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Studies on the Comparative Value of the Hot Treatment (Krantz Patent) and Common Methods of Handling Barnyard Manure

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STUDIES ON THE COMPARATIVE VALUE OF THE HOT TREATMENT (KRANTZ PATENT) AND COMMON METHODS OF HANDLING BARNYARD MANURE

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INTRODUCTION

Antidating written human history the dung of animals, chalk, marl, wood ashes and other substances were probably used to increase the productivity of the soil. These practises found their way into the earliest farming activities of the Chinese, Persians, Greeks and Romans. (3)(11) In the Hebrew scriptures mention is made of the "D ung Gate". (10) This was undoubtably a place given to the marketing of manures. That manure was used as a soil amendment in Asia Minor in Biblical times is not questioned. The famous Roman agricultural writer Cato (234 B. C.) wrote at length on manures and their handling. He gave bird manure preference and spoke of the manurial value of legumes. (3) Jethro Tull believed tillage was manure and contended that manures only benefit the soil because of improved physical condition after application. Liebig, the well known German agricultural chemist, gave prominence to the theory that small quantities of minerals added to the soil would suffice as manure. (1) Today the general ideas of soil fertility and the use of manures and fertilizers incorporates the views of these earlier students with better explanations of the relationships of one usage to the other. (13)(26)(29)(30) The study here reported is limited to the methods of handling barnyard manure and particularly to the recent development in Germany of what is known as "Hot Processing."

REVIEW OF LITERATURE

The literature on the subject of manure is very extensive. This is particularly true of the literature in the German language. On the subject in question, "Hot Processing," there are several papers from the Leipz ig Experiment Station in Germany. (7) (8)(26) There are also a number of papers of a popular nature by various German writers. (2)(5)(14)(17)(3)(etc.) The system is demonstrated at the Deutsches Museum in Munich as belonging on the ideal farm. The process is briefly described by Pittman. (13)

METHODS OF STORING MANURE

In reviewing available literature it is the cocensus of opinion among writers who have not considered in their writings the idea of the hot processing of manure, that minimum losses in stored manure are experienced when the piles are as compact, moist and cool as possible. (1)(19)(28)(30) Roofing is recommended in areas of high precipitation. Pitting or partial pitting in water tight basins is said to be valuable to check the losses caused by the perculation of liquid through the pile.

THE HOT PROCESSING OF MANURE

The newer development patented in several countries by Herman Krantz makes use of the above methods with certain

modifications. (D. R. P. 386, 512 & 388, 638 & others)(13) Chief among these modifications is a brief period of heating in a loose heap as soon after the material is removed from the barn as is possible. This is followed by a tight compacting of the pile when it has reached a temperature of 55 to 65° C. Drainage is provided to remove excess water from the manure. Specially constructed units (Gaerstaette) for the best results are marketed by the "Gaerstatt G. M. B. H." in Munich, Germany. Licenses for the commercial or farm use of the process are obtainable from the same firm. The commercial name of the processed manure is "Edelmist" and the process "Edelmistbereitung." Difficult of translation the terms mean "Rich Manure" and "Rich Manure Preparation" respectively. In the United States the process is covered by patents Number 1,459,059 and 1,643,018.

VALUE OF HOT PROCESSING AS CLAIMED BY PROPONENTS

Original experiments were conducted by those who discovered the process. The results of these experiments were exceptionally favorable to this mode of the perservation of manure as shown by increased crop yields. (15) The advantages claimed for the process were as follows: First--the gross losses during the time of storage were much smaller. (12) Second--the nitrogen content of the treated material was rendered more available which hastened and increased its assimilation by plants. The increased crop was 2.78 times the increase possible with ordinary barnyard manure. (15) Third--the keeping qualities

of the product were improved which allowed for longer periods of storage with minimum losses. (12) Fourth--Pathogenic bacteria and weed seeds contained were killed. (22)

STUDIES ON HOT PROCESSING BY VARIOUS INVESTIGATORS

The interest aroused by the results of those commercially engaged in the hot processing of manures led to numerous studies. Losses in weight were studied by Henkel and Krantz (9), Weigert (32)(34), and Remy, Klueter and Weiske(21). These results were in many instances contradictory, losses ranging from 10.25 to 32 per cent. Loss of Nitrogen was also studied by Remy, Klueter and Weiske, which study has been questioned by Glathe and others as no losses in the total nitrogen content were found. Field experiments conducted by Borneman at Konradsdarf in 1921 and continued in 1922 by O. Kron (13) showed decided crop increases in favor of the hot treated manure. Weigert (32)(34), by applications calculated to be of like total nitrogen content, showed less disease in potato hills on the plots manured with hot manure. The total yields for a two year period comparing barnyard manure to hot manure gave ratios of 1:1.94 and 1:2.13 respectively.

Biological activities in the "Gärstatt" received attention from Loehnis (16)(17) and Ruschmann (23)(24)(25) and more recently Goeters (8). Ruschmann ascribed the value of the "Edelmist Process" to the high temperature fermentation killing the vegetative cells of the bacilli, while allowing their

enzymes to act upon the other dead bacterial cells thus rendering their nitrogen compounds more soluble. Goeters' results showed greatly reduced numbers of bacteria at high and low temperatures. Correctly handled Edelmist was poor in vegetative bacterial forms. The number of spores found in Edelmist were high as compared with ordinary manure but most of these were dead. Urea bacteria were reduced in numbers but some forms persisted and helped in the completion of the process. Cellulose consumers became practically extinct but were found in barnyard manure. The high bacterial content of barnyard manure was said to account for heavy losses in dry weight and plant nutrients during storage. Stored "Edelmist" showed little increase in bacterial numbers except for forms attacking cellulose. Nitrification in soil mixtures showed "Edelmist" to be from two to three times as efficient as barnyard manure. In pot experiments the nitrogen efficiency in the pots manured with Edelmist was two to four times as great as in those manured with barnyard manure.

Scheibe (27) studied particularly the nitrogen efficiency and carbon dioxide yields of Edelmist in field and pot experiments. Nitrate nitrogen was found to be higher on the plots manured with Edelmist than those manured with barnyard manure. Carbon dioxide was released in larger amounts on the plots manured with "Edelmist." The relationship in the case of nitrogen was 1.17 to 2.7 in pot experiments while in the field the relationship depending on the age of the "Edelmist" varied from 1 to 1.71 for straw manure to 1 to 2.19 in the case of peat manure.

The straw and peat were used as bedding in the stalls. Carbon dioxide liberation in potato plots was 102 per cent for Edelmist compared with 23 per cent for barnyard manure. From carrot plots the carbon dioxide liberation was 160 per cent in the case of Edelmist manuring as compared with 43 per cent for barnyard manure. These above results are given in comparison to untreated plots.

Glathe (7), notes the following results in a study of the losses during storage as compared with piled manure. Horse manure was used.

	Hot Manure		Barnyard Manure
	Straw Manure	Peat Manure	Straw Manure
Total "N" lost	15.7%	14.8%	40.0%
Dry Weight lost	29.0%	14.5%	45.2%
Raw Weight lost	15.8% & 19.4%	10.6%	31.0%

Ehrenberg (5) considered the economic phase of the problem under German conditions. The operating costs which were for sixty head of cattle were found to be as follows: License 1500 r m, building costs 12,500 r m, with the calculated profit on the investment, due to increased value of manure, fifteen per cent net with labor costs considered.

EXPERIMENTAL WORK

Experimental study of methods of handling manure under the climatic conditions of the intermountain west seems to have received little consideration. Stoker etal., however, recently found that Russian knapweed and white top seeds lost their viability in moist heating piles of chicken manure (28). The circumstances noted have prompted the study herein reported.

PREPARATION OF EDELMIST (HOT PROCESSED) AND OTHER MANURES IN 1930-31

In December 1930 a platform was constructed to take care of a large pile of horse manure to be handled as specified in the patented process of Herman Krantz. The piles were arranged as illustrated in Diagram I. Pile "A" was made approximately four feet on a side at the base and approximately three feet on a side at the apex with a depth of about four feet. As soon as this pile had commenced heating, pile "B" of like proportions was placed against "A". With pile "B" heating, pile "C" was to be placed on the other side of "A" to be completed with pile "D". At this time "A" should have reached a temperature of 60° C and should have been tramped thoroughly and pile "E" placed on the top, the processing continuing in this manner until the manure to be processed had been brought within one large heap. This plan failed as the winter temperatures so chilled the manure that heating could not be started in the open piles. The heaps finally froze solid.

This first plan having failed of completion a bin was

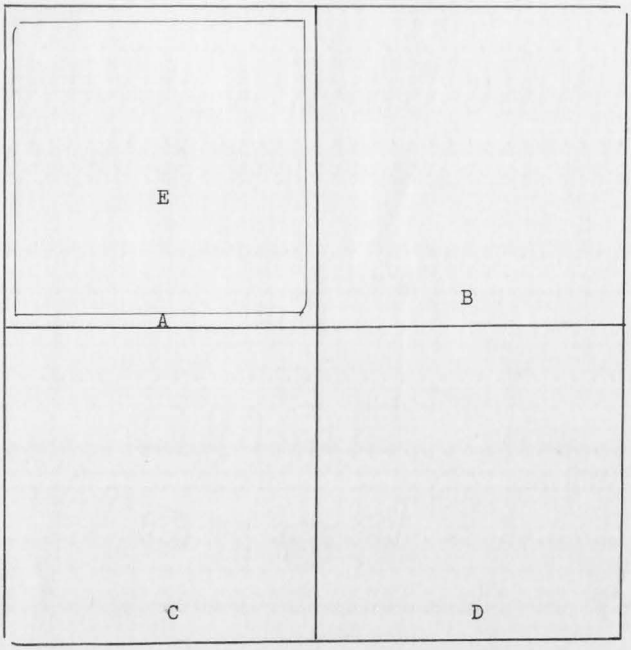


Diagram I --Method of Arranging Piles in the Hot Treatment of Manure.

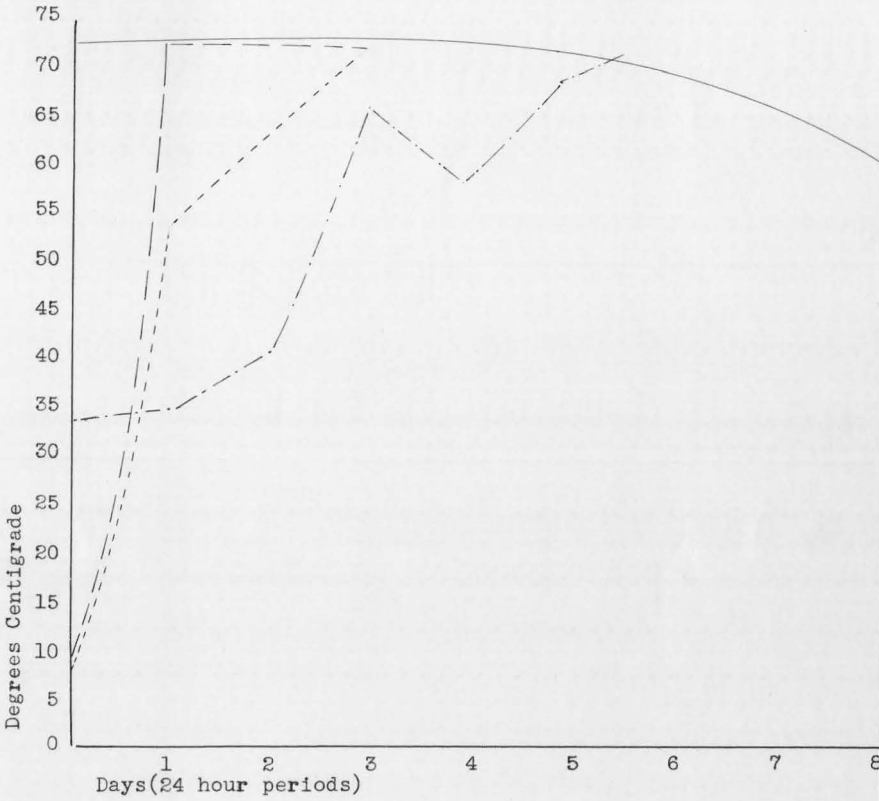
Showing the arrangement of piles calculated usable in the hot processing of manure. Beginning with "A", piles "B", "C" and "D" were to be placed as illustrated. When "A" had reached a temperature of 60° C, "E" would have been placed on top of "A", after the later pile had been thoroughly tramped. In this manner any sized heap could have been made. The units were to be approximately 4' x 4' x 4'.

constructed as shown in Photograph I. On all sides of the manure in the bin was placed about one foot of dry straw for temperature insulation. This was done in the middle of January at sub zero temperatures. This pile also failed to develope an appreciable heat but did not freeze solid, so was left in the bin in an apparently inactive condition until the 13th of February when it was noted that the pile commenced to heat. A second pile was then placed in front of the first pile. The rapid rise in the temperature of these piles is illustrated in Graph I. At temperatures of 65°-72° C the material in the piles was tramped thoroughly and another pile placed upon the top and thoroughly tramped when it had attained the desired temperature. Two additional piles were placed upon the pile in the rear of the bin and one upon the pile to the front. The third pile, in the foreground of Photograph I, was from the cow barn and did not heat satisfactorily so was not used.

