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Synthetic Farm Yard Manure.

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In this vast sub-continent, where agriculture has been the chief industry and the main stay of its millions, the cultivator from time immemorial, being conscious of the necessity of the use of manure for raising a good crop, has been generally applying what is known as Farm Yard Manure and occasionally leaf mould in places adjacent to forests. But on account of the increase of population, rising of general standard of life and other causes, not only the area that was once under extensive cultivation had to be brought under intensive culture, but also new areas had to be reclaimed and made to yield enough for the necessaries of man and animal. Thus the quondam cheerful farmer was brought face to face with the problem of producing more and more to minister to the needs of the increasing population. That is, he was compelled by dire circumstances actually to make two blades of grass grow where one grew before.

Undaunted by the situation, he began in right earnest and cheerfully to find out ways and means for shouldering this increased responsibility. As a good farmer he first turned his attention to his stock of manure and found to his surprise and chagrin that he was surrounded by limitations. The forest areas on which he depended had become mostly depleted and the remaining portion was closed against him.

Then he turned his attention to his livestock hoping for a solution from that quarter, but alas! the village common was no longer there and the quantity and quality of his stock had already become hopelessly unsatisfactory.

When he was standing aghast at the situation and was almost at his wits' end, he was further alarmed as a result of some soil surveys conducted by the chemical section of this Institute by the fact that the soils in this Presidency are almost exhausted and are further being depleted at a rapid rate of their organic matter which stands in the same relation to a soil as the life principle is to animals. It was further shown that with the deficiency of this organic matter like ready made and tinned foods to man the inorganic fertilizers in many cases not only do not benefit the crop but adversely affect it. When such a necessity for increased supply of organic matter to a "soil" was established, plant doctors, in this instance, two chemists, Richards and Hutchinson of Rothamsted looked round for a proper remedy and began their researches in about 1919 with the aid of a special grant given by the Food Production Department in England.

Using in their first investigation wheat straw as a basic material and Ammonium sulphate as starter these chemists succesfully produced a fermented material, which closely resembles the ordinary Farm Yard Manure in colour and condition and quality.

Since the above manure is produced by direct fermentation without any intervention of cattle, this was named Artificial Farm Yard Manure in contradistinction to the Farm Yard Manure which name is given to the manure which is obtained at the Farmyard by fermenting the droppings of animals with or without urine and litter and for the production of which the intervention of cattle thus becomes necessary. But on account of its name some confusion arose about composition of the artificial Farmyard manure and the farmers thought it was an artificial fertiliser. With a view to remove this misconception, the name was subsequently changed to Synthetic Farm Yard Manure. In 1921, the manufacture of Synthetic Farm Yard Manure was patented by a Company known as the Agricultural Development Co., which marketed their product under the name of "Adco."

The question then arose, if the soil needs organic matter, why not apply any available material in the raw rather than in fermented condition?

About the same time, Hutchinson, the Imperial Agricultural Bacteriologist, Pusa, started the study of fermentation of green manure, in imitation of Indigo *seeth*, the organic refuse left after the extraction of the dye. He used sannhemp—fermented and unfermented—for his experiments and arrived at the conclusion that fermented green manure was better than unfermented material.

Thus it is seen from the above experiments, that what is called Synthetic Farm Yard Manure or Adco is simply organic matter composted in a scientific way i. e., by keeping the decomposition under control.

The answer in favour of fermentation was given for the following reasons.

(1) Raw material when ploughed in unduly opens up the soil on account of its bulk and this material if dry, also draws upon the soil moisture for its own fermentation,

(2) For its thorough incorporation into the soil it offers difficulty in ordinary doses, and this is increased where increased heavy doses have to be applied.

(3) If it is dry or partly dry, it causes the nitrate of soil to be reduced as the organisms responsible for its break down require Nitrogen for their energy.

(4) The raw material forms a medium for the development of white ants.

Previous fermentation of the material overcomes all these difficulties and makes it more easily available to the crop.

Following the lead of Rothamsted the first trial at the manufacture of Synthetic Farm Yard Manure was made at Coimbatore in 1922 in the Pot Culture House of the chemical section using paddy straw and calcium cynanamide. Though we could not have any surplus paddy straw for conversion into manure, this material was selected for the first experiment with a view to under stand the technique of the method by using an easily fermentable substance.

