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<table>
<thead>
<tr>
<th>Name and Address</th>
<th>Date</th>
</tr>
</thead>
</table>

VIABILITY OF WEED SEEDS

IN

MANURE AND SILAGE

A Thesis

Presented in Partial Fulfillment of the Requirements

For the Degree of Master of Science

By

William Shevkenek

University of Saskatchewan

1934
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>IMPORTANCE</td>
<td>2</td>
</tr>
<tr>
<td>REVIEW OF LITERATURE</td>
<td>3</td>
</tr>
<tr>
<td>METHODS AND PROCEDURE</td>
<td>6</td>
</tr>
<tr>
<td>Plan of Experiments</td>
<td>6</td>
</tr>
<tr>
<td>Technique and Equipment</td>
<td>8</td>
</tr>
<tr>
<td>RESULTS</td>
<td>13</td>
</tr>
<tr>
<td>Results of Other Experiments</td>
<td>19</td>
</tr>
<tr>
<td>Some European Results</td>
<td>21</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>23</td>
</tr>
<tr>
<td>Discussion of Experiments</td>
<td>26</td>
</tr>
<tr>
<td>SUMMARY AND RECOMMENDATIONS</td>
<td>29</td>
</tr>
<tr>
<td>LITERATURE CITED</td>
<td>31</td>
</tr>
</tbody>
</table>

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INTRODUCTION

At the suggestion of E.S. Hopkins the Dominion Field Husbandman, the officials of the Experimental Station at Scott, Saskatchewan, Mr. G.D. Matthews, the Superintendent, and Mr. F.V. MacIsaac, the Assistant Superintendent in Field Husbandry, decided to have experiments conducted to determine the viability of weed seeds in manure. The writer was intrusted with the problem and left to work out his own technique. Because there was no literature on this subject, available at that time, and because it was desired to have the experiments started at once in the spring of 1933, the writer had nothing to be guided by in the working out of methods and technique. For these reasons, the methods and technique used were not as scientific as they might have been.

Similar experiments had been set out in 1930 by W.J. White, a student, at that time, working at this same place. In the following year the recovery of the weed seeds set out in this experiment was frustrated by the corrosion of the wire leads from the outside to each lot of weed seeds in the metal containers made from a fine copper alloy screen. This experiment was a complete failure, so the writer avoided the technique used in it.

Along with the main project, experiments with regard to technique were also carried out.

The writer is very much indebted to Mr. G.D. Matthews for the permission to use this work as a basis for this thesis, and to Mr. F.V. MacIsaac for the supervision and assistance, and also to Mr. T. Pavlychenko, Weed Research Assistant at the
University of Saskatchewan, for the weed seeds used in these experiments.

IMPORTANT

Where manures are spread out on the fields, this problem is extremely important, but where manures are hauled out into the pastures or some pot hole and there burned or left, never to be utilized, weed seeds in manure are of no concern. However, the majority of the farmers do spread the barnyard manures, either fresh or rotted. This is particularly true in the more densely populated regions where manure is appreciated for its fertilizing value, and is therefore used to greatest advantage. Here in the West, especially in the Great Plains region, where the soil does not yet respond very greatly to the application of manure, many farmers do not bother with spreading manure on the fields. Many do not do so for the simple reason that manuring pollutes the land with weed seeds. This is true especially of fresh manure.

If the results obtained in the working out of this problem are going to assure the farmers that if they follow a certain procedure in the methods of storing manures, after a certain length of time they can spread the same on the fields without the least bit of danger of spreading viable weed seeds, the experiments carried out will have been fully justified.
REVIEW OF LITERATURE

Perhaps the best work in regard to this problem, on this continent, was done at Maryland Agriculture Experiment Station, which is reported in its bulletin, No. 128, "The Effect of Animal Digestion and Fermentation of Manure on the Viability of Seeds." The following is a brief summary of the Maryland findings:

1. When manure is allowed to ferment in piles for 6 months, no danger of distributing weed seeds is incurred.
2. When manure is allowed to remain in piles and undergoing partial fermentation, little danger of distributing weed seeds is incurred.
3. When the manure was hauled out directly from the stable as top dressing, an average of only 12.8 percent of the seeds fed to animals germinated.
4. When manure was hauled out directly from the stable onto the land and plowed under, 2.3 percent of the seeds fed to animals came up.
5. Where the droppings remained on the pasture fields as they fell, an average of only 3.1 percent of the seeds fed to the animals germinated.

It is a well established fact that weed seeds pass through the alimentary tracts of animals without having their viability impaired. Professor A.L. Stone (5) in this regard says, "As a matter of fact, it has been shown that some weed seeds are even in better condition to germinate after having passed through the alimentary tract." Korsmo (1) in summar-
izing his own work and that of many other European workers on this problem, has figures to show just what percentages of the different weed seeds remain viable in the dung of every farm animal. In brief, his results show that none of the farm animals can digest weed seeds completely. A hen's digestion kills more weed seeds than does that of any other domestic animal. A sheep ranks next in this respect, with a pig, a horse and a cow following in the order mentioned.