The manure used was such as is taken from the average horse barn. It was made up of bedding from the stalls (wheat straw) plus wasted feed from the mangers (alfalfa hay), and the feces of the animals and what urine was absorbed by the bedding, as the barn is equiped with drain troughs. The manure used was with one exception from the same horses. Alfalfa hay and chopped barley were the feeds used.

Observations during the initial period of heating showed a loss of ammonia. The odor was very noticeable about the heating piles. A maximum temperature of 72° C was reached. (See Graph I) The temperature gradually decreased to 50° C and

Photograph I --Showing the method of building up a pile of hot processed manure.



Graph I --Temperature Curves of Heating Manure Piles.

——·——·——Represents the heating of the first pile.

— — — —Represents the heating of the second pile after the first pile had been thoroughly tramped.

- - - - - - - - - -Is the temperature curve of the pile placed on top of the second pile after it had been thoroughly tramped.

——————Represents the temperature curve in the cooling pile.

remained constant for about a week after which it gradually decreased to approximate air temperature. Fungous growth was noted at the points of contact with new heaps of manure and along the sides of the pile where aeration was not eliminated. This growth, however, appeared arrested when the piles were thoroughly tramped at high temperature. The volume of the piles thus treated was decreased approximately one half.

At the end of a six months period of storage the piles were covered with a thin layer of dry strawy material. Inside this covering was observed a moist homogenous mass of a dark brown color, without the usual manure odor and resembling in this respect the duft in a heavy forest. The original material had lost its identity except for horse hairs which had withstood the decomposition. The temperature inside the pile was lower than the temperature of the summer air.

From the completed piles samples were taken for chemical analysis and pot experiments. These were obtained by taking six random samples completely through the piles. These six samples were then thoroughly dried and mixed to make composite samples of the two piles to be used for analysis and pot tests.

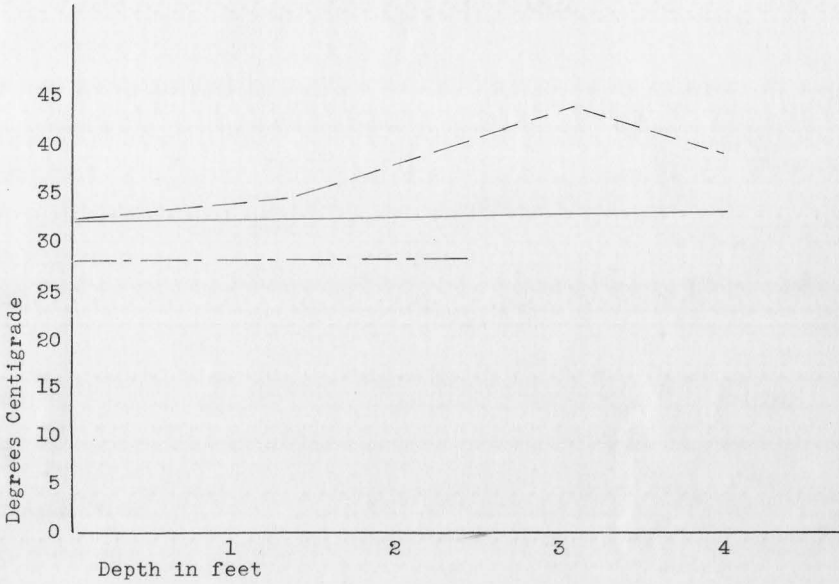
POT TESTS IN 1931 USING "EDELMIST" AND OTHER MANURES

For the purpose of comparing the relative effects of manures on yields of wheat, alfalfa and sugar beets a series of pot tests were arranged. The manures used for these tests were

hot processed manure, fresh horse manure from the same source as that which had been hot processed, and stored manure of like origin from a large compacted heap stored during the winter on the College farm.

Observations on the Character of the Manures Used.

Observations of the compacted heap at the College farm were made to ascertain the similarity of the product from this type of pile and that produced by the hot process. Test pits were dug into the heap for the purpose of obtaining samples and observing the condition present in such storage. Temperature readings were taken to see if they were comparable in the two types of piles. (see Graph II) It will be observed that within the compacted pile higher temperatures prevailed. The manure in the center of the pile in the five test holes was different from that in the outer 18 inches. This first eighteen inches was similar to the strawy covering of the hot processed piles but proportionately thicker. This outer covering was similar to musty hay and powdered readily. The manure between the 18 and 36 inch depths varied in every test hole. In some the material was well decomposed very much like the hot processed piles, while in others it was strawy and full of fungi, with some of the manure appearing as if recently taken from the barn. The bottom layer was very much like an ensilaged product with the odor of fresh manure. From all of these test holes like



Graph II --Temperatures Taken at Different Depths after a Six Months Period of Storage in Compactly Stored and Hot Processed Manure Piles.

— — —Temperature in a compactly stored manure pile.

————Air temperature in July 1931.

— - —Temperature in a small pile of hot processed manure.

samples were taken with the size of samples proportioned as much as possible to the different types of manure present. These samples were mixed and dried for analysis and pot tests.

Manure was taken at random from a heap fresh from the horse barns. The samples were prepared as were the other manures for the tests to be made.

The soil used was taken from a field on the Greenville Experiment farm which had not received manure for several years. The crop previously harvested had been wheat. The soil is of the Millville loam series. The top six inches of soil were used.

Preparation of Pots

Sufficient soil to fill 48 eight-inch pots was poured upon a cement floor and thoroughly mixed. The material was divided into four portions. With the first portion sufficient manure from the heated piles was added to equal a treatment of five tons of manure per acre calculated on an oven dry basis which would be the equivalent of about twenty tons per acre wet. To the second portion a like amount from the compact pile on the farm was added. The third portion received a like amount of fresh manure. The last was untreated. After thoroughly mixing in the manure, a like amount of water was added to each portion to bring the soil to an apparent optimum moisture content. Each of the pots was then filled with the soil to the same weights to make twelve replicates of each treatment.

Wheat and alfalfa were planted in 24 of the pots and sugar beets in the remainder. The pots were placed in a cold frame in rows representative of each treatment. In the pots planted to wheat and alfalfa, 15 kernels of wheat were sown per pot and a pinch of alfalfa seed. The beet pots received twelve seed balls per pot. Later the wheat was thinned to ten plants per pot, the alfalfa untouched and the beets to six and later to two plants per pot. The soil was maintained in a moist condition by sprinkling twice per day.

Results of 1931 Pot Tests

Due to insect attacks and later to mildew it was necessary to harvest the wheat plants before maturity. This was done ninety days after planting. The results are tabulated in Table I. The alfalfa plants remaining in the wheat pots were not thinned. The number of plants per pot and the total weight from the random sowing is tabulated in Table I. Soil analysis for nitrate nitrogen by a modified phenoldisulphonic acid method (18) and water soluble phosphorous as determined by the Corruleo-Molybdate method is given in Table I. The total nitrogen and phosphorous content of similar manures is tabulated in Table V. Analysis for potassium was considered unnecessary in these experiments as results with potassium fertilization on the soils in question have always been negative. The results from the series of plots in which beets were grown are given including nitrate nitrogen and soluble phosphorous in Table II.

Table I --The Available Phosphorous and Nitrogen and the Yield Data on Wheat and Alfalfa from Pot Tests in 1931.*

	No. of Alfalfa Plants	Weight of Alfalfa Plants	Height of Wheat Plants	Weight of Wheat Plants	ppm "P" in the soil(H_2O soluble)	ppm "NO_3" Nitrogen in the soil
Check (No Manure)	3.3	.177 g.	26.3 cm.	1.428 g.		1.10
Fresh Horse Manure	3.6	.226 g.	26.8 cm.	1.826 g.	.32	2.80
Compactly Stored Horse Manure(Greenville Farm)	6.5	.597 g.	26.4 cm.	2.461 g.	.36	12.60
Hot Processed Horse Manure	6.5	.765 g.	29.0 cm.	2.927 g.	.56	2.10
** Amount Necessary for Significance (p=.05				.059 g.	.14	6.78
** Amount Necessary for Significance (p=.01				.082 g.	.19	9.55

* Data from six replications of each treatment (treatments in rows).

** Only when Fishers' z test showed a treatment effect, are differences given which are necessary for two different probabilities.

Table II --The Available Phosphorous and Nitrogen and the Yield Data on Sugar Beets from Pot Tests in 1931.*

	Dry Wt. of Roots	Dry Wt. of Tops	ppm "NO_3" Nitrogen in the soil	ppm H_2O soluble "P" in the soil
Check (No Manure)	.037	.628	5.9	
Fresh Horse Manure	.077	.619	8.1	.09
Compactly Stored Horse Manure (Greenville Farm)	.091	.761	6.0	.82
Hot Processed Manure	.099	.595	8.1	.23
** Amount Necessary for Significance (p=.05				.40
** Amount Necessary for Significance (p=.01				.96

* Data from six replications of each treatment (treatments in rows).

** Only when Fishers' z test showed a treatment effect, are differences given which are necessary for two different probabilities.

The data from the pots containing wheat and alfalfa seemed to indicate a superior growth in the case of the pots manured with the hot processed manure and the manure stored compactly. The use of Fishers' z (6) showed these results to be significant. The sugar beet pots showed no differences in yield due to treatment but the availability of phosphorous was significantly different in the manured and unmanured soil.

POT TESTS IN 1933 USING THE SOIL PREPARED FOR THE 1931 TESTS

Because it seemed that the arrangement of the pots in rows might have unduly influenced the growth of the wheat in the outside pots where the greatest differences were observeable, the pot experiment was repeated with the soil left over from the 1931 tests. The pots were arranged in a Latin square. In this experiment smaller pots were used and the replications were cut to four for each treatment. Ten kernels of wheat were planted and upon germination thinned to the smallest number of plants per pot, which was eight.

Results of 1933 Pot Tests

Six of the plants were harvested 53 days after planting. The yield data are given in Table III. The growth was about one half of the former 90 day growth. The remaining two plants were grown to maturity, the data being given in Table III.

Table III --The Available Phosphorous and Nitrogen and the Yield Data on Wheat from Pot Tests Harvested in 1933.*

	Height of Plants in June	Dry Weight of Plants in June	Height of Mature Plants	Dry Wt. of Mature Plants	"P" in soil by Dahlberg & Browns' Method	ppm "NO_3" Nitrogen in soil
Check (No Manure)	13.22 cm.	.382 g.	22.39 cm.	.45 g.	8.	3.6
Fresh Horse Manure	13.15 cm.	.354 g.	21.24 cm.	.52 g.	16.	3.5
Compactly Stored Horse Manure(Greenville Farm)	13.06 cm.	.456 g.	23.99 cm.	.53 g.	17.	4.5
Hot Processed Horse Manure	15.16 cm.	.488 g.	22.94 cm.	.59 g.	24.	4.9
** Amount Necessary for Significance (p=.05					7.	
** Amount Necessary for Significance (p=.01					11.	

* Data from four replications of each treatment (treatments arranged in a Latin square).

** Only when Fishers' z test showed a treatment effect, are differences given which are necessary for two different probabilities.

Analysis of the soil for nitrate nitrogen from the pots showed as much variation within treatments as between different treatments so the results are not significant. In the case of analysis for soluble phosphorus by the reduction method of Dahlberg and Brown a higher soluble phosphorous rating was observed in the manured soils with apparent significant differences as is seen by a study of Table III. In no case were the differences in yield significant.

FIELD TESTS WITH "HOT PROCESSED" MANURE COMPARED TO OTHER MANURES

To compare the effect of variously treated horse manures in field experiments preparations were made to obtain manure of like source and treat sufficient of the material to arrange a series of experiments in the field as well as study the gross losses taking place during storage. The source of the manure was the same as in the original experiments, being taken from the U. S. A. C. horse barns.

Preparation of "Hot Processed" and Other Manures in 1931-32

In order to prepare the hot processed manure, a bin was constructed as in the first instance. Again it was difficult, in the open bin, to get the manure to heat satisfactorily although the experiment was begun earlier in the fall. After attempting for two weeks to get a pile started to heat by adding

water to make up for losses by evaporation, the pile was removed from the bin. This bin was then built up into a roofed shed insulated with eighteen inches of sheep manure and straw around the two inch planks, from which material the shed was constructed. The plan of the structure is illustrated in Diagram II & II A. In this new bin insulated on four sides and with the bottom six feet from the roof, 700 pounds of well mixed manure with a moisture content of 76 per cent were loosely piled and covered with planks. Later 350 pounds of manure were added to this pile before it commenced to heat. The temperature curves of this and two additional piles treated in this bin are shown in Graph III. In Graph IV the temperature curve in cooling the total piled heap is given. When the first pile had reached a temperature of 57.5° C, after being in the bin for ten days, it was tramped and 750 pounds more of loosely piled manure placed on top, which pile reached a temperature of 60° C in five days and then was thoroughly tramped. The third pile of manure placed on top of the second, as in the first instance, weighed 740 pounds and and reached a temperature of 57.5° C. The air temperature during these treatments was sub zero. The piles were separated with lath markers.

