of the latter completely. The uninoculated peas made
some growth in the presence of straw, while the inoculated peas made
considerable growth. This difference is in agreement with what has
been mentioned in a former publication on this straw effect, namely,
that additional nitrogen overcomes the injury. If the plants had been
allowed to mature, the difference might have been still more marked.
It is interesting to note that legumes, which have the property of fixing
atmospheric nitrogen in symbiosis with bacteria, seem to be independ-
ent, to some extent at least, of this nitrate competition after the
symbiosis is established.

The manure made with the fertilizer salts greatly increased the
growth of all plants, more than doubling the yield in all crops except
the inoculated peas. These results did not show injurious straw effect.

The results on barley of increasing quantities of the manure without
additional nutrients also indicated no injury due to straw. Each incre-
ment of manure increased the yield, 500 grams of manure alone giving
a higher yield than 300 grams of manure with nutrient salts in addition.

The results with "Adco" manure, however, are difficult to explain.
<table>
<thead>
<tr>
<th>Crop</th>
<th>Treatment</th>
<th>Weight in grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>Nutrient solution, no manure</td>
<td>20.6</td>
</tr>
<tr>
<td>Rape</td>
<td>Nutrient solution, no manure</td>
<td>18.4</td>
</tr>
<tr>
<td>Garden peas</td>
<td>Nutrient solution, no manure</td>
<td>31.6</td>
</tr>
<tr>
<td>Peas, inoculated</td>
<td>Nutrient solution, no manure</td>
<td>57.8</td>
</tr>
<tr>
<td>Barley</td>
<td>Nutrient solution, fresh straw</td>
<td>1.9</td>
</tr>
<tr>
<td>Rape</td>
<td>Nutrient solution, fresh straw</td>
<td>11.0</td>
</tr>
<tr>
<td>Garden peas</td>
<td>Nutrient solution, fresh straw</td>
<td>24.7</td>
</tr>
<tr>
<td>Peas, inoculated</td>
<td>Nutrient solution, fresh straw</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>Nutrient solution + 300 grams artificial manure</td>
<td>43.5</td>
</tr>
<tr>
<td>Rape</td>
<td>Nutrient solution + 300 grams artificial manure</td>
<td>47.5</td>
</tr>
<tr>
<td>Garden peas</td>
<td>Nutrient solution + 300 grams artificial manure</td>
<td>70.0</td>
</tr>
<tr>
<td>Peas, inoculated</td>
<td>Nutrient solution + 300 grams artificial manure</td>
<td>73.6</td>
</tr>
<tr>
<td>Barley</td>
<td>Nutrient solution + 300 grams artificial manure (&quot;Adco&quot;)</td>
<td>32.1</td>
</tr>
<tr>
<td>Rape</td>
<td>Nutrient solution + 300 grams artificial manure (&quot;Adco&quot;)</td>
<td>31.3</td>
</tr>
<tr>
<td>Garden peas</td>
<td>Nutrient solution + 300 grams artificial manure (&quot;Adco&quot;)</td>
<td>30.3</td>
</tr>
<tr>
<td>Peas, inoculated</td>
<td>Nutrient solution + 300 grams artificial manure (&quot;Adco&quot;)</td>
<td>30.8</td>
</tr>
<tr>
<td>Barley</td>
<td>200 grams artificial manure (salts mixture) only</td>
<td>27.7</td>
</tr>
<tr>
<td>Barley</td>
<td>300 grams artificial manure (salts mixture) only</td>
<td>34.2</td>
</tr>
<tr>
<td>Barley</td>
<td>500 grams artificial manure (salts mixture) only</td>
<td>46.3</td>
</tr>
<tr>
<td>Barley</td>
<td>200 grams artificial manure (&quot;Adco&quot;) only</td>
<td>21.3</td>
</tr>
<tr>
<td>Barley</td>
<td>300 grams artificial manure (&quot;Adco&quot;) only</td>
<td>25.0</td>
</tr>
<tr>
<td>Barley</td>
<td>500 grams artificial manure (&quot;Adco&quot;) only</td>
<td>32.0</td>
</tr>
</tbody>
</table>
Soon after the barley seedlings had established themselves, the leaf margins and tips yellowed and then turned almost white. This effect became gradually more marked. The rape plants also began to show white leaf margins, while the peas were stunted. None of the crops made good yields. Inoculation gave no increase in peas. The increasing quantities of the manure caused some increase in yield of barley, but such increase was small and all plants were badly affected with whitening leaf tips.