Stone (5) has made some discoveries with respect to purity of commercial feeds, that are astounding. He found that screenings, bran, oilcake, and mixed feeds, all contain quite a large percentage of weed seeds. Here is his statement, "A farmer noticing some dark specks in oilcake sent a sample to the Experiment Station to be examined and to the amazement of all concerned, the feed was found to contain 10 percent of weed seeds by weight, or approximately 128,484,000 unground weed seeds per ton. Included were noxious weed seeds. Some bran which was examined, was found to contain 108,256,900 weed seeds per ton, represented by 32 different kinds. Another farmer was feeding unground screenings to his sheep, which contained 55.52 percent of weed seeds by weight. Chick feed offered on the market also contains a great deal of weed seeds."

He goes on to say, "It seems then that it is hardly safe to haul manure directly onto the field. Suppose it is necessary to use such feed, can anything be done to prevent the infestation of the fields? The answer is yes.

Piling manure in piles eight or more feet in depth and leaving it there for two months will destroy the weed seeds. The fermentation of manure generates enough heat to destroy
the viability of the moistened and softened seeds.

At the time of hauling, the surface manure one foot or so in depth, should be taken off and repiled for a time, because it is not likely that any weed seeds get killed in the surface manure where it is too dry for fermentation to take place.

Another source of trouble are the manure piles themselves, for if they are left for a number of years they become excellent breeding places for weeds. A manure pile left untouched will soon have weeds grown all over and around it. These ripen and shatter seed right on the manure. This might be the main source of infestation on fields which have received applications of well rotted manure which should be absolutely free from viable weed seeds according to experimental results."

Other literature, for the sake of comparison of results, is discussed under another section.
METHODS AND PROCEDURE

Plan of Experiments

The whole study at Scott Experimental Station consisted of nine different experiments or tests. Briefly the objects of each could be listed as follows:

1. To find the effects on weed seeds left in fresh horse manure for one month.
2. To find the effects on weed seeds left in fresh cow manure for one month.
3. To find the effects on weed seeds left in manure for three months.
4. To find the effects on weed seeds left in manure for six months.
5. To find the effects on weed seeds left in manure for one year.
6. To find the effects on weed seeds left in manure for two years.
7. To find the effects of fresh manure kept wet on weed seeds left in it for one month.
8. To find the effects of fresh manure kept wet on weed seeds left in it for one month in non-metal containers.
9. To find the effects of three months of manure temperature on weed seeds.

These experiments were not started the same day nor were they set out in the order listed. Experiments 4 and 5 were set out first, on May 20. The best equipment was put into these two experiments.
The thermograph was registering temperature in Experiment 5. It was assumed that the temperatures in Experiments 3, 4, 5, and 6, will have been very similar, for in setting out each one of these it was aimed that the conditions, - depth of bed from the surface, character of bed on which the weed seeds were placed, and the kind of manure on top of the weed seeds, - should be as similar as possible.

All of these four experiments were set in ten feet from the east side of the pile, and about ten feet apart. Four other experiments were set in or near the corners at the ends of the pile. Test 9 was set in with Experiment 3. Below is a diagram showing the location of the Experiments in the manure pile over which loads were hauled and more manure added.
Table I

Germination Results

<table>
<thead>
<tr>
<th>Kind of Weed Seeds</th>
<th>Check</th>
<th>Exp. 1</th>
<th>Exp. 2</th>
<th>Exp. 3</th>
<th>Exp. 4</th>
<th>Exp. 5 &amp; 6</th>
<th>Exp. 7</th>
<th>Exp. 8</th>
<th>Exp. 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ball Mustard</td>
<td>53</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. Blue Bur</td>
<td>67</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3. Canada Thistle</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4. Cow Cockle</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>5. False Flax</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6. False Ragweed</td>
<td>13</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7. Hare's-ear Mustard</td>
<td>44</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8. Lamb's Quarters</td>
<td>76</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9. Night-flowering Catchfly</td>
<td>87</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10. Peppergrass</td>
<td>34</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11. Purslane</td>
<td>49</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12. Quack Grass</td>
<td>62</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13. Red-root Pigweed</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14. Russian Pigweed</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15. Russian Thistle</td>
<td>12</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>16. Shepherd's Purse</td>
<td>56</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>17. Sow Thistle perennial</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>18. Stinkweed</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>19. Sweet Clover</td>
<td>98</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>20. Tansy Mustard</td>
<td>(200)</td>
<td>65</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>21. Tumbling Mustard</td>
<td>(200)</td>
<td>68</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>22. Wild Buckwheat</td>
<td>51</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>23. Wild Mustard</td>
<td>26</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>24. Wild Oats</td>
<td>70</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>25. Worm-seed Mustard</td>
<td>(200)</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Technique and Equipment Used

The weed seeds used in each experiment, and the germination results for both the check and the weed seeds after they had been removed from each test, are given in Table I, on the opposite page. All the weed seeds except Wild Oats were obtained from the University of Saskatchewan Weed Nursery and were raised in 1930. Wild Oats was obtained from the local elevator and was presumably 1932 seed.

The weed seeds were counted and put in packets before setting put, 100 of the coarser seeded and 200 of the fine seeded ones, for all experiments except 8 and 9. In these two they were counted out after being removed and before setting to germinate.