While working with these heating piles eleven other sets were arranged as follows: Six piles were built in loose heaps from the manure as it came from the barn, two were compactly tramped in the open, and three compactly tramped in large galvanized iron cans which were placed inside the edge of a large manure pile and protected from the weather. The original and

Diagrams Showing Construction of Insulated Bin for Hot Treatment of Manure.

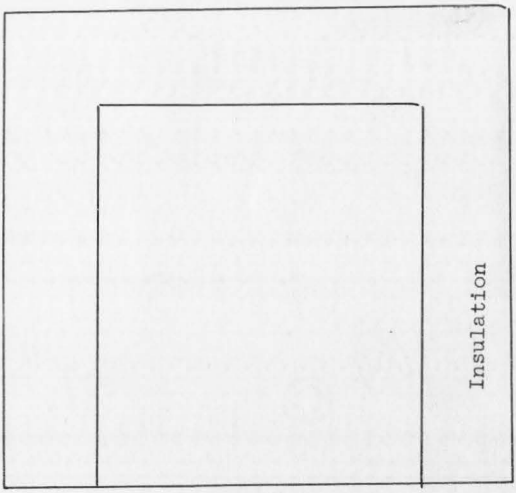


Diagram II

Scale--½" = 1' Front View. Depth 5 ft.

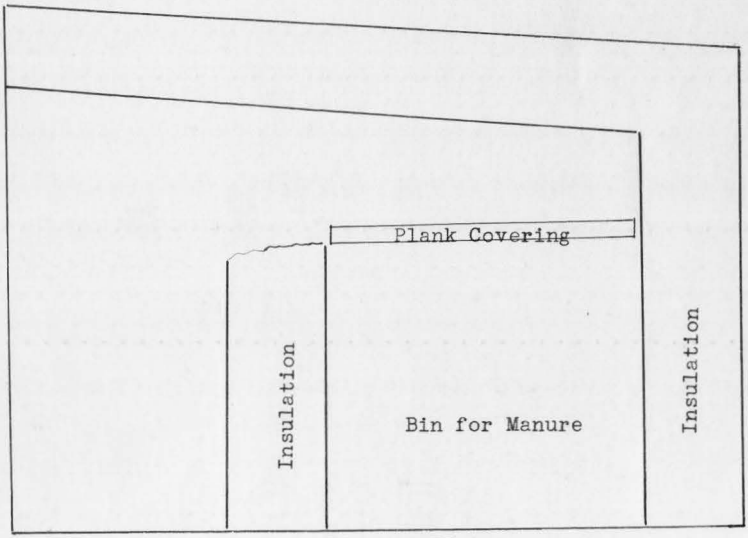
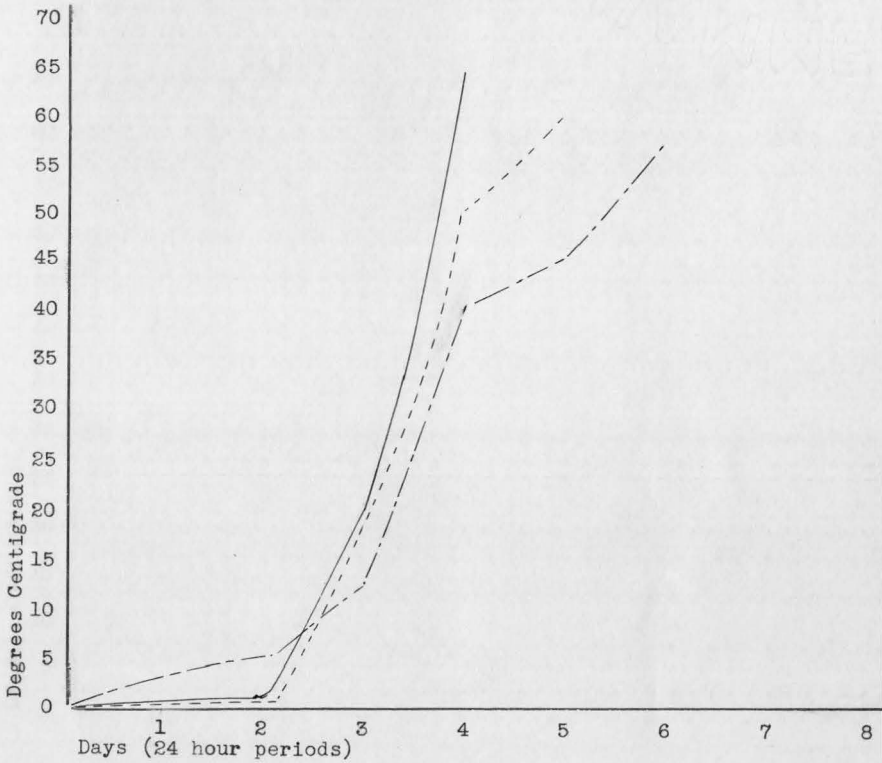


Diagram II A

Scale--½" = 1' Side View. Front of Bin Movable.

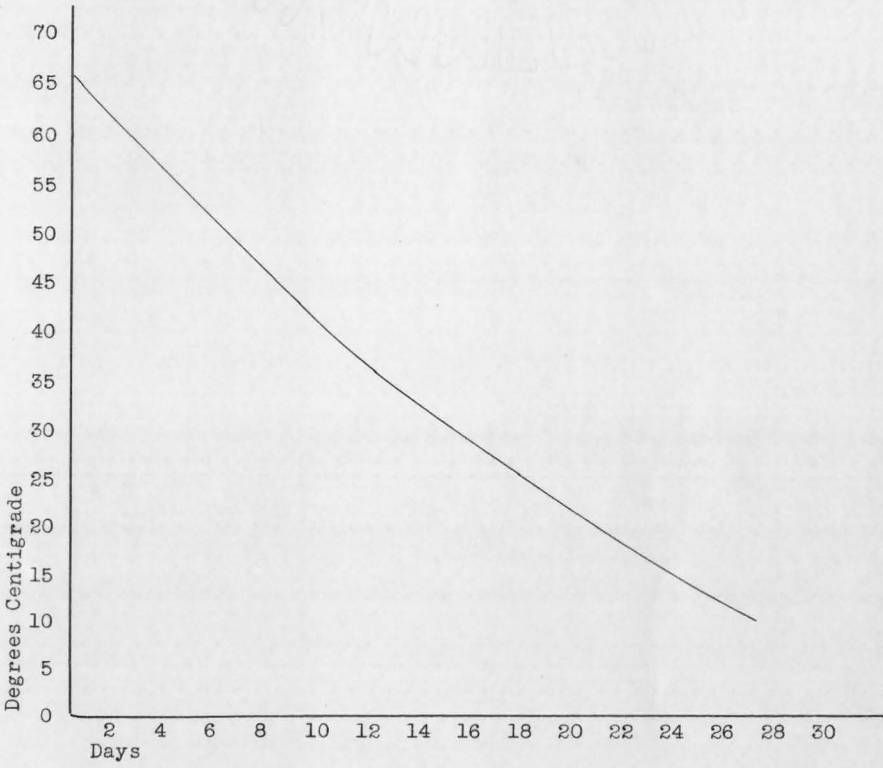


Graph III --Second Set of Temperature Curves of Heating Manure Piles.

——— - ——— —Represents the heating of the first pile, which started heating on the 4th day.

- - - - - - - - Represents the heating of the manure placed on the first pile.

———————Represents the heating of the manure placed on the second pile.



Graph IV --Curve Showing Cooling of Previously Heated Manure.

final weights of the manure in all of these piles are shown, with like data from the hot processed piles, in Table IV.

Observations on the "Hot Processed" and Other Manures in 1931-32

Observation of the piles during storage indicated that that the changes taking place were comparatively constant for the respective treatments. In the case of the hot processed piles there was a loss of ammonia as indicated by the odor during the heating process. Moisture was also given off, but due to the cold, was condensed in a large degree and froze around the cracks between the planks covering the pile. There was no noticeable increase in heat in the case of the loosely stored piles but they dried considerably until moistened by a storm and a frozen layer incircled them. The same was true of the compacted piles in question. The manure stored in containers did not freeze but the temperature remained low.

In the spring after five to six months storage the following observations were made upon the condition of the different piles: The loose piles were badly decomposed throughout the center portion by a dry fungus rot (commonly called fire fang). Fruiting bodies of a fungus were noted just under the surface of one of these loosely stored piles. The portion on the outside of the pile, which had been frozen most of the time, appeared to be very similar to the product which had gone into storage in the fall. Apparently the freezing had preserved this portion

Table IV --Dry Weight Losses of Horse Manure During Storage.

Type of Pile	Date Piled	Dry Weight in lbs.	Date Opened	Dry Weight in lbs.	Loss in lbs.	Per cent Loss	Average % Loss
Loosely Piled							
1.	8/13/31	857.	4/9/32	607.	250.	29.	26.
2.	9/10/31	880.	4/9/32	777.	103.	11.	
3.	9/21/31	524.	4/11/32	330.	194.	36.	
*4.	11/4/31	128.	4/11/32	126.	2.	1.	2.
*5.	11/4/31	150.	4/11/32	147.	3.	2.	
*6.	11/4/31	156.	4/11/32	154.	2.	3.	
Compactly Piled							
1.	8/26/31	960.	4/12/32	812.	138.	14.	17.
2.	9/21/31	420.	4/12/32	336.	84.	20.	
**3.	11/4/31	70.	4/12/32	66.	4.	8.	11.
**4.	11/4/31	68.	4/12/32	60.	8.	11.	
**5.	11/4/31	84.	4/12/32	75.	11.	13.	
Hot Processed							
***1.	12/6/31	273.	4/13/32	171.	102.	37.	46.
***2.	12/15/31	240.	4/13/32	120.	120.	50.	
***3.	12/19/31	236.	4/13/32	120.	116.	49.	

* These loose piles were small and apparently remained inactive because of temperature and humidity.

** These compact piles (compacted in containers) ripened with minimum losses.

*** The hot processed piles show large losses in weight.

of the pile from attack by fungi.

Those piles which had been compactly tramped were also decomposed similarly to those piled loosely, but to a lesser degree, which was probably due to poorer aeration. In the containers the material was similar in appearance to the material which had been tramped into them but seemed to be in a more friable condition, the straw contained having lost the brittle feel it had when stored.

That manure which had received the hot processing was well decomposed and brown to black in color, moist, odorless and friable. The fungus which seemed to have caused the most serious damage in the other piles was present along the edges of the pile. The white mycellium against the brown color was very conspicuous along small airways through the heap and on the edges. The product obtained looked very much like the best rotted portion found in limited quantities in large piles of stored manure and so much desired for lawns, shrubbery and greenhouses. During the mild winter of 1933-34, a large pile of manure from various animal sources was prepared by hot processing in an open pile. Photograph II is a picture of this pile. In rotting this heap larger units were used and some moisture supplied during the original period of heating and occasionly during the summer to maintain the pile in a moist condition. The manure is well rotted to within six inches of the surface of the heap.

Photograph II --A large pile of hot processed manure prepared in the open during the mild winter of 1933-34. Note the dark color of the decomposed manure immediately under the surface of the pile.

STUDIES ON THE COMPARATIVE VALUE OF THE HOT TREATMENT (KRANTZ PATENT) AND COMMON METHODS OF HANDLING BARNYARD MANURE

A Thesis
Submitted to the Department of Agronomy
Utah State Agricultural College
In Partial Fulfillment
of the
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By

Orval E. Winkler

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INTRODUCTION

Antidating written human history the dung of animals, chalk, marl, wood ashes and other substances were probably used to increase the productivity of the soil. These practises found their way into the earliest farming activities of the Chinese, Persians, Greeks and Romans. (3)(11) In the Hebrew scriptures mention is made of the "D ung Gate". (10) This was undoubtably a place given to the marketing of manures. That manure was used as a soil amendment in Asia Minor in Biblical times is not questioned. The famous Roman agricultural writer Cato (234 B. C.) wrote at length on manures and their handling. He gave bird manure preference and spoke of the manurial value of legumes. (3) Jethro Tull believed tillage was manure and contended that manures only benefit the soil because of improved physical condition after application. Liebig, the well known German agricultural chemist, gave prominence to the theory that small quantities of minerals added to the soil would suffice as manure. (1) Today the general ideas of soil fertility and the use of manures and fertilizers incorporates the views of these earlier students with better explanations of the relationships of one usage to the other. (13)(26)(29)(30) The study here reported is limited to the methods of handling barnyard manure and particularly to the recent development in Germany of what is known as "Hot Processing."

REVIEW OF LITERATURE

The literature on the subject of manure is very extensive. This is particularly true of the literature in the German language. On the subject in question, "Hot Processing," there are several papers from the Leipz ig Experiment Station in Germany. (7) (8)(26) There are also a number of papers of a popular nature by various German writers. (2)(5)(14)(17)(3)(etc.) The system is demonstrated at the Deutsches Museum in Munich as belonging on the ideal farm. The process is briefly described by Pittman. (13)

METHODS OF STORING MANURE

In reviewing available literature it is the cocensus of opinion among writers who have not considered in their writings the idea of the hot processing of manure, that minimum losses in stored manure are experienced when the piles are as compact, moist and cool as possible. (1)(19)(28)(30) Roofing is recommended in areas of high precipitation. Pitting or partial pitting in water tight basins is said to be valuable to check the losses caused by the perculation of liquid through the pile.