This effect was quite different from the injurious effect due to the presence of fresh straw. In fact the "Adco" manure seemed, if anything, to have reached a slightly more advanced stage of decomposition than the other manure. All plants appeared as if affected directly by some toxic agent, which probably had an injurious action also on the legume organisms used for inoculation of the peas.

The only explanation which could be thought of is based on the probable composition of the "Adco" reagent. If calcium cyanamide is used as a source of nitrogen and lime, all the former may not be changed into the form of ammonia during the period of composting. It is well known that cyanamide and some of the products formed from it in the ammonifying process are anything but beneficial to plants. This may be a possible explanation of the injury noted. The failure to ammonify might be attributed to a lumpy condition of the reagent and the later incorporation of some of the unchanged material into the sand cultures in which absorption of any injurious material would be inappreciable and ammonification probably at a minimum.

This fact should not be considered a serious objection to the "Adco" reagent, as it must be emphasized that the present investigations were made with sand cultures. This injurious effect undoubtedly would not be a serious factor when the artificial manure is applied to soils instead of to quartz sand. It must be acknowledged, in fact, that in the many practical trials in which the process has been used both in England and in this country no observations of injurious results have come to the writers' attention.

COMPOSTING WITHOUT ARTIFICIAL WATERING

In the course of this work the question arose as to whether the large amount of water necessary could be supplied entirely or in part by natural rainfall. The first experiment to determine this was made during the winter and spring of 1925-26. Since straw is usually available in the fall and manure largely used in the spring, it seemed most
logical to make the piles in the fall or early winter. Accordingly, some heaps similar to those already described were constructed on December 1, 1925. They were made up in the usual way, except that the reagents were more carefully scattered and no water added. The piles were also more firmly compacted. No subsequent forking over was done.

Altho rainfall was considerable in December, snowfall abundant during the winter, and the early spring rains normal, comparatively little rotting had taken place by May 1, 1926. Even at the end of a year these piles contained much undecomposed straw and appeared to be in poor condition to use for manuring. No vegetative work was done, however, to see whether or not the harmful effect on plants had been overcome by this method of treatment.

The slowness of the decomposition seemed to render this method of handling impractical under the conditions prevailing during this experiment. At the same time it had to be admitted that in a wetter season or in a region of higher temperatures and more abundant rainfall than that of western New York, the method might be effective within a reasonable time. It was also felt that two or three simple changes in the method of handling might be made to expedite the decomposition under conditions normal in this region. For example, it might assist considerably if the composting were started immediately after the wheat harvest, thus taking advantage of the warmer weather during the late summer and early fall. Moreover, it might be possible to secure effective rotting by supplementing the rainfall with additional water. Also, the use of some substance or chemical capable of holding moisture might hasten the process.

It was decided to investigate this last point, as it seemed the most practical. In the fall of 1927 five bins, each 8 feet square, were constructed outdoors and were filled on November 22 with wheat straw together with the various ingredients chosen to bring about the decomposition. Two methods of holding moisture were adopted, viz., sprinkling of calcium chloride over the successive layers of straw, and spreading muck over each of these layers. The muck used in this work was obtained from a field at Junius, about 5 or 6 miles northeast of the station. This muck when dug was nearly saturated with water and about 1 ton of the fresh material was used in all. As three bins were treated with the muck, it was figured that about 600 pounds, equivalent to perhaps 200 pounds dry muck, were added to each, altho no accurate measurement was made. The composition of the five composts was as follows.
Composition No. 1.—Straw, 500 pounds; ammonium sulfate, 20 pounds; calcium carbonate, 15 pounds; superphosphate, 10 pounds; potassium chloride, 8 pounds; wet muck, 600 pounds.