Since (1) optimum moisture, (2) free access of air, (3) supply of easily available Nitrogen in suitable concentration (4) neutral or slightly alkaline re-action and (5) suitable temperature are considered as a *sine qua non* for successful fermentation for the production of well rotted Artificial Farmyard Manure, 1500 lb. of air-dry straw was loosely put into a stack, the required quantity of calcium cyanamide broadcasted on the top of the heap and watered in. Fermentation started in about 24 hours and in 4 days the heap began to sink in the middle with rise of temperature. Almost daily the sides and top portion of the heap had to be watered to keep them moist and even then fermentation in these portions was scanty and unsatisfactory. On account of the high and dry winds, the exposed portions of the heap could not be kept moist enough for satisfactory fermentation. After 6 weeks when the sinking and fermentation of the heap were found to be uneven it was dismantled and the material was thoroughly mixed up and restacked. After another 3 weeks, fermention was found to have been uniform and a well rotten manure was obtained. In the process however a loss of 47 per cent of organic matter and about 14 percent of Nitrogen was observed.

The next set of experiments was carried out with guinea grass stubble and calcium cyanamide under complete aerobic and semi-aerobic conditions, the latter condition being obtained by mud plastering the exposed surfaces. The object of semi-aerobic condition was to see how far the difficulty of having uniform moisture conditions could be overcome. As in the previous experiment the exposed heap had to be continously watered while the mud plastered heap received no water for six weeks. When this was opened it was found to have had uniform fermentation, while in the exposed heap only the central portion had fermented satis factorily. In the laboratory experiment also, the same moisture difficulty occurred. A reference to the table below will show the advantages of a preliminary semiaerobic fermentation throughout. By the former method not only uniform fermentation is secured but the Nitrogen and Organic Matter losses are reduced.

	Laboratory experiment.		Large scale.	
	Nitrogen.	Organic matter.	Nitrogen.	Organic matter.
Aerobic ...	26·76%	37·7%	59.97%	32·80%
Semi-aerobic ...	9·29%	22·2%	35·23%	32·33%

The results further show, that in aerobic heaps on account of unequal fermentation, added Nitrogen is not fixed to the same extent as in semi-aerobic heaps with almost uniform fermentation.

In the light of these observations, the following experiments were conducted in 1923 with Ragi straw both in heaps and with various amounts of Nitrogen. Nitrogen was added as Ammonium sulphate or calcium cyanamide respectively at 0·75 per cent and 0·5 per cent calculated on dry matter. In the case of Ammonium sulphate lime carbanate was also added to correct the acidity.

	Ammonium sulphate series.					Calcium Cyanamide. series.				
	Higher Nitrogen per cent of loss.			Lower Nitrogen per cent of loss.			Higher Nitrogen per cent of loss.			Lower Nitrogen per cent of. loss.
	N.	O.M.		N.	O.M.		N.	O.M.		M. OM.
1. Heap	40·09	43·59	(3)	29·02	46·45	(5)	25·68	36·34	(7)	33·46 38
2. Pit	34·66	33·30	(4)	26·46	23·85	(6)	22·99	29·63	(8)	15·83 27

[Note.—N is Nitrogen. O. M. is Organic Matter].

The loss of Nitrogen from pits experiments was less in every case than that from heaps. In pits it ranged from 16 to 34 per cent and in heaps, from 26 to 40 per cent.

In all the experiments the loss of Nitrogen was very high. It might be that the high per centages of loss were due to the soakage of the liquid portion of the manure into the soil.

The following experiments were designed :—

(1) To prevent absorption, if any, of the liquid portion of manure by the soil.

(2) To find out the effect on fermentation and loss of Nitrogen of a lower amount of Nitrogen than 0·75 per cent the standard fixed at Rothamsted.

(3) Semi-aerobic fermentation from start to finish of the experiment as it was considered likely that the huge loss of Nitrogen and Organic matter occurred when the heaps were changed from semiaerobic to full aerobic conditions. These experiments were therefore conducted in cemented pucca brick tubs, with a drainage pipe attached so as to enable the collection of any liquid portion that might flow out and additions of such effluent to the fermenting material again from time to time.