THE HOT PROCESSING OF MANURE

The newer development patented in several countries by Herman Krantz makes use of the above methods with certain

modifications. (D. R. P. 386, 512 & 388, 638 & others)(13) Chief among these modifications is a brief period of heating in a loose heap as soon after the material is removed from the barn as is possible. This is followed by a tight compacting of the pile when it has reached a temperature of 55 to 65° C. Drainage is provided to remove excess water from the manure. Specially constructed units (Gaerstaette) for the best results are marketed by the "Gaerstatt G. M. B. H." in Munich, Germany. Licenses for the commercial or farm use of the process are obtainable from the same firm. The commercial name of the processed manure is "Edelmist" and the process "Edelmistbereitung." Difficult of translation the terms mean "Rich Manure" and "Rich Manure Preparation" respectively. In the United States the process is covered by patents Number 1,459,059 and 1,643,018.

VALUE OF HOT PROCESSING AS CLAIMED BY PROPONENTS

Original experiments were conducted by those who discovered the process. The results of these experiments were exceptionally favorable to this mode of the perservation of manure as shown by increased crop yields. (15) The advantages claimed for the process were as follows: First--the gross losses during the time of storage were much smaller. (12) Second--the nitrogen content of the treated material was rendered more available which hastened and increased its assimilation by plants. The increased crop was 2.78 times the increase possible with ordinary barnyard manure. (15) Third--the keeping qualities

of the product were improved which allowed for longer periods of storage with minimum losses. (12) Fourth--Pathogenic bacteria and weed seeds contained were killed. (22)

STUDIES ON HOT PROCESSING BY VARIOUS INVESTIGATORS

The interest aroused by the results of those commercially engaged in the hot processing of manures led to numerous studies. Losses in weight were studied by Henkel and Krantz (9), Weigert (32)(34), and Remy, Klueter and Weiske(21). These results were in many instances contradictory, losses ranging from 10.25 to 32 per cent. Loss of Nitrogen was also studied by Remy, Klueter and Weiske, which study has been questioned by Glathe and others as no losses in the total nitrogen content were found. Field experiments conducted by Borneman at Konradsdarf in 1921 and continued in 1922 by O. Kron (13) showed decided crop increases in favor of the hot treated manure. Weigert (32)(34), by applications calculated to be of like total nitrogen content, showed less disease in potato hills on the plots manured with hot manure. The total yields for a two year period comparing barnyard manure to hot manure gave ratios of 1:1.94 and 1:2.13 respectively.

Biological activities in the "Gärstatt" received attention from Loehnis (16)(17) and Ruschmann (23)(24)(25) and more recently Goeters (8). Ruschmann ascribed the value of the "Edelmist Process" to the high temperature fermentation killing the vegetative cells of the bacilli, while allowing their

enzymes to act upon the other dead bacterial cells thus rendering their nitrogen compounds more soluble. Goeters' results showed greatly reduced numbers of bacteria at high and low temperatures. Correctly handled Edelmist was poor in vegetative bacterial forms. The number of spores found in Edelmist were high as compared with ordinary manure but most of these were dead. Urea bacteria were reduced in numbers but some forms persisted and helped in the completion of the process. Cellulose consumers became practically extinct but were found in barnyard manure. The high bacterial content of barnyard manure was said to account for heavy losses in dry weight and plant nutrients during storage. Stored "Edelmist" showed little increase in bacterial numbers except for forms attacking cellulose. Nitrification in soil mixtures showed "Edelmist" to be from two to three times as efficient as barnyard manure. In pot experiments the nitrogen efficiency in the pots manured with Edelmist was two to four times as great as in those manured with barnyard manure.

Scheibe (27) studied particularly the nitrogen efficiency and carbon dioxide yields of Edelmist in field and pot experiments. Nitrate nitrogen was found to be higher on the plots manured with Edelmist than those manured with barnyard manure. Carbon dioxide was released in larger amounts on the plots manured with "Edelmist." The relationship in the case of nitrogen was 1.17 to 2.7 in pot experiments while in the field the relationship depending on the age of the "Edelmist" varied from 1 to 1.71 for straw manure to 1 to 2.19 in the case of peat manure.

The straw and peat were used as bedding in the stalls. Carbon dioxide liberation in potato plots was 102 per cent for Edelmist compared with 23 per cent for barnyard manure. From carrot plots the carbon dioxide liberation was 160 per cent in the case of Edelmist manuring as compared with 43 per cent for barnyard manure. These above results are given in comparison to untreated plots.

Glathe (7), notes the following results in a study of the losses during storage as compared with piled manure. Horse manure was used.

	Hot Manure		Barnyard Manure
	Straw Manure	Peat Manure	Straw Manure
Total "N" lost	15.7%	14.8%	40.0%
Dry Weight lost	29.0%	14.5%	45.2%
Raw Weight lost	15.8% & 19.4%	10.6%	31.0%

Ehrenberg (5) considered the economic phase of the problem under German conditions. The operating costs which were for sixty head of cattle were found to be as follows: License 1500 r m, building costs 12,500 r m, with the calculated profit on the investment, due to increased value of manure, fifteen per cent net with labor costs considered.

EXPERIMENTAL WORK

Experimental study of methods of handling manure under the climatic conditions of the intermountain west seems to have received little consideration. Stoker etal., however, recently found that Russian knapweed and white top seeds lost their viability in moist heating piles of chicken manure (28). The circumstances noted have prompted the study herein reported.

PREPARATION OF EDELMIST (HOT PROCESSED) AND OTHER MANURES IN 1930-31

In December 1930 a platform was constructed to take care of a large pile of horse manure to be handled as specified in the patented process of Herman Krantz. The piles were arranged as illustrated in Diagram I. Pile "A" was made approximately four feet on a side at the base and approximately three feet on a side at the apex with a depth of about four feet. As soon as this pile had commenced heating, pile "B" of like proportions was placed against "A". With pile "B" heating, pile "C" was to be placed on the other side of "A" to be completed with pile "D". At this time "A" should have reached a temperature of 60° C and should have been tramped thoroughly and pile "E" placed on the top, the processing continuing in this manner until the manure to be processed had been brought within one large heap. This plan failed as the winter temperatures so chilled the manure that heating could not be started in the open piles. The heaps finally froze solid.

This first plan having failed of completion a bin was

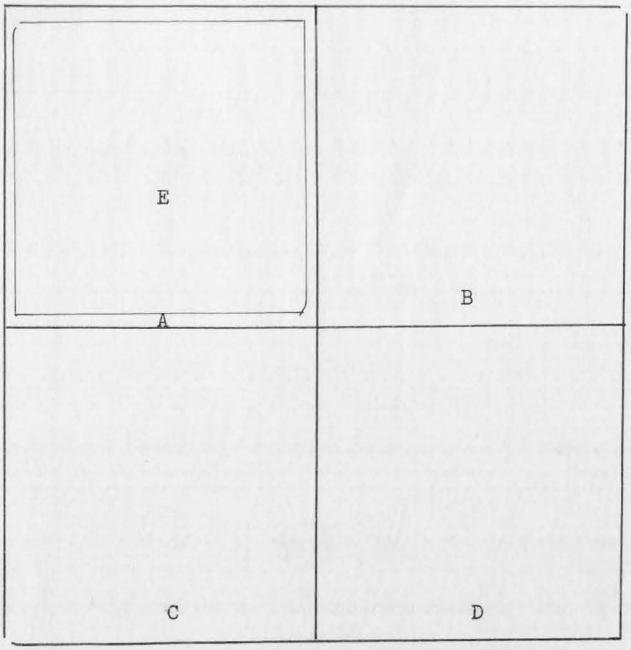


Diagram I --Method of Arranging Piles in the Hot Treatment of Manure.

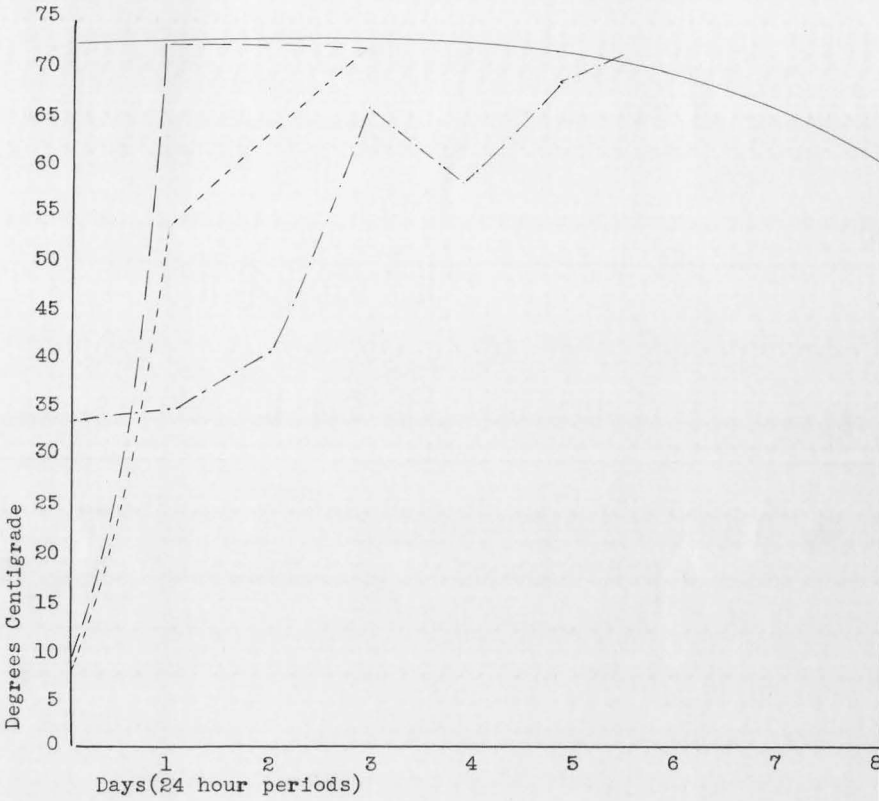
Showing the arrangement of piles calculated usable in the hot processing of manure. Beginning with "A", piles "B", "C" and "D" were to be placed as illustrated. When "A" had reached a temperature of 60° C, "E" would have been placed on top of "A", after the later pile had been thoroughly tramped. In this manner any sized heap could have been made. The units were to be approximately 4' x 4' x 4'.

constructed as shown in Photograph I. On all sides of the manure in the bin was placed about one foot of dry straw for temperature insulation. This was done in the middle of January at sub zero temperatures. This pile also failed to develope an appreciable heat but did not freeze solid, so was left in the bin in an apparently inactive condition until the 13th of February when it was noted that the pile commenced to heat. A second pile was then placed in front of the first pile. The rapid rise in the temperature of these piles is illustrated in Graph I. At temperatures of 65°-72° C the material in the piles was tramped thoroughly and another pile placed upon the top and thoroughly tramped when it had attained the desired temperature. Two additional piles were placed upon the pile in the rear of the bin and one upon the pile to the front. The third pile, in the foreground of Photograph I, was from the cow barn and did not heat satisfactorily so was not used.

The manure used was such as is taken from the average horse barn. It was made up of bedding from the stalls (wheat straw) plus wasted feed from the mangers (alfalfa hay), and the feces of the animals and what urine was absorbed by the bedding, as the barn is equiped with drain troughs. The manure used was with one exception from the same horses. Alfalfa hay and chopped barley were the feeds used.

Observations during the initial period of heating showed a loss of ammonia. The odor was very noticeable about the heating piles. A maximum temperature of 72° C was reached. (See Graph I) The temperature gradually decreased to 50° C and

Photograph I --Showing the method of building up a pile of hot processed manure.



Graph I --Temperature Curves of Heating Manure Piles.

——·——·——Represents the heating of the first pile.

— — — —Represents the heating of the second pile after the first pile had been thoroughly tramped.

- - - - - - - - - -Is the temperature curve of the pile placed on top of the second pile after it had been thoroughly tramped.

——————Represents the temperature curve in the cooling pile.

remained constant for about a week after which it gradually decreased to approximate air temperature. Fungous growth was noted at the points of contact with new heaps of manure and along the sides of the pile where aeration was not eliminated. This growth, however, appeared arrested when the piles were thoroughly tramped at high temperature. The volume of the piles thus treated was decreased approximately one half.

At the end of a six months period of storage the piles were covered with a thin layer of dry strawy material. Inside this covering was observed a moist homogenous mass of a dark brown color, without the usual manure odor and resembling in this respect the duft in a heavy forest. The original material had lost its identity except for horse hairs which had withstood the decomposition. The temperature inside the pile was lower than the temperature of the summer air.

From the completed piles samples were taken for chemical analysis and pot experiments. These were obtained by taking six random samples completely through the piles. These six samples were then thoroughly dried and mixed to make composite samples of the two piles to be used for analysis and pot tests.

