HUMUS OR ARTIFICIALS.

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In approaching the subject of manuring the question may be asked, why do we manure at all?

The most obvious answer is that manures are applied in order that farm and garden crops may be grown. Yet this answer is hardly sufficient, for it has been proved at the Rothamsted Experimental Station that crops can be grown of a sort, where for many years no manure has been added; and there are many meadow lands which still yield a fair crop of hay and have not received any manurial dressing for several years. In such cases the plants are supplied with nourishment from the materials rendered available in the soil through the action of weathering agents, etc.

The soil cannot be dissociated from the atmosphere and to consider the soil in a proper manner one has to take into consideration atmospheric water and temperature. The soil is an anchorage for the plants growing on it, the seat of root development, root nutrition, all plant changes, whether they be chemical, physical or biological. A soil is a very complex material in regard to its chemical composition and physical structure. The mineral matter exists in various grades from stones to colloidal clay being in fact a minutely discontinuous structure.

Clay consists of secondary minerals, such as kaolinite, beidellite, montmorillonite, etc., complex alumino-silicates formed by the decomposition of the original minerals in the parent rock, its particles fall within the colloidal range and have very great surface activity. As a result, a clay soil is far more active physically and chemically than a sandy one. Associated with this mineral colloid is humus an organic product of biochemical origin. Humus is particularly important in those soils which are deficient in clay as it then provides the colloidal matter that is otherwise lacking and so improves their physical and chemical properties. Organic matter is also beneficial to very heavy clays by opening them up and improving their structure.

The rôle of organic matter in the soil is undoubtedly important. Although Howard's writings may have concentrated attention on this problem, the discovery of the importance of humus and organic matter is not of recent origin. The high crop producing value of human and agricultural waste has been known for centuries and advantage has been taken of it by the Chinese, King (1926). As early as 1893 Voelcker considered 'the spread of a good system of utilizing human and household refuse, street sweeping, etc., on the land as a most potent factor in the improvement of Indian agriculture'. Leather too emphasized this point in 1895 in India and Russell in England in 1922. Even before Voelcker, Baker in 1885 in his book on 8 years tour of Ceylon describes the cheapest way of making manure on an estate giving details of the 'Geoffrey' pit in which refuse is packed for fermentation.

In the last few years after the vigorous propaganda in England and colonies by Howard on his retirement from India in favour of his 'Indore Process', increased attention has been given by agricultural workers to the question of the respective merits of natural humus and artificial fertilizers in restoring soil fertility. Even Lord Hankey was persuaded by this propaganda to support organic manuring and he wrote a comprehensive article in a leading London Weekly in 1944. There had just an appeal made also in the House of Lords for a Government enquiry involving long-term experiments to test the theory of humus *versus* artificials. The official response was hardly sympathetic to the idea, the Government view being that the problem remains one of using humus and artificials in the right proportions.

Compared with artificials organic manures have been claimed to be of specific importance in some direction. With the discovery of vitamins and their importance in nutrition a further weight has been attached to the possible rôle of organic manures in soils. The animal obtains its vitamins from the plants which it consumed as food and the plant manufactures them or perhaps obtain them from the soil and it appears probable that the micro-organisms which are abundant in humus play an important part in the synthesis of vitamins. Evidence to this effect has been brought forward by several investigators. The effect of injection of yeast extracts and extracts from biological media has been studied by Hausen (1930), Virtanen and Hausen (1933 and 1934) and Subrahmanyan and Siddappa (1933). Hausen observed that the addition of vitamin C to plants grown in sterile water-culture before flowering increased their height and weight and up to a limit the vitamin C content. Virtanen and Hausen noted that the plants were able to take up the growth regulating factor (or factors) in the yeast extract through their roots and thus suggested the importance of micro-organisms in the soil. Subrahmanyan and Siddappa studied the effects of extracts from activated sludge, organic manure and soil in addition to yeast extract and came to the same conclusion as obtained by the previous workers. McCarrison (1926) showed that the grain produced on farm-yard manure contained more vitamins than that grown with artificials. Vishwanath and Suryanarayanan found that seed from a crop of ragi (*eleucine coracana*) grown with farm-yard manure gave greater yields than crops sown with seeds raised on artificials. Ramiah (1933) reported that the forage crops grown on farm-yard manure are similarly rich in vitamins. L. J. Harris analysed wheat grown on organics and inorganics at Rothamsted but found no difference in the vitamin content of the differently manured grain.