Composition No. 2.—Straw, 500 pounds; ammonium sulfate, 15 pounds; calcium carbonate, 12 pounds; superphosphate, 8 pounds; potassium chloride, 6 pounds; calcium chloride, 50 pounds.

Composition No. 3.—Straw, 500 pounds; ammonium sulfate, 15 pounds; calcium carbonate, 12 pounds; superphosphate, 8 pounds; potassium chloride, 6 pounds.

Composition No. 4.—Straw, 500 pounds; ammonium sulfate, 15 pounds; calcium carbonate, 12 pounds; wet muck, 600 pounds.

Composition No. 5.—Muck only, 600 pounds.

No water was added to any of these composts except that which they received from the natural rainfall. There was considerable rainfall soon after the composts were set up so that they were much more completely saturated with water before freezing than had been the composts in 1925.

It is of interest to record the cost of the ingredients added to each of these composts per ton of straw. These were as follows: Compost No. 1, $3.70; compost No. 2, $6.80; compost No. 3, $2.80; compost No. 4, $2.00; and compost No. 5, nothing. To these figures must be added, first, the cost of the labor of preparation and of the muck in composts Nos. 1, 4, and 5, if this had to be purchased, and second, the value of the straw for which the farmer in this region under present conditions can obtain about $8.00 a ton.

In the spring it was evident that some of these composts were rotting more rapidly than those prepared during 1925-26, especially composts Nos. 1 and 4. Nothing was done to the composts at this time, however, and they were left undisturbed until fall, when it was more convenient to carry on greenhouse work to determine whether or not the harmful properties of the straw had been destroyed. They were finally removed October 29, 1928, at which time representative samples were taken to use in the vegetative work. At this time compost No. 1 was well rotted in the center, No. 2 was not much rotted, No. 3 was fairly well decomposed, No. 4 was very well rotted, while almost no decomposition had taken place in No. 5. In this last compost, which had been given muck alone, the straw was blackened, but still coarse and undecomposed. It was apparent that calcium chloride had not aided the decomposition, while decomposition had gone on much more rapidly with the muck than with the fertilizer ingredients alone. It was also evident that muck sup-
plied all the nutrient elements necessary, except the nitrogen, for the decomposition organisms. Muck alone, however, was entirely insufficient for the purpose.

It was planned to carry on vegetative experiments with these composts, altho it was realized that no good checks on the different composts could be run. Each of the composts had a different amount of nutrient elements added to it, and they must, therefore, vary a great deal not only in the state of the straw, but in their fertilizer value due to the mineral matter added. It was impossible to plan satisfactory checks because there was no way of telling how much of these original nutrients were still present and how much had leached out during the 11 months of composting. It was decided, therefore, merely to set up a series of greenhouse cultures containing three arbitrarily chosen quantities of each compost without further nutrients, and to check these against other cultures containing mineral nutrients and different quantities of nitrogen with and without fresh straw. It was considered that this would at least show whether or not the composting had eliminated the harmful effect of the straw.

In this greenhouse work each culture was set up in a pot containing

Table 3.—Results of Greenhouse Work on Composts Prepared Without Artificial Watering.