The material used in these experiments was also Ragi straw with Ammonium sulphate as starter at the rate of 0.5 percent on dry matter. Two experiments were started. In No. 1 the material was covered with galvanised sheets and in No. 2 it was mud-plastered. The following results were obtained.

	Percent loss of	
	Nitrogen.	Organic matter.
No. 1 Pit covered with galvanised sheet	54.05	66.88
No. 2 Pit mudplastered ...	44.12	53.77

Here too the losses of Nitrogen and organic matter were more in the open tub than in the one which was mud-plastered. In both fermentation was not uniform, part of the material (about half) in the open pit, and (about 1/8) in the mud plastered pit remaining unfermented. To a depth of 4 inchs from the top surface the material in the unplastered pit was so fresh as at start, owing to the fact that any moisture added evaporated away quickly. With all the care in watering unmoist patches occurred here and there under both the systems, but this was more in No. 1. The greater fermentation in No. 2 shows the advantage of mudplastering the material so as to prevent loss of moisture in the early stages when the material is dry and incapable of retaining any moisture. When once hydration of the material takes place and fermentation starts the material becomes more and more retentive of moisture.

The next set of experiments was carried out in ordinary earthen flower pots, (japanned inside) to find out (1) the optimum starter nitrogen required for active and maximum fermentation and also (2) the rate of loss of nitrogen, when the necessary starter Nitrogen is added (a) in one lot at the beginning and (b) when added at intervals in divided doses.

The materials were air dry Ragi straw and canetrash with calcium cyanamide as starter.

The following results were obtained:—

No.	Details of experiments.	Percent Loss or gain in nitrogen	average.	Percent Loss or gain in nitrogen.	Average.
1	Control No. starter 1500 grams ...	5·009		48·52	
2	Air-dry Ragi straw only ...	4·232	462	55·28	51·9
3	Basic material 0.25 per cent nitrogen ...	28·10		61·39	
4	1500 grams Ragi Straw. Calcium Cyanamide...	6·56	17·00	55·93	58·66
5	Do. plus 0.50 per cent nitrogen ...	40·22		55·93	
6	Do. do. ...	30·26	35·24	57·50	56·72
7	Do. plus 0·75 per cent nitrogen ...	43·87		55·19	
8	Do. do. ...	29·43	36·65	49·81	52·50
9	Do. plus 1·00 per cent nitrogen ...	48·87		48·80	
10	Do. do. ...	36·64	42·75	45·93	47·37
11	Do. plus 0·5 per cent nitrogen added in 2 lots at intervals ...	12·52	23·00	49·44	53·47
12	Do. do. ...	33·57		57·50	
13	Do. plus 0·75 per cent nitrogen added in 3 lots at intervals ...	45·94	45·94	57·87	56·02
14	Do. do.	45·94		54·17	
15	Do. plus 1·00 per cent nitrogen added in 4 lots at intervals ...	33·16	33·35	50·83	47·04
16	Do. do.	33·54		43·24	
17	Do. plus 1·25 per cent nitrogen in 5 lots at intervals ...	27·96	69.2	46·11	44·03
18	Do. do.	25·26		41·91	

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No.	Details of experiments.	Percent Loss or gain in Nitrogen.	Average.	Percent Loss or gain in Nitrogen.	Average.
19	Do. plus 0·75 per cent added in one lot at start and the pot buried ...	28·09	23·09	49·72	49·72
20	Do. plus 0·25 per cent nitrogen added as fresh cow-dung ...	23·82	23·82	56·52	56·52
19	Control No. starter ...	31·6	37·33	41·3	45·6
20	750 grams air dry cane trash only ...	43·06		49·6	
21	Cane trash plus 0·25 percent ...	14·29	9·73	44·6	39·4
22	Nitrogen Calcium Cyanamide ...	5·16		34·1	
23	Cane trash plus 0·5 per cent ...	25·04	28·76	45·4	47·4
24	Nitrogen ...	32·47		49·4	
25	Cane trash plus 0·75 per cent ...	31·76	28·24	41·0	42·0
26	Nitrogen ...	24·72		43·1	
27	Cane trash plus 1·00 per cent ...	41·43	43·39	46·6	48·0
28	Nitrogen ...	45·34		49·9	
41	Cane trash plus 1·00 per cent Nitrogen pot buried in soil ...	27·84	27·84	40·0	40·0
42	Cane trash plus 0·25 per cent Nitrogen cow-dung ...	46·21	46·21	36·1	36·1