Although the importance of growth-regulating factor is amply demonstrated in the growth of plants and organisms there are certain other points which need further elucidation. With the existing data and conflicting views it is not possible to conclude with regard to the influence of manuring on the nutritional value and yield of foodstuff. Till now the stimulating effect of yeast, biological media and other growth regulating substances has been shown only on the growth and height of stems and flowering, but not on the yield, a point of fundamental importance to the farmer. Secondly, the temperature in the compost may be high enough to destroy any existing carotene and vitamins during the composting process. It has been shown at Jealott's Hill that carotene is correlated to the protein content in the herbage, and it is well known that carotene is easily transformed into vitamin A in the body. Incidentally this vitamin is the main growth-promoting factor in animals. Therefore judicious manuring with organics and inorganics will produce good and healthy herbage with an adequate protein and carotene content. It may thus appear premature to suppose at present that organics produce foodstuffs richer in vitamins than inorganics.

The advocates of organic manuring recall the age-long destructiveness of man to soil. Once famous granaries and hunting grounds in the Middle East, North Africa, China and Russia, have long since become deserts and great civilizations have perished in consequence. The same process is apparently proceeding apace in North America, Australia, Africa and elsewhere, so new lands of promise are threatened in Europe and even in Britain. The compostors attribute this widespread erosion to the failure to put back what has been taken out by over-production with the result that the essential humus is disappearing. Modern methods, including certain chemical fertilizers are indicated as a potent contributory cause. For a hundred years now since Liebig started applying chemistry to agriculture, farmers have relied increasingly on artificials. No one denies that bumper crops can be obtained by this method as proved in the last two Wars but the compostors believe that chemicals poison the life in the soil, destroy the earthworms, which aerate it and probably also the mycorrhiza, the beneficial fungü which it has been found give a stimulus to health and resistance to disease—highly contentious arguments.

Sir Albert Howard to whom the present controversy over organics *versus* artificials is due, had become a faddist and in his zeal for his Indore method of composting went to the extent of condemning some standard and well established methods of maintaining the organic matter content of the soil. He emphasized with almost a religious fervour that humus manufactured only by the Indore method could alone bestow the blessings and advantage on soils and crops attributed to organic matter. He even called into question the well established practice of green manuring as a source of humus and insisted on composting of the green manures before incorporation into the soil.

The arguments adduced in favour of composting were essentially twofold:—

(1) That composting is necessary to adjust the C-N ratio of crude vegetable materials without which operation the organisms responsible for decomposition are presented with an abundant supply of energy producing material but experience a deficiency of readily available N necessary for building up their body tissues. Consequently when green manure is added to the soil, the micro-organisms, augment the nitrogen supply from the only possible source, viz., the soil nitrate. If this happens, there is a grave risk of temporary nitrogen starvation for any crop grown contemporaneously.

(2) Decomposed material contains accessory food materials whose nature and properties though still almost obscure affect growth vitally and favourably. In particular, as regards plantation crops such substances encourage mycorrhizal habit of root development which is presumed to be specially beneficial.

Of these two arguments the first is based on certain well established principles of biochemistry and micro-biology, but begs the question as to whether all vegetable material requires this pre-treatment and in particular, whether green manures as used on tea estates contain enough nitrogen to satisfy the normal microbiological economy when decomposing. Author's work (1945, 1946, 1947) at the Tea Research of Ceylon has borne chiefly on this question of nitrogen metabolism of decomposing green manures.

The Carbon-Nitrogen Ratio of Green Manures.

The rapidity with which loppings of green manures or tea pruning leaf are dispersed when allowed to remain on the surface of the soil gives a rough indication that their nitrogen content is not of the same order as the mature wastes from either annual or perennial plants. On examination, the chief green manures in Ceylon and other readily available wastes were found to be easily divisible into two distinct groups of which Table I provides details.

The first group comprises materials which are grown interplanted with tea; the second, with respect to the first and last entries represents waste material from outside sources. Grevillea rebusta is grown in tea but its contribution is from a leaf fall and not from a direct lopping for incorporation. It is at once evident that on the basis of any theory that the carbon-nitrogen ratio is relevant to the question of disposal of vegetable matter and that the ratio 10 is optimal, material grown with the tea needs no adjustment at all and can be used without scruple as a green manure. In fact since, as will be shown later, a portion of the nitrogen is readily mineralized, to compost this material under circumstances where leaching losses cannot at all times be avoided, is likely to lead to a definite loss of nitrogen available for plant nutrition and not to its conservation. In this respect the position of tea

TABLE I.
Carbon-Nitrogen Ratios of Waste Materials.