<table>
<thead>
<tr>
<th>Pot No.</th>
<th>Grams of straw or compost added</th>
<th>Mineral nutrients added</th>
<th>Dry weight in grams of crops after seven weeks’ growth*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. 1, 200</td>
<td>None</td>
<td>2.00</td>
</tr>
<tr>
<td>2</td>
<td>No. 1, 400</td>
<td>None</td>
<td>2.85</td>
</tr>
<tr>
<td>3</td>
<td>No. 1, 800</td>
<td>None</td>
<td>5.50</td>
</tr>
<tr>
<td>4</td>
<td>No. 2, 200</td>
<td>None</td>
<td>1.80</td>
</tr>
<tr>
<td>5</td>
<td>No. 2, 400</td>
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<td>1.90</td>
</tr>
<tr>
<td>6</td>
<td>No. 2, 800</td>
<td>None</td>
<td>2.15</td>
</tr>
<tr>
<td>7</td>
<td>No. 3, 200</td>
<td>None</td>
<td>1.80</td>
</tr>
<tr>
<td>8</td>
<td>No. 3, 400</td>
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<td>2.00</td>
</tr>
<tr>
<td>9</td>
<td>No. 3, 800</td>
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<td>4.20</td>
</tr>
<tr>
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<td>No. 4, 200</td>
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<td>2.80</td>
</tr>
<tr>
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<td>No. 4, 400</td>
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<td>3.70</td>
</tr>
<tr>
<td>12</td>
<td>No. 4, 800</td>
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<td>4.40</td>
</tr>
<tr>
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<td>No. 5, 200</td>
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</tr>
<tr>
<td>14</td>
<td>No. 5, 400</td>
<td>None</td>
<td>1.40</td>
</tr>
<tr>
<td>15</td>
<td>No. 5, 800</td>
<td>None</td>
<td>1.80</td>
</tr>
<tr>
<td>16</td>
<td>Fresh straw, 54</td>
<td>Complete, with NaNO₃, 0.5 gram</td>
<td>1.20</td>
</tr>
<tr>
<td>17</td>
<td>Fresh straw, 54</td>
<td>Complete, with NaNO₃, 1 gram</td>
<td>2.10</td>
</tr>
<tr>
<td>18</td>
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<td>Complete, with NaNO₃, 0.5 gram</td>
<td>6.70</td>
</tr>
<tr>
<td>19</td>
<td>None</td>
<td>Complete, with NaNO₃, 1 gram</td>
<td>8.00</td>
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<tr>
<td>20</td>
<td>None</td>
<td>Complete, except for nitrogen</td>
<td>1.35</td>
</tr>
</tbody>
</table>

*These seedlings were allowed to grow until they had apparently reached a growth limit, due to lack of nitrogen.
30 pounds of Ottawa sand mixed with 8 grams of calcium carbonate. Forty-two barley seeds were planted in each pot and the seedlings thinned to 21 plants. The nutrient solution added to pots Nos. 16 to 19 contained the following:

\[
\text{Ca}(\text{H}_3\text{PO}_4)_2 \cdot \text{H}_2\text{O} \quad \text{1.8 grams per culture}
\]
\[
\text{K}_2\text{SO}_4 \quad \text{3.5 grams per culture}
\]
\[
\text{MgSO}_4 \cdot 7\text{H}_2\text{O} \quad \text{1.2 grams per culture}
\]

The plan of this experiment and the dry weights of the plants when harvested seven weeks after sowing are given in Table 3.

The following notes, taken on December 10, are also of interest, as indicating the nutrient value of the various composts. On this date it was noted that the seedlings in composts Nos. 1, 3, and 4 increased in size and color with the increasing quantities of the compost added. With composts Nos. 2 and 5, on the other hand, the seedlings were about the same in all three of the pots regardless of the quantity of compost added. This, of course, indicated that composts Nos. 2 and 5 had no nutrient value for the barley seedlings, a fact borne out by dry weights of the crops at the end of the experiment. In the case of pots containing fresh straw the seedlings had poor color and were very small, the culture with 1 gram of nitrate being no better than the one with only 0.5 gram. The two pots with mineral nutrients including nitrogen showed good growth, as was to be expected.