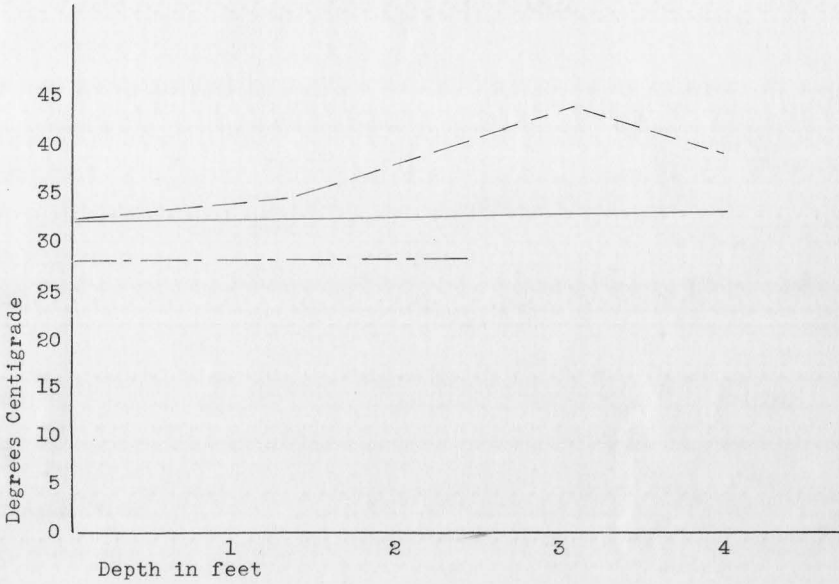
POT TESTS IN 1931 USING "EDELMIST" AND OTHER MANURES

For the purpose of comparing the relative effects of manures on yields of wheat, alfalfa and sugar beets a series of pot tests were arranged. The manures used for these tests were

hot processed manure, fresh horse manure from the same source as that which had been hot processed, and stored manure of like origin from a large compacted heap stored during the winter on the College farm.

Observations on the Character of the Manures Used.

Observations of the compacted heap at the College farm were made to ascertain the similarity of the product from this type of pile and that produced by the hot process. Test pits were dug into the heap for the purpose of obtaining samples and observing the condition present in such storage. Temperature readings were taken to see if they were comparable in the two types of piles. (see Graph II) It will be observed that within the compacted pile higher temperatures prevailed. The manure in the center of the pile in the five test holes was different from that in the outer 18 inches. This first eighteen inches was similar to the strawy covering of the hot processed piles but proportionately thicker. This outer covering was similar to musty hay and powdered readily. The manure between the 18 and 36 inch depths varied in every test hole. In some the material was well decomposed very much like the hot processed piles, while in others it was strawy and full of fungi, with some of the manure appearing as if recently taken from the barn. The bottom layer was very much like an ensilaged product with the odor of fresh manure. From all of these test holes like



Graph II --Temperatures Taken at Different Depths after a Six Months Period of Storage in Compactly Stored and Hot Processed Manure Piles.

— — —Temperature in a compactly stored manure pile.

————Air temperature in July 1931.

— - —Temperature in a small pile of hot processed manure.

samples were taken with the size of samples proportioned as much as possible to the different types of manure present. These samples were mixed and dried for analysis and pot tests.

Manure was taken at random from a heap fresh from the horse barns. The samples were prepared as were the other manures for the tests to be made.

The soil used was taken from a field on the Greenville Experiment farm which had not received manure for several years. The crop previously harvested had been wheat. The soil is of the Millville loam series. The top six inches of soil were used.

Preparation of Pots

Sufficient soil to fill 48 eight-inch pots was poured upon a cement floor and thoroughly mixed. The material was divided into four portions. With the first portion sufficient manure from the heated piles was added to equal a treatment of five tons of manure per acre calculated on an oven dry basis which would be the equivalent of about twenty tons per acre wet. To the second portion a like amount from the compact pile on the farm was added. The third portion received a like amount of fresh manure. The last was untreated. After thoroughly mixing in the manure, a like amount of water was added to each portion to bring the soil to an apparent optimum moisture content. Each of the pots was then filled with the soil to the same weights to make twelve replicates of each treatment.

Wheat and alfalfa were planted in 24 of the pots and sugar beets in the remainder. The pots were placed in a cold frame in rows representative of each treatment. In the pots planted to wheat and alfalfa, 15 kernels of wheat were sown per pot and a pinch of alfalfa seed. The beet pots received twelve seed balls per pot. Later the wheat was thinned to ten plants per pot, the alfalfa untouched and the beets to six and later to two plants per pot. The soil was maintained in a moist condition by sprinkling twice per day.

Results of 1931 Pot Tests

Due to insect attacks and later to mildew it was necessary to harvest the wheat plants before maturity. This was done ninety days after planting. The results are tabulated in Table I. The alfalfa plants remaining in the wheat pots were not thinned. The number of plants per pot and the total weight from the random sowing is tabulated in Table I. Soil analysis for nitrate nitrogen by a modified phenoldisulphonic acid method (18) and water soluble phosphorous as determined by the Corruleo-Molybdate method is given in Table I. The total nitrogen and phosphorous content of similar manures is tabulated in Table V. Analysis for potassium was considered unnecessary in these experiments as results with potassium fertilization on the soils in question have always been negative. The results from the series of plots in which beets were grown are given including nitrate nitrogen and soluble phosphorous in Table II.

Table I --The Available Phosphorous and Nitrogen and the Yield Data on Wheat and Alfalfa from Pot Tests in 1931.*

	No. of Alfalfa Plants	Weight of Alfalfa Plants	Height of Wheat Plants	Weight of Wheat Plants	ppm "P" in the soil(H_2O soluble)	ppm "NO_3" Nitrogen in the soil
Check (No Manure)	3.3	.177 g.	26.3 cm.	1.428 g.		1.10
Fresh Horse Manure	3.6	.226 g.	26.8 cm.	1.826 g.	.32	2.80
Compactly Stored Horse Manure(Greenville Farm)	6.5	.597 g.	26.4 cm.	2.461 g.	.36	12.60
Hot Processed Horse Manure	6.5	.765 g.	29.0 cm.	2.927 g.	.56	2.10
** Amount Necessary for Significance (p=.05				.059 g.	.14	6.78
** Amount Necessary for Significance (p=.01				.082 g.	.19	9.55

* Data from six replications of each treatment (treatments in rows).

** Only when Fishers' z test showed a treatment effect, are differences given which are necessary for two different probabilities.

Table II --The Available Phosphorous and Nitrogen and the Yield Data on Sugar Beets from Pot Tests in 1931.*

	Dry Wt. of Roots	Dry Wt. of Tops	ppm "NO_3" Nitrogen in the soil	ppm H_2O soluble "P" in the soil
Check (No Manure)	.037	.628	5.9	
Fresh Horse Manure	.077	.619	8.1	.09
Compactly Stored Horse Manure (Greenville Farm)	.091	.761	6.0	.82
Hot Processed Manure	.099	.595	8.1	.23
** Amount Necessary for Significance (p=.05				.40
** Amount Necessary for Significance (p=.01				.96

* Data from six replications of each treatment (treatments in rows).

** Only when Fishers' z test showed a treatment effect, are differences given which are necessary for two different probabilities.

The data from the pots containing wheat and alfalfa seemed to indicate a superior growth in the case of the pots manured with the hot processed manure and the manure stored compactly. The use of Fishers' z (6) showed these results to be significant. The sugar beet pots showed no differences in yield due to treatment but the availability of phosphorous was significantly different in the manured and unmanured soil.

POT TESTS IN 1933 USING THE SOIL PREPARED FOR THE 1931 TESTS

Because it seemed that the arrangement of the pots in rows might have unduly influenced the growth of the wheat in the outside pots where the greatest differences were observeable, the pot experiment was repeated with the soil left over from the 1931 tests. The pots were arranged in a Latin square. In this experiment smaller pots were used and the replications were cut to four for each treatment. Ten kernels of wheat were planted and upon germination thinned to the smallest number of plants per pot, which was eight.

Results of 1933 Pot Tests

Six of the plants were harvested 53 days after planting. The yield data are given in Table III. The growth was about one half of the former 90 day growth. The remaining two plants were grown to maturity, the data being given in Table III.

Table III --The Available Phosphorous and Nitrogen and the Yield Data on Wheat from Pot Tests Harvested in 1933.*

	Height of Plants in June	Dry Weight of Plants in June	Height of Mature Plants	Dry Wt. of Mature Plants	"P" in soil by Dahlberg & Browns' Method	ppm "NO_3" Nitrogen in soil
Check (No Manure)	13.22 cm.	.382 g.	22.39 cm.	.45 g.	8.	3.6
Fresh Horse Manure	13.15 cm.	.354 g.	21.24 cm.	.52 g.	16.	3.5
Compactly Stored Horse Manure(Greenville Farm)	13.06 cm.	.456 g.	23.99 cm.	.53 g.	17.	4.5
Hot Processed Horse Manure	15.16 cm.	.488 g.	22.94 cm.	.59 g.	24.	4.9
** Amount Necessary for Significance (p=.05					7.	
** Amount Necessary for Significance (p=.01					11.	

* Data from four replications of each treatment (treatments arranged in a Latin square).

** Only when Fishers' z test showed a treatment effect, are differences given which are necessary for two different probabilities.

Analysis of the soil for nitrate nitrogen from the pots showed as much variation within treatments as between different treatments so the results are not significant. In the case of analysis for soluble phosphorus by the reduction method of Dahlberg and Brown a higher soluble phosphorous rating was observed in the manured soils with apparent significant differences as is seen by a study of Table III. In no case were the differences in yield significant.

FIELD TESTS WITH "HOT PROCESSED" MANURE COMPARED TO OTHER MANURES

To compare the effect of variously treated horse manures in field experiments preparations were made to obtain manure of like source and treat sufficient of the material to arrange a series of experiments in the field as well as study the gross losses taking place during storage. The source of the manure was the same as in the original experiments, being taken from the U. S. A. C. horse barns.

Preparation of "Hot Processed" and Other Manures in 1931-32

In order to prepare the hot processed manure, a bin was constructed as in the first instance. Again it was difficult, in the open bin, to get the manure to heat satisfactorily although the experiment was begun earlier in the fall. After attempting for two weeks to get a pile started to heat by adding

water to make up for losses by evaporation, the pile was removed from the bin. This bin was then built up into a roofed shed insulated with eighteen inches of sheep manure and straw around the two inch planks, from which material the shed was constructed. The plan of the structure is illustrated in Diagram II & II A. In this new bin insulated on four sides and with the bottom six feet from the roof, 700 pounds of well mixed manure with a moisture content of 76 per cent were loosely piled and covered with planks. Later 350 pounds of manure were added to this pile before it commenced to heat. The temperature curves of this and two additional piles treated in this bin are shown in Graph III. In Graph IV the temperature curve in cooling the total piled heap is given. When the first pile had reached a temperature of 57.5° C, after being in the bin for ten days, it was tramped and 750 pounds more of loosely piled manure placed on top, which pile reached a temperature of 60° C in five days and then was thoroughly tramped. The third pile of manure placed on top of the second, as in the first instance, weighed 740 pounds and and reached a temperature of 57.5° C. The air temperature during these treatments was sub zero. The piles were separated with lath markers.

While working with these heating piles eleven other sets were arranged as follows: Six piles were built in loose heaps from the manure as it came from the barn, two were compactly tramped in the open, and three compactly tramped in large galvanized iron cans which were placed inside the edge of a large manure pile and protected from the weather. The original and

Diagrams Showing Construction of Insulated Bin for Hot Treatment of Manure.

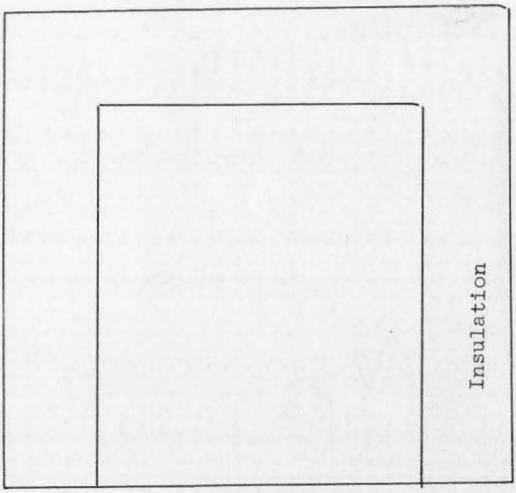


Diagram II

Scale--½" = 1' Front View. Depth 5 ft.