The packets were made from Monel Metal Wire Screening which is an alloy of nickel and copper, made by the B. Greening Wire Co., Hamilton, Ontario. This Monel Screen Cloth was of a size 32 meshes per inch and let through fine seeds such as Peppergrass, Tansy Mustard etc. As indicated in Table I, 200 seeds of each of these were counted out. These fine seeds were first put in a small paper packets or envelope which was inserted into the metal packet. It was hoped that if the paper rotted away it would partly close the meshes by forming a pasty mass and thus prevent the weed seeds from coming out of the closed packets.

For identification purposes a tag was attached to each packet. In Experiments 4 and 5, numbered brass tags were attached to the packets by means of steel wire which was about one tenth of an inch in diameter. As a precaution, these tags
were from 6 to 10 inches away from the packets attached so far away to keep away any chemical reactions which might result from the interaction of manure acids and the brass, which might corrode the weed seeds and kill them.

In Experiments 1, 2, 3, 6, and 7, rubber tags were used. These were homemade from a rubber auto tube. They were attached to the packets by rolling one end in with the open end of the packets when sealing the latter. The other end of the tag was cut into strips, the number of these indicating the number of the packet. A notched strip or fringe indicated number 10. Diagrams showing packets and tags will be found on the following page.

Lack of weed seeds and equipment were the limiting factors in setting up more elaborate experiments.

In every case the packets were laid in a circle one to two feet in diameter, in the centre of which was placed vertically a post of known length, around which manure was packed in covering up the packets. This was a 2 x 2 piece of lumber of suitable length not exceeding 36 inches in length. A plan on paper was made of all details with exact measurements, as to how the packets were arranged and the exact measurements for locating each experiment from fixed posts just outside the manure pile. With further piling on of manure these posts in the centre of each experiment were completely covered up and driven over with subsequent loads. At the time of removal there was no difficulty in locating each experiment from the external markings.

In making a bed on which to lay the packets containing the weed seeds, for Experiments 3, 4, 5, 6, and 9, fresh undecomposed manure was thrown aside until a rather hard bed of partly
Packet used in Experiments 4 and 5.

Packet used in other Experiments.

Rubber labels

Indicating No. 14.

Indicating No. 22.
Table II

Outline of Procedure and Some Results

<table>
<thead>
<tr>
<th>Experiment Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Time in</td>
<td>1 month</td>
<td>1 month</td>
<td>3 months</td>
<td>6 months</td>
<td>1 year</td>
<td>2 years</td>
<td>1 month</td>
<td>1 month</td>
<td>3 months</td>
</tr>
<tr>
<td>Manure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date Experiment Set Out</td>
<td>May 27</td>
<td>May 27</td>
<td>May 26</td>
<td>May 20</td>
<td>May 20</td>
<td>May 26</td>
<td>July 14</td>
<td>Aug. 23</td>
<td>May 26</td>
</tr>
<tr>
<td>Date Experiment Taken Out</td>
<td>June 27</td>
<td>June 27</td>
<td>Aug. 28</td>
<td>Nov. 13</td>
<td></td>
<td></td>
<td>Aug. 14</td>
<td>Sept. 23</td>
<td>Aug. 28</td>
</tr>
<tr>
<td>Number of Kinds of Weed Seeds *</td>
<td>7</td>
<td>6</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>13</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Depth of Manure above Seeds When Set Out</td>
<td>26 inches</td>
<td>26 inches</td>
<td>38 inches</td>
<td>38 inches</td>
<td>40 inches</td>
<td>40 inches</td>
<td>24 inches</td>
<td>24 inches</td>
<td>38 inches</td>
</tr>
<tr>
<td>Depth of Manure above Seeds When Removed</td>
<td>23 inches</td>
<td>24 inches</td>
<td>44 inches</td>
<td>50 inches</td>
<td></td>
<td></td>
<td>22 inches</td>
<td>22 inches</td>
<td>44 inches</td>
</tr>
<tr>
<td>Special Treatment</td>
<td>In Fresh Horse Manure</td>
<td>In Fresh Cow Manure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fresh Seeds in non-metal Inverted Moist Containers Bottle</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The kinds of weed seeds in each Experiment are indicated by (0) in Table I.
decomposed manure was reached. Experiments 1 and 2 were in cocks of fresh manure, each, one load in size. These were located at the south end of the manure pile, one in each corner where no more manure was added. Experiments 7 and 8 were also set on beds of fresh manure, but the manure on top of these was packed.

Experiments 7, 8, and 9, are different in that they are checks upon some factors in the other experiments. In Experiment 9, to eliminate all factors except temperature, the weed seeds were placed in a small bottle which was loosely corked with a perforated cork and set in an inverted position in the middle of the Experiment 3 setting. Experiment 7 was put in with a view to study the fermentation of manure under conditions different than those usually found on the Prairies, as well as to find out how the weed seeds would be affected by such a fermentation. Experiment 8 was put in after Experiment 7 was removed, because in that experiment it appeared that the corrosion of the metal packets might have produced detrimental effects upon the weed seeds. To check up on this, non-metal containers were used; the other conditions were similar to those in Experiment 7. To get some idea of the temperatures developed by the fermentation in these two experiments a maximum and minimum thermometer was placed in with the weed seeds. A thermograph would have been better but such was not available.