For the reason stated above, this was not regarded as a scientifically controlled experiment and sweeping conclusions are not justified. A few points are apparent, however. It is possible, as shown by the results with compost No. 3, to overcome the harmful effects of the straw by composting under natural rainfall without anything present to absorb the moisture except the straw, provided a long enough period is employed. The composts apparently were slightly better fertilizers when muck had been incorporated with them, but whether this was due to the fertilizing value of the muck itself or to the better decomposition of the straw in its presence was undetermined. Muck alone did not bring about any decomposition of the straw or convert it into a good manure, for the seedlings supplied with compost No. 5 made no better growth than in the pots with fresh straw or those with no nitrogen. Calcium chloride was plainly unsatisfactory as a means of holding or attracting moisture, as it apparently prevented the conversion of the straw into a satisfactory manure. The plants grown with this compost were no better than those with fresh straw.
DISCUSSION

It has been clearly shown that if some care is taken in forming and maintaining the compost piles, both of the nutrient reagents used will help effectively to rot down straw to artificial manure in three or four months. At the same time the injurious straw effect is practically overcome. Proper care involves a number of operations, as follows:

1. Proper building of the pile.
2. Proper treatment with reagent.
3. Adequate watering.
4. Subsequent watering to keep down the temperature and keep the pile moist.
5. Occasional forking over.

All these operations require considerable labor. Further, the process necessitates an adequate water supply. This is not always available. Water is required in large volume, especially if much straw or other dry refuse is handled. It is estimated that 800 gallons per ton of dry straw is necessary during the formation of the heap. Daily watering of the heap during the initial fermentation may be necessary.

If it is convenient for a farmer to keep his compost piles exposed to natural rainfall for a period of 10 months, or possibly for only 6 or 8 months, a certain amount of rotting can be obtained without the amount of labor required in artificial watering, provided the natural rainfall is sufficient in his locality. This process can be hastened by mixing the compost with peat or muck, if such material is available.

It is very questionable whether the process is practical for the general New York farmer if he has to use artificial watering to maintain the moisture content. The farmer generally considers that labor conditions in this region do not justify him in giving the farm manure itself the attention necessary to prevent loss of nutrients. Such being the case, he is hardly likely to furnish the amount of labor required for composting straw when artificial watering is necessary. He probably could get much greater return from the amount of labor spent in the proper handling of farm manure.

Whether or not the plan of composting the straw under natural rainfall is practical, must be decided by the farmer himself. This would depend upon the amount of rainfall in the fall and spring in his particular locality, and also upon whether it is feasible for him to allow the composts to stand for the greater part of a year before making use of them as manure.
To the market gardener the process may prove a help, or to anyone who is willing to give the process the attention demanded; or again, under conditions where water is easily and cheaply obtainable. In regions or countries where farm economics are on a different basis from that of New York, the process might be useful.

The cost of the process is of course a further consideration. Besides the labor involved is the value of the straw itself and the cost of the reagents. The cost of the 165 pounds of fertilizer mixture described on page 8 for treating 1 ton of dry straw varies from $2.50 to $3.50, based on 1927 fertilizer prices. The straw itself may be sold by the farmer under present conditions for about $8.00 a ton. As one ton of straw does not yield over 3 tons of artificial manure, this makes the final product cost at least $4.00 a ton, regardless of the labor involved. Such a cost is hardly justified in this locality at present.

It should be remarked further that the cost of preparing the compost is very much greater if one uses the “Adco” reagent now on the market. The company selling this reagent insists that their patents cover the entire process and that no one can use any other nitrogenous material for the composting of straw or similar refuse without infringing on their patent. Whether or not these claims are justified legally is being determined at present by a lawsuit under way in the state of Missouri.

The conclusion seems almost unavoidable that under New York conditions this process of making artificial manure hardly seems practical. This is particularly true if one must depend upon artificial watering, or if one has to employ the “Adco” reagent, as it is claimed, in order to avoid infringement upon the patent rights of the company selling this reagent.