	Material.	Carbon %	Nitrogen %	Ratio.
Type A.	Frythrina lithosperma	40·62	2·54	15·97
	Gliricidia sepium	40·48	2·74	14·77
	Tithonia diversifolia	36·91	3·37	10·96
	Tephrosia vogelii	43·40	3·46	12·56
	Tea pruning leaf	42·63	3·19	13·38
	Waste manufactured tea	42·73	3·97	10·75
	Green weeds	34·99	2·01	17·43
Type B.	Andropogon nardus	39·92	1·37	29·07
	Grevillea robusta	48·78	1·04	47·10
	Pennisetum sp.	36·92	0·96	38·50

as a subject for green manuring is specially favourable. It is a perennial kept artificially in a continuous vegetative phase and as far as is known is capable of absorbing and utilizing nitrogen over the greater part of its growth cycle between one pruning operation and the next.

The Nitrogen Factor of Green Manures.

The consideration of carbon-nitrogen ratios provides only a working rule for the division of vegetable material into categories requiring or not requiring fermentation as the case may be, in order to be sure that no ill-effects will follow their use. A more detailed and conclusive picture is given by the determination of the 'nitrogen factor' of the material. The nitrogen factor is defined by Hutchinson and Richards as 'the additional inorganic nitrogen immobilized as organic nitrogen by 100 gms. of any material in the process of decomposition'. If, in accordance with the theory described earlier, a material does not contain enough nitrogen for its own decomposition, the deficiency can be made up from inorganic sources. At the end of the fermentation the quantity of added inorganic nitrogen used by the organisms will have been elaborated into organic nitrogen in their tissues. Since it is simple to evaluate inorganic and organic nitrogen separately, a balance sheet of the two types at the beginning and end of a fermentation readily gives the amount of nitrogen converted, or, to use the originator's phrase immobilized.

From a large number of such balance sheets four typical examples are gathered together in Table II.

TABLE II.
Nitrogen Transformations in Fermenting Green Materials.

Material.	Original material			Fermented material			N. factor (d) − (a)	N. loss (c) − (f)
	Organic N. per cent (a)	Mineral N. % (added) (b)	Total N. per cent (c)	Organic N. per cent (d)	Mineral N. (found) (e)	Total N. per cent (f)		
Andropogon nardus ..	1·37	1·09	2·46	1·98	0·41	2·39	+0·61	0·07
Tephrosia vogelii (A) ..	3·46	1·11	4·57	2·72	1·56	4·28	−0·74	0·29
Tephrosia vogelii (B) ..	3·46	Nil	3·46	2·85	0·67	3·52	−0·61	−0·06
Tea leaf	3·19	Nil	3·19	2·53	Nil	2·53	−0·66	0·66

The Andropogon nardus (Maana grass) shows the course of events followed when a material that has too wide a carbon-nitrogen ratio (see Table I) for immediate use is decomposed. It absorbs inorganic nitrogen and elaborates it and finishes with more 'organic' nitrogen than it had to start with; it consequently has a positive nitrogen factor. Such a material used directly would accordingly cause temporary nitrogen starvation.

Tephrosia as instanced by example (A) finishes its fermentation with less 'organic' nitrogen and more inorganic nitrogen than it possessed or was given to start with, and consequently its nitrogen factor is negative. It also loses an appreciable quantity of the total initial nitrogen. On the evidence of this example it should be possible to decompose Tephrosia satisfactorily by means of its own nitrogen only. Example (B) using the same material without any addition shows this to be the case. The nitrogen factor is negative and of the same order as in the previous example.

Tea leaf behaves in a manner similar to green manure of narrow carbon-nitrogen ratio in that it decomposes without additional nitrogen, but it has failed in our tests to produce any mineralization. Its negative nitrogen factor is thus equivalent to its nitrogen loss.