Because these three experiments are quite different from the rest, the methods used for each one should be discussed more fully.
Experiment 7 was set in with the object of finding out what effects will manure kept moist, produce on the weed seeds. The idea was to prevent fire-fanging and denitrification of manure. Because it was of interest to know just how low the temperature could be kept down by frequent moistening, a thermometer was set in with the seeds, a thermograph not being available.

The moistening was done by pouring about 20 gallons of water on the manure concerned with the experiment, about 20 inches in radius from the post in the centre marking the experiment, on the following days:— at the time of setting, July 14, 17, 20, 25, 29, August 2, 7, and 11. The manure was well tramped after each watering. The temperature of the water and consequently that of the weed seeds and the manure in question was 64 degrees F.

Experiment 8 received the same treatment or at least its equivalent. Watering was done on the day of setting out and three days later. After that watering was not necessary because it rained very frequently for almost a month.

Experiment 9 was really part of Experiment 3, for except for the exclusion of manure liquids it received exactly the same treatment. There were more than a hundred seeds of each kind in the bottle. The germination test of these seeds after the removal from the manure was made both on the soil in a tray and between sheets of blotting paper.

In germinating the weed seeds, blotting paper was used for the checks. The weed seeds that were removed from the manure were tested for germination in a large tray of soil
free from weed seeds. It was believed that a \( \frac{1}{2} \) inch layer of soil would absorb the manure impurities on the seeds better than blotting paper and thus insure better germination.

For other details see Table II opposite page 11.

RESULTS

Briefly, the results were negative in every case; that is not one weed seed germinated from any of the experiments. However, some remarks should be made on the condition of the weed seeds at the time of removal, and also the condition of the manure. Both of these might help to explain just what factors did the killing. Some results in brief form appear in Table II opposite page 11.

In Experiment 1, weed seeds left in horse manure for one month, the packets when removed were quite dry and so were the weed seeds in them. Little bits of a light green salt on the packets indicated that some sweating must have taken place. The manure had fire-fanged all throughout the inside of the cock; no actual rotting had taken place. The Blue Bur and Lamb's Quarters appeared to have been unaffected; Quack Grass and Wild Oats showed effects of having been burnt, that is, they were discolored to a mouldy brown color something like that of bin-burnt grain. More than half of the Russian Pigweed seed had shrivelled up. The same was true of Stinkweed. Tansy Mustard became discolored to a dark purplish brown. It was concluded that the high temperature raised by the rapid fermentation of the fresh manure was the active agent in killing the weed seeds.
Experiment 2, weed seeds left in cow manure for one month, produced the same results but due to entirely different effects. Moulding and rotting was responsible for killing the weed seeds here. In this experiment fresh moist dung was placed over the packets to insure uniform results. There was no evidence of heating. It was realized that if some seeds had happened to be in the straw and not in contact with any moist dung they would in all probability have not been damaged. The seeds when removed from the packets were soft, stuck together and pretty well decomposed.

In Experiment 3, weed seeds left in manure for three months, the manure was dry and partly fire-fanged all the way down to within an inch of the bed of the setting. This was due to the fact that the manure which was returned into the hole after the packets were set in, was very dry for the precipitation after the disappearance of snow was not sufficient to produce any rotting effects. Because the packets had been placed on a damp bed of manure, the seeds in them were quite damp but not soaked in any manure liquid. There were the usual splotches of the green salt on the packets, and parts of some packets appeared as though they had been in a fire, which effect must have been produced as a result of chemical reactions and the heat produced thereby.

The weed seeds upon removal from the packets, were all badly discolored and some were rotted while others remained quite firm. Russian Thistle was badly shrivelled up, so badly that there was practically nothing to remove. Sweet Clover seed shrivelled up into a bit of residue. Wild Oats rotted
into manure itself. The small seeds such as those of Tansy Mustard, were found as little bits of scab in the paper into which they were wrapped before being placed in the metal packets. Quite a few of the Cow Cockle seeds did not shrivel up but could be easily broken up. The rest were more or less recognizable but were soft and rotted.

Just for curiosity, numbered cardboard labels were coated with paraffin and placed along side the packets in this experiment to see how they would withstand rotting. They rotted away completely.

Experiment 4, weed seeds left in manure for six months, yielded results similar to those of Experiment 3. The manure was about 50 inches thick above the bed on which the packets rested. Except for the top foot or so the manure was extremely hard packed and dry. It had fire-fanged and was still hot at the time of the removal of the packets.

The steel wire connecting the metal labels to the packets was so corroded that in the process of removing some of the wires broke. The labels themselves were not much corroded but had a coating of some copper salt. The packets likewise had bits of the greenish salt on them.

Since the packets were placed on a hard damp bed, they all had a fair amount of moisture and the weed seeds should actually have rotted. The heat was just as great as the hand could bear. The weed seeds when taken out were all rotted and flattened out due to the great pressure of packing.

The weed seeds in Experiments 5 and 6, weed seeds left in manure for one and two years respectively, have not yet been removed, and judging from the results already obtained,
it seems as though it will not be necessary to remove them.

In Experiment 1, weed seeds left in wet manure for one month, in spite of the fact that the manure was kept moist, a very high temperature had been created. When the packets were removed they were hotter than the hand could bear. The maximum temperature was not recorded because it was beyond the limit of the thermometer, which was 125 degrees Fahrenheit. Judging by the amount of mercury forced out into the bulb, one would say that the temperature must have risen to about 170 degrees.