N. B.—Air dry cane trash, 750 grams in each pot.

Fermentation was quite satisfactory in all, higher or lower concentration of Nitrogen having the same effect on fermentation. Nitrogen loss occurred even with the lowest concentration (0·25 per cent Nitrogen) and this loss was greater with ragi straw than with cane-trash. Though Nitrogen is necessary for fermentation, the above experiments point to the fact that addition of easily available Nitrogen results in loss of nitrogen independent of concentration, but to a certain extent such loss depends upon the nature of the basic material.

In the pots that were buried fermentation was complete and uniform without any water except what was added initially, where as the pots that were kept on surface had to be watered every now and then to keep up the moisture necessary for active fermentation. This indicates the necessity and advantage of mud plastering the material in the beginning so that the necessary moisture for normal fermentation may be retained without resorting to constant watering thus reducing the total amount of water required for complete disintegration of the material.

The next set of experiments was done in pots with "Adco complete mixture" and "Adco Accelerator" two patented chemical starters supplied by Messrs. Shaw Wallace and Co., Calcutta. These were compared with similar mixtures made up in the laboratory which included a phosphate in the form of tricalcic phosphate since the patented mixtures contained also a phosphate. Also the influence of fermentation on Ragi staw of dried and powdered Farm Yard Manure when added in quantity necessary to supply the same rate of Nitrogen as the above mixtures was also tested.

The results are below:—

Air-dry Ragi straw; 1 kilo in each glazed pot.

No.	Details of experiment.	Percent loss of gain in Nitrogen.	Percent average balance of duplicate.	Percent loss of dry matter.	Percent average of duplicates dry matter.
11	Ragi straw only control ...	2·17	0·9	71·99	69·67
12	do. ...	0·384		67·34	
13	Ragi straw plus Adco mixture enoughto supply 0·75 per cent Nitrogen ...	32·99	34·05	65·01	64·90
14	do. ...	35·12		64·80	
16	Ragi straw plus Calcium Cyanamide mixture made up in laboratory enough to supply 0·75% ...	34·31	33·60	64·59	64·5
17	do. [nitrogen ...	32·91		64·48	
18	Ragi straw plus Farm Yare Manure dried and powdered 0·75 nitrogen ...	8·313	12·96	58·83	60·33
19	do. ...	17·61		61·83	
	Ragi green; 1 kilo in each pot and Adco accelator.				
1	Control-ragi stems and leaves only ...	13·01	12·16	55·41	54·6
2	do. ...	11·31		53·82	
3	Green ragi straw plus Adco accelarator to supply 0·22 per cent nitrogen ...	26·68	29·01	50·00	50·8
4	do. ...	31.34		51·59	
5	Green ragi straw plus Calcium Cyanamide mixture made up to supply 0·22 per cent nitrogen ...	28·48	20·56	50·00	48·57
6	do. ...	31·34		47·23	
7	Green ragi straw plus Farm Yard Manure dried and powdered to supply 0·22 % nitrogen.	31·41	25·48	57·77	55·04
8	do. ...	19·55		52·32	

Though there was slight fermentation in the control pots the resultant product did not attain the plastic condition of Farm Yard Manure. But there was little or no loss of Nitrogen. In the case of treated pots fermentation was thorough and uniform, thus pointing to the necessity of starter Nitrogen. The patented starters were in no way superior to the mixtures similarly made up, either in accelerating fermentation or in lessening Nitrogen loss. Even with an almost inert material as Farm Yard Manure, Nitrogen loss occurred, though fermentation was equally satisfactory. These losses might be due to the higher concentrations of Nitrogen (.75 percent) in the case of day ragi straw whereas green material did not require even 0.22 percent Nitrogen on dry matter. In the case of air-dry straw with 0.75 percent Nitrogen as Farm Yard Manure the loss is only about 13 percent whereas with green material, a Nitrogen supply of 0.22 percent has resulted almost doubling the loss (25.48 percent).