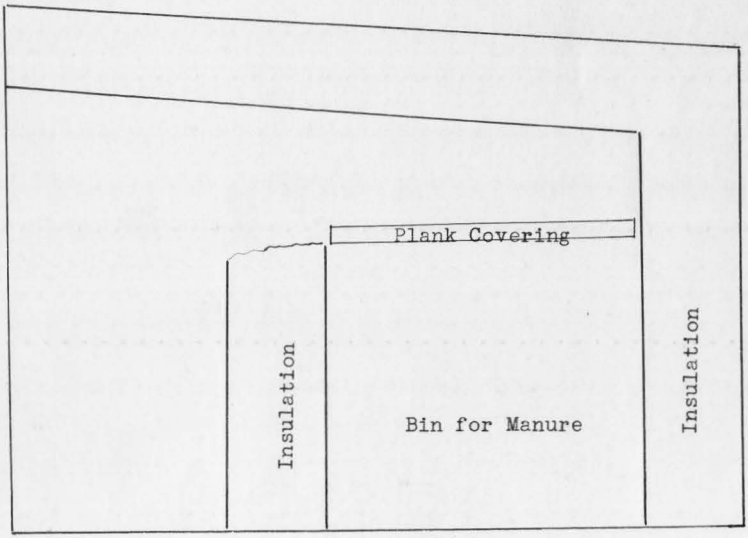
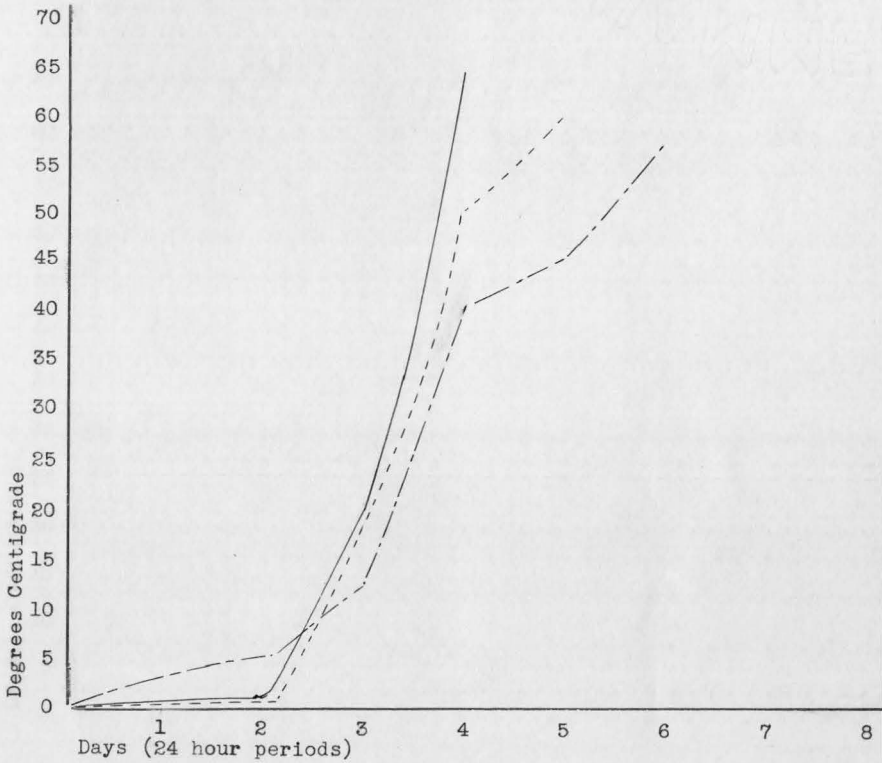


Diagram II A

Scale--½" = 1' Side View. Front of Bin Movable.

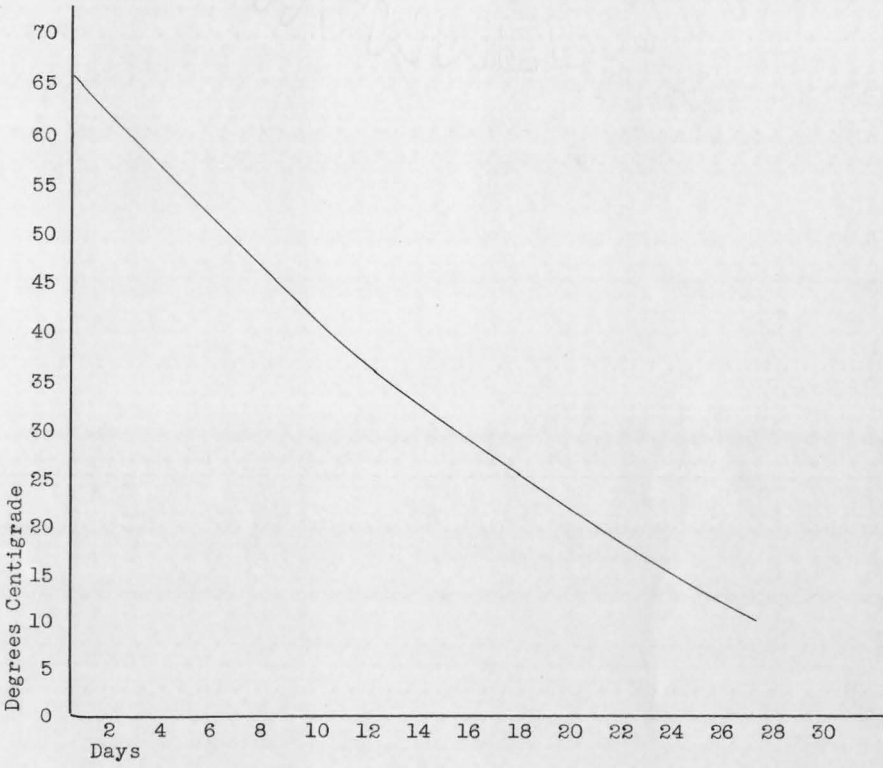


Graph III --Second Set of Temperature Curves of Heating Manure Piles.

——— - ——— —Represents the heating of the first pile, which started heating on the 4th day.

- - - - - - - - Represents the heating of the manure placed on the first pile.

———————Represents the heating of the manure placed on the second pile.



Graph IV --Curve Showing Cooling of Previously Heated Manure.

final weights of the manure in all of these piles are shown, with like data from the hot processed piles, in Table IV.

Observations on the "Hot Processed" and Other Manures in 1931-32

Observation of the piles during storage indicated that that the changes taking place were comparatively constant for the respective treatments. In the case of the hot processed piles there was a loss of ammonia as indicated by the odor during the heating process. Moisture was also given off, but due to the cold, was condensed in a large degree and froze around the cracks between the planks covering the pile. There was no noticeable increase in heat in the case of the loosely stored piles but they dried considerably until moistened by a storm and a frozen layer incircled them. The same was true of the compacted piles in question. The manure stored in containers did not freeze but the temperature remained low.

In the spring after five to six months storage the following observations were made upon the condition of the different piles: The loose piles were badly decomposed throughout the center portion by a dry fungus rot (commonly called fire fang). Fruiting bodies of a fungus were noted just under the surface of one of these loosely stored piles. The portion on the outside of the pile, which had been frozen most of the time, appeared to be very similar to the product which had gone into storage in the fall. Apparently the freezing had preserved this portion

Table IV --Dry Weight Losses of Horse Manure During Storage.

Type of Pile	Date Piled	Dry Weight in lbs.	Date Opened	Dry Weight in lbs.	Loss in lbs.	Per cent Loss	Average % Loss
Loosely Piled							
1.	8/13/31	857.	4/9/32	607.	250.	29.	26.
2.	9/10/31	880.	4/9/32	777.	103.	11.	
3.	9/21/31	524.	4/11/32	330.	194.	36.	
*4.	11/4/31	128.	4/11/32	126.	2.	1.	2.
*5.	11/4/31	150.	4/11/32	147.	3.	2.	
*6.	11/4/31	156.	4/11/32	154.	2.	3.	
Compactly Piled							
1.	8/26/31	960.	4/12/32	812.	138.	14.	17.
2.	9/21/31	420.	4/12/32	336.	84.	20.	
**3.	11/4/31	70.	4/12/32	66.	4.	8.	11.
**4.	11/4/31	68.	4/12/32	60.	8.	11.	
**5.	11/4/31	84.	4/12/32	75.	11.	13.	
Hot Processed							
***1.	12/6/31	273.	4/13/32	171.	102.	37.	46.
***2.	12/15/31	240.	4/13/32	120.	120.	50.	
***3.	12/19/31	236.	4/13/32	120.	116.	49.	

* These loose piles were small and apparently remained inactive because of temperature and humidity.

** These compact piles (compacted in containers) ripened with minimum losses.

*** The hot processed piles show large losses in weight.

of the pile from attack by fungi.

Those piles which had been compactly tramped were also decomposed similarly to those piled loosely, but to a lesser degree, which was probably due to poorer aeration. In the containers the material was similar in appearance to the material which had been tramped into them but seemed to be in a more friable condition, the straw contained having lost the brittle feel it had when stored.

That manure which had received the hot processing was well decomposed and brown to black in color, moist, odorless and friable. The fungus which seemed to have caused the most serious damage in the other piles was present along the edges of the pile. The white mycellium against the brown color was very conspicuous along small airways through the heap and on the edges. The product obtained looked very much like the best rotted portion found in limited quantities in large piles of stored manure and so much desired for lawns, shrubbery and greenhouses. During the mild winter of 1933-34, a large pile of manure from various animal sources was prepared by hot processing in an open pile. Photograph II is a picture of this pile. In rotting this heap larger units were used and some moisture supplied during the original period of heating and occasionly during the summer to maintain the pile in a moist condition. The manure is well rotted to within six inches of the surface of the heap.

Photograph II --A large pile of hot processed manure prepared in the open during the mild winter of 1933-34. Note the dark color of the decomposed manure immediately under the surface of the pile.

Chemical Studies of the Manures Used

The material going into the various piles and the final products obtained were analyzed for total nitrogen and phosphorous. These data are given in Table V. The per ton nitrogen value based upon the nitrogen content of the original manure, less storage losses as tabulated in Table IV, is reported in Table VI. Pound for pound (oven dry) the stored manures contained significantly more nitrogen and phosphorous. Of all the stored manures the smallest loss of nitrogen was observed in the hot processed piles. Calculated on a per ton basis the stored product in this last instance, although dry weight losses of 45 per cent were noted, retained all the nitrogen originally present.

Table V --The Per Cent Total Nitrogen and Phosphorous in the Manures Used.

	Per cent Total "N"	Significant Difference p= .01	Total* Per cent "p"
Fresh Horse Manure	1.271		.179
		.066	
Loosely Stored Horse Manure	1.375		.299
		.003	
Compactly Stored Horse Manure	1.382		.250
		.080	
Hot Processed Horse Manure 1930-1931	2.325		.534
		.000	
Hot Processed Horse Manure 1931-1932	2.343		.353

*Differences to show significance are not given in case of the phosphorous content because these determinations were made on composited samples.

Table VI --The Relative Losses of Nitrogen Calculated in Pounds Per Ton on a Dry Weight Basis.**

	Pounds Per Ton	Per Cent Loss
Original Horse Manure Fresh from the Barn	27.40	
Loosely Stored Approximately Seven Months	17.66	35
Compactly Stored Approximately Seven Months	19.09	30
Hot Processed & Stored Approximately Six* Months	27.35	None

* It was not possible to show a loss of nitrogen in the Hot Processed piles studied.

** Computed by taking the percentage of nitrogen in a ton of the original manure and that amount of nitrogen present in the same manure reduced in weight by a period of storage.

Sampling was done by taking a number of handfuls at random from the broken piles. These samples were then mixed thoroughly for analysis. In order to determine the nature of the decomposition which had taken place in the different piles during these experiments, a proximate organic analysis of composite samples representative of the different treatments studied was made by the method used by Waksman and Stevens (31). These data are reported in Tables VII, VIII and IX. The higher percentage of crude protein found in the hot processed manure (Table VII) serves as a check on the findings reported in Table V, where the total nitrogen content of the manures was reported. The relative amounts of nitrogen, soluble in water and acids, do not seem to change during the process. (Table IX) The loss in dry weight of the hot processed manure is associated with corresponding

Table VII --Proximate Chemical Analysis of Horse Manures Used.

	Fresh Manure 1930	Fresh Manure 1931	Stored Loosely 7½ Mths.	Stored Compactly 7 Mths.	Stored Compactly at Greenville 1930	Hot Processed Stored 8 Mths. 1930-31	Hot Processed Stored 5 Mths. 1931-32
pH	5.5	5.5	5.5	6.0	6.0	6.0	5.0
Percent							
Moisture	11.60	11.00	13.20	10.80	10.80	11.20	10.80
Ether Soluble	.97	1.10	.78	.65	.33	.07	.37
Alcohol Soluble	4.52	5.32	3.35	4.61	4.72	12.68	9.55
Cold & Hot H_2O Soluble	14.86	18.72	18.40	15.30	20.69	24.35	24.97
Reducing Sugar*	(2.55)	(2.55)	(2.15)	(2.86)	(2.86)	(2.50)	(3.70)
Hemicelluloses	7.34	9.60	8.21	5.29	1.93	2.41	2.49
Celluloses	6.38	5.88	5.54	3.98	1.55	1.46	1.64
Lignin	50.33	49.86	47.50	40.21	30.97	34.06	25.28
Crude Protein	4.81	4.63	4.61	5.38	8.81	10.75	8.31
Ash	15.10	17.02	22.46	24.48	31.77	28.96	23.81
Total Accounted For**	104.61	112.20	108.85	99.90	100.77	114.74	112.52

* The reducing sugars are not figured in the total percent as they are accounted for in the H_2O soluble fraction.