The manure was moist and partly rotted. Although it had been kept moist and packed, there was evidence of fire-fanning taking place in little scattered spots. The wet manure extended about 40 inches in diameter and some distance below the weed seeds. All around this the manure was dry.

The manure which was in contact with any metal had turned black due to the staining products from the corrosion of the packets. As a result of this the weed seeds in each one of the packets had also turned black and might have been killed by the chemical products formed.

In this wet and actively rotting manure the rubber identification tags came through without being in the least damaged.

In Experiment 2, weed seeds in non-metal containers in wet manure for one month, the weed seeds were not counted out before being placed into the manure. A sufficient quantity of each kind was placed in cardboard boxes and set in the manure without any identification tags. Cardboard boxes such as were found in the office, from paper clips etc., were used. The
plan on paper of their arrangement was solely relied upon for
the identification of each kind.

At the time of removal great care was exercised in taking
out the packets which had been flattened out and rotted into manure
manure itself. Each lot had to be picked up with some manure
surrounding it, put in a paper bag, taken in, and then 100
seeds of each were counted out.

With regard to temperature the same thing occurred as in
Experiment 7.

There was no discoloration of the manure around the
containers this time, nor was there much discoloration of the
weed seeds. Only Tansy Mustard turned to a black color, while
the others turned slightly brownish if anything.

Cow Cockle had germinated in the manure pile. On some
seeds the radicles were 3 millimeters long. All the seeds
were soft and well rotted.

The conclusion from this experiment is that metal
containers or no metal containers, rotted manure kills weed
seed within one month.

In Experiment 9, the weed seeds in the bottle were
absolutely dry when removed; no manure liquid had got into the
bottle. The humidity within the bottle must have been the same
as that in the surrounding manure. Some of the seeds were
slightly discolored as if fire-fanged, but the texture was
not affected in any way. Since none of the seeds germinated,
either in the soil or between blotting paper, it was conclusively
proven that the temperature created by the fermentation
of manure kills the weed seeds.
The temperature records to date, as recorded by the thermograph in the one year experiment, are shown below.

![Graph A](image)

May 20, 4 P.M.  
May 26, 10 P.M.

Each smallest division represents 1 hour along the horizontal line and 1 degree Fahrenheit vertically.

Graph A represents temperatures from the time of setting out (May 20, 4 P.M.), on for almost a week. Graph B represents temperatures for the week ending with December 11, 10 A.M.

### Weekly Temperatures

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 22, 4 P.M.</td>
<td>159</td>
<td>Sept. 4, 4 P.M.</td>
</tr>
<tr>
<td>May 25, 4 P.M.</td>
<td>157</td>
<td></td>
</tr>
<tr>
<td>June 5, 4 P.M.</td>
<td>155</td>
<td>18,</td>
</tr>
<tr>
<td>June 12, 4 P.M.</td>
<td>151</td>
<td>25,</td>
</tr>
<tr>
<td>June 19, 4 P.M.</td>
<td>143</td>
<td>Oct. 2,</td>
</tr>
<tr>
<td>June 26, 4 P.M.</td>
<td>137</td>
<td>9,</td>
</tr>
<tr>
<td>July 3, 4 P.M.</td>
<td>140</td>
<td>16,</td>
</tr>
<tr>
<td>July 10, 4 P.M.</td>
<td>134</td>
<td>23,</td>
</tr>
<tr>
<td>July 17, 4 P.M.</td>
<td>134</td>
<td>30,</td>
</tr>
<tr>
<td>July 24, 4 P.M.</td>
<td>132</td>
<td>Nov. 6,</td>
</tr>
<tr>
<td>July 31, 4 P.M.</td>
<td>126</td>
<td>13,</td>
</tr>
<tr>
<td>Aug. 7, 4 P.M.</td>
<td>126</td>
<td>20,</td>
</tr>
<tr>
<td>Aug. 14, 4 P.M.</td>
<td>128</td>
<td>27,</td>
</tr>
<tr>
<td>Aug. 21, 4 P.M.</td>
<td>123</td>
<td>Dec. 4,</td>
</tr>
<tr>
<td>Aug. 28, 4 P.M.</td>
<td>122</td>
<td>11,</td>
</tr>
</tbody>
</table>

After this the temperature went down very uniformly and very gradually.
Results of Other Experiments

The above results confirm the results obtained at the Central Experimental Farm, on this same project.

Weed seeds placed in cow manure and in horse manure in July 1931 were incapable of germinating one month later.

Weed seeds placed in mixed manure in December 1930 and removed five months later did not germinate.

In December 1931 weed seeds placed in horse manure for periods of one, two, three, and four months showed that there was only a very small percentage of these seeds germinated after one month in contact with manure. After storage in horse manure for one month, out of 30 species of weed seeds, only one seed of each of the following germinated: Dock, Peppergrass, and Perennial Sow Thistle. After two months, one of Bladder Campion and one of Peppergrass germinated. After three months, one of Milkweed and one of Chicory germinated.

A similar project to determine the viability of weed seeds in silage, was begun in 1932 at the Central Experimental Farm, but the results on this have not yet been published.