The general conclusions from all the above big scale and pot experiments seem to show that

(1) semi-aerobic fermentation for a time in pits, mud plastered for a month in case of straws and for a longer period in case of tougher materials followed by aerobic fermentation, helps in inducing uniform disintegration of material by preventing loss of moisture and reducing loss of Nitrogen by making the dry stiff material more plastic and capable of fixing the added nitrogen.

(2) Active and soluble forms of starter Nitrogen-such as Ammonium sulphate, Calcium cyanamide Urine etc., always end in loss of nitrogen, whereas a slowly available starter such as fresh cattle dung, or good farm yard manure considerably reduces such loss.

(3) With green material no starter Nitrogen is necessary.

It was found from the last set of experiments that addition of phosphates is helpful in bringing out quicker fermentation by stimulating the fermentative organisms to greater activity. This increased activity again enables them to fix the Nitrogen faster and thus Nitrogen loss is much reduced.

The following experiments wore done with a view to test whether an addition of insoluble phosphate with calcium cyanamide would increase fermentation and reduce Nitrogen loss.

Two sets of experiments were conducted for this purpose one in cement tubs on the Central Farm using paddy straw and the other at the Groundnut Experiment Station, Palakuppam with cumbu straw. On the Central Farm calcium cyanamide and Trichy phosphate were used as starters and at Palakuppam Ammonium Sulphate and bonemeal. The following results were obtained.

Central Farm.	Paddy-straw calcium cyanamide percent loss or gain of Nitrogen.	Trichy phosphate percent loss of Organic matter.
Heap Tub (one) open	-5.81	68.32
,, Tub (two) mud plastered	17.24	59.52
	18.62	68.74
Palakuppam·	Cumbu straw - Ammo. sulphate-	Bonemeal.
Pit I	26.4	35.9
Pit II	20.2	31.8

As the cumbu straw used was old the organic matter loss is about half of that of previous experiments. The nitrogen loss also is much less than what happened in some previous experiments i.e., 50.75 percent.

In the case of paddy straw, there is a decided gain in Nitrogen. In all the previous experiments also carried out with this material the loss of nitrogen was not great. It appears that paddy straw fixes up the nitrogen more quickly and to a higher degree than other materials and that the softer the material, the lesser is the loss of Nitrogen.

When all the above experiments indicated Nitrogen loss in a lesser or greater degree, it was thought that such losses might be due to the active and easily available nature of the starters. To test this point the following 3 sets of experiments using cane trash and varagu straw with and without cactus as basic material and bonemeal as starter were conducted in Palur and in the Chunampet Zamindary with the following results.

PALUR.

	Cane – trash percent loss of N.	Cane – trash percent loss of O. M.		Cane trash + cactus percent loss of N.	Cane trash + cactus percent loss of O. M.
Pit 1	15.08	69.44	Pit 3	3.60	52.98
Pit 2	10.69	63.88	Pit 4	5.23	55.08

CHUNAMPE.

	percent loss of N.	percent loss of O. M.
Varagu straw + cactus (pit.)	53.13	73.90
Cane trash + cactus (pit.)	30.72	73.40

The Chunampet experiments show a big loss, probably due to over fermentation. In the Palur experiment with trash and cactus the organic matter loss is within limits and the loss of nitrogen is negligible. With cane trash alone fermentation had gone beyond the limit and the loss of nitrogen is more.

In Chunampet the sample was like a lump of clay. The Palur samples were in condition, showing here and there the original structure of the material but breaking to pieces when handled and the material was plastic and soft.

The above experiments lead to the following conclusions:

(1) The loss of Nitrogen can be reduced by substituting Bonemeal and Farm Yard Manure or fresh cattle dung for the quick acting Nitrogenous starters used in earlier experiments.

(2) This loss of Nitrogen depends upon the nature of the basic material (soft or tough) and on the nature of the starter (active or slow).

(3) When the organic matter is reduced by 50 percent of its original weight optimum fermentation is reached.