** Most of the totals being well over 100%, it is believed that this discrepancy is largely accounted for by duplication of mineral matter in both extracts and the ash plus smaller errors in nitrogenous compounds and the cumulative error in the experiment. This possibility is shown in Table VIII.

Table VIII --The Apparent Error in Table VII is Largely Eliminated by Subtracting the Per Cent of Residual Ash from the Total Per Cent of Ash of an Untreated Sample.

	Fresh Horse Manure 1930	Fresh Horse Manure 1931	Horse Manure Stored Loosely 7½ Mths.	Horse Manure Stored Compactly 7 Mths.	Horse Manure Stored Compactly at Greenville 1930	Horse Manure Hot Processed Stored 8 Mths. 1930-31	Horse Manure Hot Processed Stored 5 Mths. 1931-32
Per Cent							
Original Ash (Table VII)	15.10	17.02	22.46	24.48	31.77	28.96	29.81
Residual Ash	8.15	6.22	15.65	20.95	22.16	15.53	17.63
Difference	6.95	10.80	6.81	3.53	9.61	13.43	12.18
Total Accounted For (Table VII)	104.81	118.20	108.85	90.90	100.77	114.74	112.52
Above Difference	6.95	10.80	6.81	3.53	9.61	13.43	12.18
Apparent Correct Total	97.66	101.40	102.04	103.66	91.16	101.31	100.34

Table IX --Distribution of the Total Nitrogen Content as found in the Extracts from the Proximate Chemical Analysis.

	Fresh Horse Manure 1930	Fresh Horse Manure 1931	Horse Manure Stored Loosely 7½ Mths.	Horse Manure Stored Compactly 7 Mths.	Horse Manure Stored Compactly at Greenville 1930	Horse Manure Hot Processed Stored 8 Mths. 1930-31	Horse Manure Hot Processed Stored 5 Mths. 1931-32
Per Cent "N"							
H_2O Extract	.65	.65	.70	.79	.99	.95	.94
2% HCL Extract	.23	.23	.25	.23	.32	.35	.31
80 % H_2SO_4 Extract	.14	.16	.22	.19	.26	.20	.22
In Residue	.40	.35	.17	.14	.83	.87	.80
Total	1.42	1.39	1.34	1.35	2.40	2.37	2.27
Untreated Sample	1.36	1.27	1.38	1.38	2.20	2.27	2.21

increases in the percentage ash content. Certain ash constituents are also rendered more soluble by the processes of decomposition as indicated by their higher solubilities in water Table VII & VIII). In the decomposed manure the fraction soluble in alcohol also increases as a result of the processes of decomposition.

Arrangement and Treatment of Plots

After taking samples from the various piles of manure for analytical purposes, the replicate piles of each treatment were thoroughly mixed for field application. The field area used was one which had not received manure for several seasons. Four fifths of it, however, had received an application of treble super phosphate the year previous. The method of arrangement of treatments is shown in the Latin Square of Diagram III. Five treatments of five replications each were thus arranged on approximate eightieth acre plots. When planted to sugar beets, this allowed for four 42 foot rows with a discard of one row on each side of each plot and two on the borders. Manure was spread at the rate of 14 tons to the acre (wet basis).* The appearance of the area after being manured can be seen in Photograph III. From this Photograph, the arrangement can be partially followed by the check plots and those receiving the hot

*At the time the field was manured it was believed that the moisture content of the various manures were the same. Later analysis showed this assumption incorrect and as a result a slightly larger application of the manures not hot processed was made.

Photograph III --Showing the field plots after the manure was applied. The darker color of five of the plots is due to the application of hot processed manure.

processed manure, which was darker in color. The other plots were treated as follows: Five with manure from the tramped piles and galvanized iron containers (these were mixed because it was believed from observations in large piles of compacted manure that both products are present in about the proportions used); five with the manure from the loosely piled heaps; and five with fresh horse manure from the same source as that which had been stored in the other piles. As the experimental area had been fall plowed, it was necessary to disk the manure into the soil before planting.

Diagram III --Arrangement of 80th Acre Field Plots Showing Formerly Phosphated Area.

C	E	D	A	B	
D	B	A	E	C	Previously fertilized with treble superphosphate.
E	D	B	C	A	
B	A	C	D	E	
A	C	E	B	D	Not previously fertilized.

A = Check (No Manure)
B = Fresh Horse Manure--14 tons per acre.
C = Horse Manure Stored Loosely--14 tons per acre.
D = Horse Manure Stored Compactly--14 tons per acre.
E = Horse Manure "Hot Processed" --14 tons per acre.

Summary of Field Results

A good stand of beets was obtained during the growing season of 1932. Early in the season there appeared to be treatment differences but by the time of harvest these had disappeared. A composite of six soil samples taken in June from each plot showed no significant differences in NO_3 nitrogen, as shown in Table X, but were significantly different in water soluble phosphorous, as is noted by comparing manured with unmanured plots. Also in Table X are harvest data from the 1932 season including number and weight of beets, weight of tops and sugar content & purity. The yield of roots was significantly greater on all the manured treatments as compared with the unmanured treatments. Significant differences are also to be observed between the kinds of manures used. The compacted and hot processed manures gave significantly better yields than the treatments with either fresh or loosely stored manure.

Sugar beets were replanted on this area in 1933, with no further manuring, and the same data secured as in 1932 (Table XI). Yields of roots and tops were significantly different on the manured and unmanured plots. Plots, which had received stored manure of any of the kinds used, yielded more than the plots which had received fresh manure the previous season.

As the northern four-fifths of the field area used in the experiments had received applications of treble superphosphate (Diagram III), the possibility of a residual influence masking the effect on previously unfertilized ground was considered

Table X --The Available Nitrogen and Phosphorous, the Yield, Sugar Content and Purity of Sugar Beets following Various Manurial Treatments on Field Plots in 1932.

	ppm "NO_3" Nitrogen in June	ppm "P" H_2O Soluble in June	No. of Beets Harvested per acre	Weight of Roots (lbs. per acre)	Weight of Tops (lbs. per acre)	Ratio of Tops to Roots	Sugar (Per Cent)	Purity (Per Cent)
Checks (No Treatment)	16.0	.01	14,400	14,672	10,544	.72	17.2	82.9
Fresh Horse Manure	13.5	.46	14,720	18,648	12,772	.68	16.5	86.4
Horse Manure Loosely Stored 7½ Months	17.0	1.22	15,600	19,088	13,024	.68	17.7	88.2
Horse Manure Compactly Stored 7 Months	14.5	1.22	16,320	19,936	15,912	.79	17.1	85.7
Horse Manure Hot Processed Stored 5 Mths.	17.5	.41	15,720	19,962	13,104	.66	17.3	86.7
* Significant Differences (p=.05		.41		880				
* Significant Differences (p=.01		.58		814				

* Only when Fishers' z test showed a treatment effect, are differences given which are necessary for two different probabilities.

Table XI --The Available Nitrogen and Phosphorous, the Yield, Sugar Content and Purity of Sugar Beets Following Various Manurial Treatments on Field Plots in 1933.

	ppm "NO_3" Nitrogen in June	Available "P" in June (comparative units)	No. of Beets Harvested per acre	Weight of Roots per acre (lbs.)	Weight of Tops per acre (lbs.)	Ratio of Tops to Roots	Sugar (per Cent)	Purity (per Cent)
Checks (No Treatment)	17.6	2.4	10,240	9,152	7,776	.85	19.5	87.0
Fresh Horse Manure	12.8	4.0	12,630	12,688	9,864	.77	19.7	87.7
Horse Manure Loosely Stored 7½ Months	12.8	3.2	12,480	14,560	9,328	.64	19.7	87.4
Horse Manure Compactly Stored 7 Months	12.7	3.4	13,840	15,664	11,616	.74	20.0	89.5
Horse Manure Hot Processed Stored 5 Mths.	15.0	3.6	13,280	14,288	11,104	.78	19.8	87.7
* Significant Differences (p=.05				1,290	1,449			
* Significant Differences (p=.01				1,808	2,029			

* Only when Fishers' z test showed a treatment effect, are differences given which are necessary for two different probabilities.

Table XII --Yield of Sugar Beets on the South Series of Field Plots which had not Received an Application of Treble Superphosphate.

	Year	No. of Beets Harvested	Average No. of Beets	Wt. of Roots	Average Wt. of Roots	Wt. of Tops	Average Wt. of Tops	Ratio of Tops to Roots
Checks (No Treatment)	1932	11,280	8,800	8,720	6,080	6,640	4,880	.80
	1933	6,320		3,440		2,120		
Fresh Horse Manure	1932	14,480	13,240	17,440	14,580	11,040	9,920	.68
	1933	12,000		11,720		8,800		
Horse Manure Loosely Stored 7½ Months	1932	13,840	12,820	18,720	13,480	12,240	9,720	.72
	1933	12,000		8,240		7,200		
Horse Manure Compactly Stored 7 Months	1932	15,440	13,520	17,600	15,400	15,840	12,760	.82
	1933	11,600		13,200		9,680		
Horse Manure Hot Processed Stored 5 Mths.	1932	15,440	13,080	19,920	16,280	14,000	13,000	.80
	1933	10,720		12,640		12,000		

(Table XII). The average yield of sugar beets over a two year period on this series of plots showed the order of yields to be as follows: First with hot processed manure, second with compactly stored manure, third with fresh manure, fourth with loosely stored manure and fifth unmanured.

In 1934 corn was planted on the plots but due to drouth conditions and lack of irrigation water practically no growth was made. Observation of the area showed no apparent significant differences.

SUMMARY AND CONCLUSIONS

1. The method for the preparation of Edelmist has been described and its relative value compared with manures handled in other ways.
   a. Barnyard manures, (particularly those commonly called hot) can be decomposed by allowing an initial period of heating on small piles to approximately 60° C to be followed by thoroughly compacting them.
   b. The obtained product is only about one-half the bulk and weight of the original manure but retains the bulk of the important fertilizing elements, nitrogen and phosphorous. The product would seem to be especially desirable for use in town on lawns, gardens and in greenhouses where only a well rotted, odorless manure is desirable.
2. The nature of some of the remaining products following the

decomposition of manure placed in loosely piled heaps, solidly compacted piles, and hot processed piles, was followed by the use of a proximate chemical analysis as used by Waksman & Stevens in peat studies.

a. There is in the fresh manure a higher percentage of hemicelluloses, celluloses, and lignin with these products decreasing with increased decomposition.

b. The percentage of soluble materials in the water and alcohol soluble fractions increase with decomposition and the ether soluble fraction decreases with decomposition.

3. Pot experiments were conducted in an attempt to ascertain the relative value of differently treated horse manures, as shown by crop yields, by the presence of nitrate nitrogen and available phosphorous.

a. The 1931 pot tests gave significant yield differences of wheat in favor of the hot processed manure but a similar test in 1933 did not substantiate these results.

b. The availability of phosphorous was increased significantly by the application of any of the manures used.

c. Nitrate nitrogen was not significantly affected in pots by any of the manurial treatments studied.

4. Field experiments carried on over a three year period, with a Latin Square arrangement of five treatments with five replications, to study the yield of certain field crops showed significant yield differences of sugar beets for two successive years in favor of fertilizing with stored manures

over fresh manure and significant differences in favor of fertilizing with compacted or hot processed manure over all others for the first season. The drouth made the 2rd seasons data valueless.

a. Nitrate nitrogen was not significantly affected by any of the manurial treatments.

b. In every instance the availability of phosphorous was increased on the field plots which were manured.

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Table V --The Per Cent Total Nitrogen and Phosphorous in the Manures Used.

	Per cent Total "N"	Significant Difference p= .01	Total* Per cent "p"
Fresh Horse Manure	1.1271	.066	.179
Loosely Stored Horse Manure	1.3375	.080	.299
Compactly Stored Horse Manure	1.3382	.080	.250
Hot Processed Horse Manure 1930-1931	2.3325	.099	.534
Hot Processed Horse Manure 1931-1932	2.3543		.353

* Differences to show significance are not given in case of the phosphorous content because these determinations were made on composited samples.

Table VI --The Relative Losses of Nitrogen Calculated in Pounds Per Ton on a Dry Weight Basis.**

	Pounds Per Ton	Per Cent Loss
Original Horse Manure Fresh from the Barn	27.40	
Loosely Stored Approximately Seven Months	17.66	35
Compactly Stored Approximately Seven Months	19.09	30
Hot Processed & Stored Approximately Six* Months	27.35	None

* It was not possible to show a loss of nitrogen in the Hot Processed piles studied.

** Computed by taking the percentage of nitrogen in a ton of the original manure and that amount of nitrogen present in the same manure reduced in weight by a period of storage.

Sampling was done by taking a number of handfuls at random from the broken piles. These samples were then mixed thoroughly for analysis. In order to determine the nature of the decomposition which had taken place in the different piles during these experiments, a proximate organic analysis of composite samples representative of the different treatments studied was made by the method used by Waksman and Stevens (31). These data are reported in Tables VII, VIII and IX. The higher percentage of crude protein found in the hot processed manure (Table VII) serves as a check on the findings reported in Table V, where the total nitrogen content of the manures was reported. The relative amounts of nitrogen, soluble in water and acids, do not seem to change during the process. (Table IX) The loss in dry weight of the hot processed manure is associated with corresponding

Table VII --Proximate Chemical Analysis of Horse Manures Used.