Before expecting a discovery to be universally accepted it has to be backed up by scientific data and field experiments collected over several years particularly in agricultural research but Howard hated long range field experiments and detested statistics. That being so, some of his claims were hardly justified since they were based on a few isolated instances. The function of earthworms is undoubtedly important in soil processes in so far as they break up and distribute plant residues through the top soil but they do not aid humification as has been commonly supposed. The claim that fertilizers reduce the earthworm population is not supported by work at Rothamsted. The plots manured with ammonium sulphate had almost the same earthworms population as the check plots. At Cornell manured plot had about four times the earthworms population as on unmanured. As long as acidity is corrected there is no danger of earthworm population to be adversely affected.

The claims that micro-organic population and mycorrihza are affected by treatment with ammonium sulphate is also based on one or two instances. In fact Rothamsted experiments have shown that the judicious application of nitrogenous fertilizer results in increased microbiological activity. The only instance where mycorrhiza was affected was in one of the experiments of Rayner at forestry nurseries at Wareham. The soil was thin and acidic and lacked in colloidal material and hence had reduced buffering action. Such isolated instances need addition of lime to correct the acidity.

The fertility of the soil depends on a number of complex factors besides the intrinsic characteristic of the soil. The use of manures and fertilizers is only one of the several factors in maintaining soil fertility and crop production at a high level. Proper drainage, maintenance of soil organic matter, prevention of soil erosion, improvement of the physical condition of the soil, liming wherever needed, are all necessary for productive farming.

It is an established fact that all cultivated soils in India are invariably deficient in nitrogen, generally deficient in phosphorus and frequently deficient in potassium. It naturally follows therefore that nitrogen stands foremost in the list of essential elements to be added to the soil followed by phosphorus and potassium.

Farm-yard manure is one of the important organic manures used in India. The quantity of cattle manure produced in India is estimated at 120 million tons on dry basis equivalent to 200 million tons of wet manure (Acharya, 1949). The composition of this manure on dry basis is about 0·5% N; 0·25% P_2O_5 and K_2O. On the basis of crude estimate for availability of nutrients, one ton of average

F.Y.M. provides 5 lbs. of N and K_2O and 1 lb. of P_2O_5. According to Parr (1946) the output of F.Y.M. is only sufficient to manure one acre in every ten.

The amount of town refuse compost produced annually in India approximates to 10 million tons and this amounts to 10 million tons supplying 0·05 million tons of N, 0·04 million tons of P_2O_5 and 0·1 million tons of K_2O (Acharya, 1949). The average composition of this compost is 0·8% N, 0·9% P_2O_5 and 0·8% K_2O. Even if the village compost scheme is successful it is estimated to produce only 1 ton compost per acre of cultivated land.

The quantity of N and P_2O_5 put together in F.Y.M. and composts is thus hardly enough for getting increased yield of crops at the rates these nutrients are worked out for different crops. It may be pointed out that any means of increasing crop production with consequent increase in crop residues as a result of judicious application of inorganics will increase the amount of organic matter which can be composted or incorporated as such with an appropriate doze of nitrogen for satisfactory decomposition.

Composts and organic manures are slow acting. It is also not known how much of the nitrogen in composts becomes available and over what period. Views are conflicting under field conditions, though Shrikhande (1943, 1945) has shown under laboratory conditions that 60% nitrogen becomes available from green manures and composts and oil cakes in 60 to 70 days beyond which there is insignificant mineralization. This slow action of organic manure is hardly going to be of much help in the present crisis.

When seeds germinate and shoot comes up the plant has to fend for itself and its tiny rootlets have to hunt for available food failing which it dies. For this readily available nitrogen is necessary. This need can easily and readily be met by sulphate of ammonia or nitrate. Moreover, in the first 4-5 weeks after germination, nutrient requirements particularly of nitrogen are heavy and they can be met readily only by quick acting manures like the artificials. After this the nitrogen requirements slow down—at this stage organic manures or composts may be serviceable.

Therefore under existing conditions artificials followed by organics will be more useful and consistent with reasoned crop growing and it should be clearly understood that both the forms of manures can be complimentary but never competitive in view of the advantages conferred by both on the plant and the soil. What is needed is a judicious application of organics and artificials the former for maintaining the soil in good tilth and conferring other advantages on the soil and plant and the latter for effecting quick growth and increased yield. What is needed today is an increase in quantity of agricultural produces to save people from starvation. The question of quality by organic manuring can be settled by laying down long term field experiments to settle the controversy.

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