However, we have results on this project from the Experimental Station at Rosthern where some weed seeds were set in silage in 1930. A brief outline of the procedure and the results obtained will be given.

Four groups of seeds were placed in the silos, two in the trench silo and two in the half pit silo at different depths. The weed seeds were enclosed in fine brass screen and grouped together with heavy wire. They were placed in silos at the time
the silos were being filled, which was about September 1st. One was placed in the centre at about 5 feet from the bottom of the trench silo, and the other in the same place at about 2 feet from the top. The same arrangement was followed in the half pit silo, one group was placed near the centre and close to the bottom and the other on the level with the ground.

The weed seeds used were:

Wild Oats  
Wild Buckwheat  
Russian Pigweed  
Ball Mustard  
Lamb's Quarters  
Stinkweed

One hundred seeds of each were used in every case with the exception of Wild Oats, where 1000 were used.

Results

The weed seeds were exposed while feeding in the trench silo first, the top lot being taken out on December 15, 1930, and the second lot the next day. The heavy steel wire which fastened the packets together was corroded through, and the zinc tag nearly eaten away in the higher lot where apparently there was more air. The brass screens were encrusted with a greenish deposit resembling copper carbonate. The seeds in the higher lot were badly discolored and in a few cases badly decomposed. The lot at the lower level was darkened considerably, but did not show as much decomposition as the higher lot. The brass screen in the lower lot showed no green deposit and the steel wire was corroded very little. The seeds from both lots were sent to the Dominion Seed Laboratory at Saskatoon for germination test the results of which showed that not one
Table III

Norwegian Germination Test of Weed Seeds which Passed
Through the Intestine of Horse, Cow, and Pig.

Percentage of Viable Seeds Recovered from the Dung

<table>
<thead>
<tr>
<th>Weed Seeds</th>
<th>Horse</th>
<th>Cow</th>
<th>Pig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rumex acetosella</td>
<td>26.43</td>
<td>70.57</td>
<td>5.00</td>
</tr>
<tr>
<td>Chenopodium album</td>
<td>2.50</td>
<td>16.29</td>
<td>20.36</td>
</tr>
<tr>
<td>Matricaria inodora</td>
<td>10.40</td>
<td>24.03</td>
<td>0.02</td>
</tr>
<tr>
<td>Galeopsis tetraklit</td>
<td></td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>Spergula arvensis</td>
<td>0.05</td>
<td>2.40</td>
<td>0.36</td>
</tr>
<tr>
<td>Rumex domesticus</td>
<td>22.95</td>
<td>90.40</td>
<td>11.25</td>
</tr>
<tr>
<td>Brassica campestris</td>
<td>5.10</td>
<td>2.22</td>
<td></td>
</tr>
<tr>
<td>Chrysanthemum leucanthemum</td>
<td></td>
<td>7.47</td>
<td></td>
</tr>
<tr>
<td>Barbarea vulgaris</td>
<td>5.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thlaspi arvensse</td>
<td>37.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinapis arvensse</td>
<td>5.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erysimum cheiranthoides</td>
<td>0.79</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
seed germinated. From this test it was concluded that weed seeds in silage in the trench silo were completely killed by the fermentation which took place. The results from the half pit silo were very similar.

Some European Results

Korsmo (1) has brought together the results of practically all the workers on weeds in Europe, and published them in a book. The following are some of the extracts from that book.

With regard to the percentage of viable seeds found in fresh dung, experiments carried out in Norway showed that on the average 11.75% of the weed seeds fed to a horse remained viable after passing through the alimentary tract, and similarly 26.4% of those fed to a cow, and likewise 7.4% of those fed to a pig. The detailed results of this experiment are given in Table III on the opposite page.

The above experiment and a few other similar ones do not take into consideration the fact that there are weed seeds dropped into ordinary manure through feeding and bedding. Korsmo thinks that most of the weeds resulting from manure are the result of this rather than of incomplete digestion. This idea is supported by an experiment carried out in Sweden, where it was found that 48 seeds germinated in manure without bedding and 194 in manure that had bedding in it. That is, there were four times as many viable seed seeds in manure with bedding as in manure without it.

It is generally conceded that some weed seeds in manure are destroyed by fermentation. Korsmo believes this also but
not to the same extent that one on this continent would be inclined to believe, for the results obtained here are different in some respects. Korsmo says that experiments have shown that in old fermented manure, even after six months of storage, kept wet and packed and allowing no oxidation, a great deal of the weed seeds remain viable. There must be reasons for this. Perhaps the methods of storing manure in the old countries have something to do with the results obtained. It seems as though keeping the manure wet and well packed, and thus excluding the air, does prolong the period which is required to kill the seeds. Such methods are not practised here unless it be in the older settled parts of this continent. Fire-tamping which is so detrimental to the weed seeds, and in the Old Land regarded detrimental to the manure, is allowed to take place in most manure piles here.