	Fresh Manure 1930	Fresh Manure 1931	Stored Loosely 7½ Mths.	Stored Compactly 7 Mths.	Stored Compactly at Greenville 1930	Hot Processed Stored 8 Mths. 1930-31	Hot Processed Stored 5 Mths. 1931-32
pH	5.5	5.5	5.5	6.0	6.0	6.0	5.0
Percent							
Moisture	11.60	11.00	13.20	10.80	10.80	11.20	10.80
Ether Soluble	.97	1.10	.78	.65	.33	.07	.37
Alcohol Soluble	4.52	5.32	3.35	4.61	4.72	12.68	9.55
Cold & Hot H_2O Soluble	14.86	18.72	18.40	15.30	20.69	24.35	24.97
Reducing Sugar*	(2.55)	(2.55)	(2.15)	(2.86)	(2.86)	(2.50)	(3.70)
Hemicelluloses	7.34	9.60	8.21	5.29	1.93	2.41	2.49
Celluloses	6.38	5.88	5.54	3.98	1.55	1.46	1.64
Lignin	50.33	49.86	47.50	40.21	30.97	34.06	25.28
Crude Protein	4.81	4.63	4.61	5.38	8.81	10.75	8.31
Ash	15.10	17.02	22.46	24.48	31.77	28.96	23.81
Total Accounted For**	104.61	112.20	108.85	99.90	100.77	114.74	112.52

* The reducing sugars are not figured in the total percent as they are accounted for in the H_2O soluble fraction.

** Most of the totals being well over 100%, it is believed that this discrepancy is largely accounted for by duplication of mineral matter in both extracts and the ash plus smaller errors in nitrogenous compounds and the cumulative error in the experiment. This possibility is shown in Table VIII.

Table VIII --The Apparent Error in Table VII is Largely Eliminated by Subtracting the Per Cent of Residual Ash from the Total Per Cent of Ash of an Untreated Sample.

	Fresh Horse Manure 1930	Fresh Horse Manure 1931	Horse Manure Stored Loosely 7½ Mths.	Horse Manure Stored Compactly 7 Mths.	Horse Manure Stored Compactly at Greenville 1930	Horse Manure Hot Processed Stored 8 Mths. 1930-31	Horse Manure Hot Processed Stored 5 Mths. 1931-32
Per Cent							
Original Ash (Table VII)	15.10	17.02	22.46	24.48	31.77	28.96	29.81
Residual Ash	8.15	6.22	15.65	20.95	22.16	15.53	17.63
Difference	6.95	10.80	6.81	3.53	9.61	13.43	12.18
Total Accounted For (Table VII)	104.81	118.20	108.85	90.90	100.77	114.74	112.52
Above Difference	6.95	10.80	6.81	3.53	9.61	13.43	12.18
Apparent Correct Total	97.66	101.40	102.04	103.66	91.16	101.31	100.34

Table IX --Distribution of the Total Nitrogen Content as found in the Extracts from the Proximate Chemical Analysis.

	Fresh Horse Manure 1930	Fresh Horse Manure 1931	Horse Manure Stored Loosely 7½ Mths.	Horse Manure Stored Compactly 7 Mths.	Horse Manure Stored Compactly at Greenville 1930	Horse Manure Hot Processed Stored 8 Mths. 1930-31	Horse Manure Hot Processed Stored 5 Mths. 1931-32
Per Cent "N"							
H_2O Extract	.65	.65	.70	.79	.99	.95	.94
2% HCL Extract	.23	.23	.25	.23	.32	.35	.31
80 % H_2SO_4 Extract	.14	.16	.22	.19	.26	.20	.22
In Residue	.40	.35	.17	.14	.83	.87	.80
Total	1.42	1.39	1.34	1.35	2.40	2.37	2.27
Untreated Sample	1.36	1.27	1.38	1.38	2.20	2.27	2.21

increases in the percentage ash content. Certain ash constituents are also rendered more soluble by the processes of decomposition as indicated by their higher solubilities in water Table VII & VIII). In the decomposed manure the fraction soluble in alcohol also increases as a result of the processes of decomposition.

Arrangement and Treatment of Plots

After taking samples from the various piles of manure for analytical purposes, the replicate piles of each treatment were thoroughly mixed for field application. The field area used was one which had not received manure for several seasons. Four fifths of it, however, had received an application of treble super phosphate the year previous. The method of arrangement of treatments is shown in the Latin Square of Diagram III. Five treatments of five replications each were thus arranged on approximate eightieth acre plots. When planted to sugar beets, this allowed for four 42 foot rows with a discard of one row on each side of each plot and two on the borders. Manure was spread at the rate of 14 tons to the acre (wet basis).* The appearance of the area after being manured can be seen in Photograph III. From this Photograph, the arrangement can be partially followed by the check plots and those receiving the hot

*At the time the field was manured it was believed that the moisture content of the various manures were the same. Later analysis showed this assumption incorrect and as a result a slightly larger application of the manures not hot processed was made.

Photograph III --Showing the field plots after the manure was applied. The darker color of five of the plots is due to the application of hot processed manure.

processed manure, which was darker in color. The other plots were treated as follows: Five with manure from the tramped piles and galvanized iron containers (these were mixed because it was believed from observations in large piles of compacted manure that both products are present in about the proportions used); five with the manure from the loosely piled heaps; and five with fresh horse manure from the same source as that which had been stored in the other piles. As the experimental area had been fall plowed, it was necessary to disk the manure into the soil before planting.

Diagram III --Arrangement of 80th Acre Field Plots Showing Formerly Phosphated Area.

C	E	D	A	B	
D	B	A	E	C	Previously fertilized with treble superphosphate.
E	D	B	C	A	
B	A	C	D	E	
A	C	E	B	D	Not previously fertilized.

A = Check (No Manure)
B = Fresh Horse Manure--14 tons per acre.
C = Horse Manure Stored Loosely--14 tons per acre.
D = Horse Manure Stored Compactly--14 tons per acre.
E = Horse Manure "Hot Processed" --14 tons per acre.

Summary of Field Results

A good stand of beets was obtained during the growing season of 1932. Early in the season there appeared to be treatment differences but by the time of harvest these had disappeared. A composite of six soil samples taken in June from each plot showed no significant differences in NO_3 nitrogen, as shown in Table X, but were significantly different in water soluble phosphorous, as is noted by comparing manured with unmanured plots. Also in Table X are harvest data from the 1932 season including number and weight of beets, weight of tops and sugar content & purity. The yield of roots was significantly greater on all the manured treatments as compared with the unmanured treatments. Significant differences are also to be observed between the kinds of manures used. The compacted and hot processed manures gave significantly better yields than the treatments with either fresh or loosely stored manure.

Sugar beets were replanted on this area in 1933, with no further manuring, and the same data secured as in 1932 (Table XI). Yields of roots and tops were significantly different on the manured and unmanured plots. Plots, which had received stored manure of any of the kinds used, yielded more than the plots which had received fresh manure the previous season.

As the northern four-fifths of the field area used in the experiments had received applications of treble superphosphate (Diagram III), the possibility of a residual influence masking the effect on previously unfertilized ground was considered

Table X --The Available Nitrogen and Phosphorous, the Yield, Sugar Content and Purity of Sugar Beets following Various Manurial Treatments on Field Plots in 1932.

	ppm "NO_3" Nitrogen in June	ppm "P" H_2O Soluble in June	No. of Beets Harvested per acre	Weight of Roots (lbs. per acre)	Weight of Tops (lbs. per acre)	Ratio of Tops to Roots	Sugar (Per Cent)	Purity (Per Cent)
Checks (No Treatment)	16.0	.01	14,400	14,672	10,544	.72	17.2	82.9
Fresh Horse Manure	13.5	.46	14,720	18,648	12,772	.68	16.5	86.4
Horse Manure Loosely Stored 7½ Months	17.0	1.22	15,600	19,088	13,024	.68	17.7	88.2
Horse Manure Compactly Stored 7 Months	14.5	1.22	16,320	19,936	15,912	.79	17.1	85.7
Horse Manure Hot Processed Stored 5 Mths.	17.5	.41	15,720	19,962	13,104	.66	17.3	86.7
* Significant Differences (p=.05		.41		880				
* Significant Differences (p=.01		.58		814				

* Only when Fishers' z test showed a treatment effect, are differences given which are necessary for two different probabilities.

Table XI --The Available Nitrogen and Phosphorous, the Yield, Sugar Content and Purity of Sugar Beets Following Various Manurial Treatments on Field Plots in 1933.

	ppm "NO_3" Nitrogen in June	Available "P" in June (comparative units)	No. of Beets Harvested per acre	Weight of Roots per acre (lbs.)	Weight of Tops per acre (lbs.)	Ratio of Tops to Roots	Sugar (per Cent)	Purity (per Cent)
Checks (No Treatment)	17.6	2.4	10,240	9,152	7,776	.85	19.5	87.0
Fresh Horse Manure	12.8	4.0	12,630	12,688	9,864	.77	19.7	87.7
Horse Manure Loosely Stored 7½ Months	12.8	3.2	12,480	14,560	9,328	.64	19.7	87.4
Horse Manure Compactly Stored 7 Months	12.7	3.4	13,840	15,664	11,616	.74	20.0	89.5
Horse Manure Hot Processed Stored 5 Mths.	15.0	3.6	13,280	14,288	11,104	.78	19.8	87.7
* Significant Differences (p=.05				1,290	1,449			
* Significant Differences (p=.01				1,808	2,029			

* Only when Fishers' z test showed a treatment effect, are differences given which are necessary for two different probabilities.

Table XII --Yield of Sugar Beets on the South Series of Field Plots which had not Received an Application of Treble Superphosphate.

	Year	No. of Beets Harvested	Average No. of Beets	Wt. of Roots	Average Wt. of Roots	Wt. of Tops	Average Wt. of Tops	Ratio of Tops to Roots
Checks (No Treatment)	1932	11,280	8,800	8,720	6,080	6,640	4,880	.80
	1933	6,320		3,440		2,120		
Fresh Horse Manure	1932	14,480	13,240	17,440	14,580	11,040	9,920	.68
	1933	12,000		11,720		8,800		
Horse Manure Loosely Stored 7½ Months	1932	13,840	12,820	18,720	13,480	12,240	9,720	.72
	1933	12,000		8,240		7,200		
Horse Manure Compactly Stored 7 Months	1932	15,440	13,520	17,600	15,400	15,840	12,760	.82
	1933	11,600		13,200		9,680		
Horse Manure Hot Processed Stored 5 Mths.	1932	15,440	13,080	19,920	16,280	14,000	13,000	.80
	1933	10,720		12,640		12,000		

(Table XII). The average yield of sugar beets over a two year period on this series of plots showed the order of yields to be as follows: First with hot processed manure, second with compactly stored manure, third with fresh manure, fourth with loosely stored manure and fifth unmanured.

In 1934 corn was planted on the plots but due to drouth conditions and lack of irrigation water practically no growth was made. Observation of the area showed no apparent significant differences.

SUMMARY AND CONCLUSIONS

1. The method for the preparation of Edelmist has been described and its relative value compared with manures handled in other ways.
   a. Barnyard manures, (particularly those commonly called hot) can be decomposed by allowing an initial period of heating on small piles to approximately 60° C to be followed by thoroughly compacting them.
   b. The obtained product is only about one-half the bulk and weight of the original manure but retains the bulk of the important fertilizing elements, nitrogen and phosphorous. The product would seem to be especially desirable for use in town on lawns, gardens and in greenhouses where only a well rotted, odorless manure is desirable.
2. The nature of some of the remaining products following the

decomposition of manure placed in loosely piled heaps, solidly compacted piles, and hot processed piles, was followed by the use of a proximate chemical analysis as used by Waksman & Stevens in peat studies.

a. There is in the fresh manure a higher percentage of hemicelluloses, celluloses, and lignin with these products decreasing with increased decomposition.

b. The percentage of soluble materials in the water and alcohol soluble fractions increase with decomposition and the ether soluble fraction decreases with decomposition.

3. Pot experiments were conducted in an attempt to ascertain the relative value of differently treated horse manures, as shown by crop yields, by the presence of nitrate nitrogen and available phosphorous.

a. The 1931 pot tests gave significant yield differences of wheat in favor of the hot processed manure but a similar test in 1933 did not substantiate these results.

b. The availability of phosphorous was increased significantly by the application of any of the manures used.

c. Nitrate nitrogen was not significantly affected in pots by any of the manurial treatments studied.

4. Field experiments carried on over a three year period, with a Latin Square arrangement of five treatments with five replications, to study the yield of certain field crops showed significant yield differences of sugar beets for two successive years in favor of fertilizing with stored manures

over fresh manure and significant differences in favor of fertilizing with compacted or hot processed manure over all others for the first season. The drouth made the 2rd seasons data valueless.

a. Nitrate nitrogen was not significantly affected by any of the manurial treatments.

b. In every instance the availability of phosphorous was increased on the field plots which were manured.

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