(4) Depending upon the nature of the softness or toughness of original material the resulting material is either plastic like Farm Yard Manure or remains fibrous and soft.

(5) The composition of the resulting manure varies a good deal depending upon the nature of the starting material and the time of the year in which the experiment is done. Thus during heavy rains, certain amount of leaching of soluble constituents is bound to occur.

The combined action of cattle dung and bonemeal was tested qualitatively on a large scale on very refractory materials, such as cactus leaves, dry stalks of cotton, of chillies and Bengal gram : and it is gratifying to note that all these fermented quite satisfactorily in 6 to 8 months ; during this period even the hard spines of cactus became soft enough to be handled without fear of pricking. After several trials with various materials in different parts of the Presidency the following technique of manufacture has been envolved.

A pit of convenient size say 12 feet x 6 feet x 3 feet should be dug on high ground. The basic material is uniformly and loosely put to a depth of 9 to 12 inches, and water is evenly sprinked till the whole of the material gets moist, every part of the heap should be carefully watered so that no portion remains unmoist. This is the most important point in the construction of the heap. On many occasions dry patches here and there are noted as a result of imperfect watering, the unmoist and untreated portions remain unaffected, while the moist and treated portion rots.

When the whole material is thus moistened, 1 to 2 lb of fine bonemeal is evenly broadcasted and over this a very thin suspension of cattle dung say 10 to 20 lbs. moist dung in 5 to 10 gallons of water is applied, taking care that this gets into every part of the material. A second layer of the basic material is now put on the first layer, moistened and treated as before. Thus the whole of the material is disposed of till a depth of 6 to 9 feet is reached when the heap is mud plastered. After fermentation has proceeded semi aerobically for 4 to 6 weeks depending upon the nature of the material, the plaster is removed so that aerobic fermentation may proceed. If at the time the heap is found to have sunk unevenly, it indicates that in the unsunk portions there has been non-fermentation due to lack of moisture. To correct the defect fermenting material may be forked once, necessary water added and the heap left to ferment. Forking is done with a view to loosen the material and thus to secure almost free entry of air. Moreover a thorough mixing of the material by forking helps quicker fermentation of the unfermented portion by supplying the necessary moisture; for fermented material is capable of retaining more moisture than unfermented material and gives it up when needed. After forking, the material may be thickly mulched with straw to prevent rapid loss of moisture due to evaporation. In about 3 to 4 months, the raw material reaches a stage when it could be used as manure. This is so with soft materials but tougher stuff requires 6 months to one year to reach the proper stage. Thus the time of fermentation required for complete disintegration depends solely on the nature of the basic material used.

All the weeds collected from fields could be used for the above purpose and almost any fermentable organic matter dry or green which is otherwise unfit for use barring the highly lignified tissues can with advantage be converted into the much needed organic manure with very little cost, since the process of manufacture needs no materials that are not ordinarily obtained on an ordinary farm. Thus the cultivator is able to increase his stock of organic manure and by its application enrich his fields.

*Summary.

The sources of natural supply of manures having been getting less and less with the increase of population and extension of cultivation, the necessity for making good the deficiency arose.

Richards and Hutchinson of Rothamsted began researches in this direction and came to the conclusion that all organic matter largely being wasted on farms could be converted into good manure similar in qualities to the farm yard manure by the adoption of certain processes chiefly by controlling decomposition of organic matter.

Hutchinson, making parellal experiments in India concluded that fermented organic matter proved a better substitute for farm yard manure than unfermented material.

Following the lead thus given by the investigations at Rothamsted and by Mr. Hutchinson, a series of experiments were conducted in Madras, using cane trash and prickly pear (cactus) as material and cowdung as starter with the addition of a phosphate as invigorator in the process.

And the processes evolved as suited to local conditions have been found out to be to subject the material to semi-aerobic conditions in the beginning and full aerobic (i. e. permitting of perfect aeration) conditions later so as to secure optimum fermentation resulting in a good well rotten manure possessing all the qualities of farm yard manure.

Any fermentable organic matter can be used barring substances which have highly woody (ligneous) tissue.

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*Paper read at the M. A. S. U. Conference in July 1928.