On the question of how many weed seeds are scattered on the land with the different manures, Feilitzen shows that manuring one hectare (2.5 acres) with 150 loads or 60 tons of manure, the following number of weed seeds were added to the soil:

Table IV

<table>
<thead>
<tr>
<th>Kind of Manure</th>
<th>Summer Manure</th>
<th>Winter Manure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh</td>
<td>Fermented</td>
</tr>
<tr>
<td>Horse</td>
<td>900 000</td>
<td>540 000</td>
</tr>
<tr>
<td>Cow</td>
<td>2640 000</td>
<td>480 000</td>
</tr>
<tr>
<td>Pig</td>
<td>1740 000</td>
<td>660 000</td>
</tr>
<tr>
<td>Sheep</td>
<td>600 000</td>
<td>420 000</td>
</tr>
<tr>
<td>Chicken</td>
<td>780 000</td>
<td>540 000</td>
</tr>
</tbody>
</table>
DISCUSSION

The results obtained at Maryland Experiment Station indicate that six months of storage will kill all the viable seeds in manure. Wisconsin Experiment Station results indicate that two months of the same treatment is sufficient. The results obtained at the Central Experimental Farm give support to the results obtained at Scott Experimental Station. The technique at each place was undoubtedly quite different. The climatic conditions and the storage conditions also could not have been identical. One would expect these factors to have a bearing upon the type of killing of the seeds. In the more humid regions such as in the eastern part of this continent and also the western coast, the manures are kept in a moister condition naturally. The result is that in such manures more of the true fermentation is taking place, while in the dry and loose manures where air penetrates throughout the whole pile, fire-fanging, oxidation, and denitrification are taking place. In the latter process there is much more heat created than in the former. The temperatures created in Experiments 7 and 8 do not quite support this last statement, but it is easily accounted for when one takes into consideration the fact that only a small part of the manure was kept moist. This would be stimulated to heat rapidly by the surrounding manure which was fire-fanging.

It is strange to note from the results obtained at Maryland Experiment Station, that if fresh manure is hauled out on the field and plowed under immediately or soon after, that only 2.3% of the weed seeds fed to animals germinated, whereas 12.8% germinated where it was used as a top dressing. Evidently
this indicates that manure still fresh and damp, if plowed under, decomposes to such an extent that it is quite effective in killing most of the weed seeds included in it.

On the basis of the above deductions there is justification for the Maryland Experiment Station making its recommendation that manures be stored for six months, and Korsmo's remark that it takes even longer than six months to kill weed seeds in manure. It seems that manures given the proper storage treatments should be stored for at least a year.

From the results obtained at Scott it is evident that if horse manure is left loose and dry, - a treatment given manures on most Prairie farms, - and allowed to fire-fanning, no viable weed seeds would remain after fire-fanning had been completed. Under normal conditions this process takes much less than a month. The temperature recorded in Experiment 5 showed that the peak was reached within the first two days.

The above however, does not apply to fresh cow manure. Only those weed seeds in contact with moist dung would undergo decomposition. Since no heating takes place, it stands to reason that the seeds included in the straw from the bedding would be entirely unaffected. Because of this fact it did not seem necessary to put in a check on this factor in Experiment 2.

For two reasons it is most unsafe to spread fresh cow manure and to a lesser extent stored cow manure. First, cow manure contains more undigested or viable seeds than any other manure. Second, cow manure does not heat, although it might ferment if the proportion of straw that it contained was small and the amount of moisture great. These remarks are based on the observations made when digging out the packets in Experiment
2, and on general knowledge of the behavior of cow manure at least in this part of the country.

It is only logical that one should recommend to mix horse and cow manure on the pile when hauling each out to store. One could go even further and suggest the dumping on the manure pile of weeds, vegetative or animal scrap, and any trash that contains weed seeds, providing that such is scattered thinly on the pile and covered with a layer of horse manure, and the whole pile is artificially watered in dry seasons when rainfall is not sufficient to insure a prompt and uniform fermentation and decomposition.

To get the best results from stored manure the practices adopted in the older countries as regards storing manure should be followed. Such practices could be expressed as four rules:

1. Mix the different manures and materials for composting.
2. Keep the manure wet, but not so wet that leaching will take place. If at all possible leaching should be prevented.
3. Keep the manure well packed to exclude the air and prevent fire-fanging and other detrimental reactions. Packing if uniformly done insures a uniform fermentation and decomposition of manure.
4. Store manure as long as is required to kill all the weed seeds. This will depend upon the following factors:
   a. Trash. - The greater the amount of straw and other trash in the manure the longer it will take to ferment and decompose.
   b. Temperature. - The lower the temperature is kept the longer should the manure be stored. It is desirable to keep
the temperature low because the fermentation is not too rapid then. This yields a rich and good quality manure.

c. **Moisture**,- As a rule the greater the amount of moisture the longer should the manure be stored. This is due to the fact that moisture is a requirement for low temperature. However, a dry trashy manure may be stored for an indefinite period and not undergo decomposition which is desirable, at least not a uniform decomposition and fermentation.

d. **Kind of Manure**,- Horse manure requires much less time to ferment than any other kind of manure.

e. **Uniformity**,- This is very important in getting the quickest results for usually the last thing holds up everything, and very often the whole thing is marred by incompleteness. Straw should not be found in great clumps, packing and wetting should be uniformly done. Then there will be no danger of the weed seeds being killed in one place in the manure pile and not in another.

**Discussion of Experiments**

**Experiment 1**,- The real object of this experiment was to find out what happens to the weed seeds in a cock of fresh horse manure left to stand without any treatment whatsoever, a practice very commonly found where manure is just thrown outside the barn door to be hauled away during some slack period. No packing nor artificial moistening was given. The results obtained apply to the inside manure only. They could not be expected to apply to the surface manure about one foot in depth, where no fire-fanging
took place.

**Experiment 2.** Here again the results obtained are not applicable to the surface manure on the cock, nor are they applicable to the greater part of the trashy part of the manure which was not in contact with any moist dung.

**Experiment 3.** The manure here was very dry except for the bed upon which the packets were placed. Had the weed seeds been placed higher up in the dry manure they would likewise have been killed due to the fire-fanning which took place. The manure was very trashy and far from being decomposed, but as can be inferred from Experiment 1, it is possible to get killing of weed seeds without having complete decomposition of manure.

For Experiments 4, 5, and 6, there are no remarks to make, for the last two have not yet been removed and Experiment 4 was very similar to 3. The method of labelling the packets was different from that used in the first three experiments. The brass tags attached to the packets with steel wire were not as satisfactory as the rubber tags used in the other experiments.

**Experiment 7.** The object of this experiment was to imitate the conditions in the more humid regions and observe the results. As mentioned previously, wetting manure and packing it inhibits fire-fanning, hastens decomposition, and restricts denitrification. A pronounced reaction on the metal of the packets is only to be expected. Since the screen metal was an alloy of copper and nickel, the green deposit found on the packets was most likely copper biureate or nickel biureate or both. No chemical analysis of these salts was made. It is quite likely that the reaction between uric acid in the manure
and the metals produced corrosive effects which might have been responsible for killing the weed seeds. It was with the idea of checking up on this very factor that Experiment 8 was set out.

Experiment 8.—The results obtained here still maintain that weed seeds stored in moist manure get killed within one month. Although very little discoloring of the seeds took place, the viability was greatly or rather completely impaired by the damp heat created in the manure. The results of this experiment do not indicate that the metal was responsible for killing the weed seeds in Experiment 7, nevertheless, the discoloration of the manure and everything around the metal would make one disapprove of using any metal containers for weed seeds for similar experiments in the future. Metal screening could be used quite safely in dry manure.

Since this time, the writer has learned that it is possible to obtain a screen cloth made out of horse hair, which withstands corrosion and produces no harmful effects on the weed seeds.
SUMMARY AND RECOMMENDATIONS

1. Experiments on this problem have been carried out in various parts of Europe, Maryland Experiment Station, Wisconsin Experiment Station, Dominion Central Experimental Farm, Rosthern Experimental Station, and Scott Experimental Station. The results from most of these were quite conclusive.

2. It is a well known fact that weed seeds pass through the alimentary tracts of animals without losing their vitality.

3. In addition to polluted dung, barnyard manure gets polluted directly through bedding and wasted feed if either or both contain weed seeds.

4. Therefore on every farm, it is a certainty that fresh manure will be polluted with viable weed seeds and should not be spread on the land as such but should be stored for at least three months and not more than a year. Fresh manure may be spread on pasture land. Leaving manure stored for more than a year results in an unnecessary loss of nitrogen and also in the accumulation of weeds on and around the pile, which shatter seed and pollute the surface manure.

5. Before spreading stored manure, the undecomposed surface manure about one foot in depth, should be carefully taken off and dumped where a new pile is to be started. The undecomposed surface manure is bound to contain some viable weed seeds.

6. Results have shown that where horse manure had been allowed to fire-fang, it is free from viable seeds, surface manure excluded.

7. A high temperature resulting from too rapid a fermentation is the active agent in killing the weed seeds. Therefore
manures that have fire-fanged can be safely spread on the
land any time after this process has taken place. For other
reasons, it is not a good practice to let manures fire-fanged.
8. Weed seeds in contact with moist cow dung decay and get
killed within one month.
9. Cow manure by itself, especially when it contains a
great deal of bedding straw, is not very efficient in destroy-
ing the viability of the weed seeds when stored, excepting
those seeds which come in contact with moist dung.
10. It is advisable when storing to mix horse and cow man-
ure to allow the fermentation to take place more thoroughly
in the pile.
11. Weed seeds kept in moist horse manure get killed with-
in one month.
12. To get the best results from stored manure, both from
the standpoint of killing the weed seeds and from the stand-
point of rotting with the smallest loss of nitrogen possible,
manure in dry regions should be wetted artificially during
the dry spells.
13. In regions of rainfall greater than here, it is recom-
mended that manure be stored for at least two months before
spreading on the land.
14. In Europe it has been shown that it takes more than
six months of storing to make sure that manure is free from
viable seeds.
15. No weed seeds are capable of germination after having
undergone fermentation in the silage. Therefore it is safe
to use weeds, even weeds with ripe seeds, for ensilage. The
weed seeds get killed before the ensilage is fed to the stock.
16. In the matter of equipment, for future experiments it would be best not to use any metal containers for seeds put in moist manure although they could be used in fairly dry manure. Rubber tags or labels are by far better than metal tags or waxed paper tags.

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5. Wisconsin Experiment Station,- Prof. A.L. Stone's article "Weed Seeds in Manure" in Hoard's Dairyman, Aug. 13, 1930.