THE USE OF GREEN MANURES AND WASTE MATERIALS*

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When your Chairman invited me to address this meeting and kindly suggested a range of topics including that of green manuring, my first objective was to decide what aspect of so large a subject I should choose. I have spoken frequently on this topic, and I feel that it has been so much in the public eye for the past eighteen months that the most profitable line I can take is to go back to fundamental considerations and to discuss them in the light of present day needs.

I shall in the main content myself with trying to give you a picture of what happens when vegetable material undergoes decomposition, either in the soil or in a heap such as is prepared in compost manufacture. The end in view is the production of humus, but the first point I wish to emphasize is that humus is not entirely an end in itself. Humus in itself has valuable properties mainly connected with the physical condition of the soil. It is not in itself a plant food, though certain of the products of decomposition of vegetable material in the process of humification are valuable nutrients. Unless therefore the production of humus is carefully controlled, the benefits one is entitled to expect from the by-products of the process may be altogether absent.

The most striking example of humus production on a mass production scale is that of moor peat, yet in a raw state peat soils are notoriously infertile. I mention this because it affords a good illustration of the fact that humus by itself divorced from other considerations is no criterion of agricultural excellence. Similarly all materials of vegetable origin are not equally efficient in producing humus and its valuable by-products. Let us for a little while consider why.

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THE PART PLAYED BY MICRO-ORGANISMS

Vegetable material is decomposed by the activities of micro-organisms, both fungi and bacteria. They are not consciously altruistic, and their main concern is food. As in higher organisms, the food they require is of two types, that which supplies energy for their activities, and that which supplies body-building material. The energy-supplying foods are mainly sugars and starches and other allied compounds that the chemist classifies as carbohydrates. For body building the organisms depend, as we do, largely on proteins. Having consumed these foods, their tissues exhibit a very nice balance of the two main constituents of these foods, carbon and nitrogen, and so, on their death, they tend to cause an accumulation in the soil of material of fairly standardised composition with respect to these two elements. That is the reason why the ratio of carbon to nitrogen in soil is, within reasonable limits, so constant, with a value of roughly ten. Now the logical outcome of this manner of decomposition is that if the organisms find a very abundant supply of carbon, they will grow and reproduce themselves up to the limit prescribed by the amount of nitrogen available to them. On the other hand, if nitrogen is plentiful and carbonaceous material is short, activity will stop when the latter is exhausted. The ideal is attained *for them* when the vegetation they are attacking supplies balanced rations of both foods. In nature this seldom happens. There is sometimes a surplus of nitrogen and this from a cropping point of view is generally advantageous, for this surplus nitrogen, broken down into simpler compounds, becomes readily available to the crop. Sometimes there is a surplus of carbon and then the organism demolishes what nitrogen is in the vegetation to start with, and subsequently sets out to commandeer further supplies in the form of nitrates and other simple forms present in the soil. This is obviously unsatisfactory agriculturally because it means that there will for some time be an acute shortage of simple nitrogenous compounds upon which the crop can live. In point of fact, if the material used as microbial food has a carbon-nitrogen ratio much greater than 10, nitrogen starvation for the crop can be expected for some time. If the ratio is less than 10, a readily available excess of nitrogen can be expected for the crop.

Provided the excess is not so great that it can be leached away before the crop has time to use it, this is all to the good. One other point remains. Carbon, as has been said, is an energy provider. It is partly used up in the process of breathing to produce carbon dioxide gas which is liberated. The complete picture in brief therefore is that materials of high carbon-nitrogen ratio will lose carbon and retain nitrogen till the equilibrium figure of 10 is reached, whilst materials of low carbon-nitrogen ratio will lose nitrogen and to a large extent retain carbon till they also arrive at the same equilibrium point. That is the basic conception I want to present to you; the rest will be more familiar territory, the explanation of how this fundamental fact affects the everyday processes of agriculture.

AN UNBALANCED CARBON-NITROGEN RATIO

To give you something more tangible than a word picture of these processes, I will describe a small experiment that formed a sideline to an investigation of Dr. Gadd's. The photograph labelled No 1* shows two turnip seedlings grown in sand to which a complete nutrient solution had been added in both cases in equivalent amounts. To the tin on the right, containing the very obviously dwarfed plant, a quantity of shredded filter paper inoculated with a fungus capable of rotting it was also added. Filter paper is practically pure cellulose, *i.e.*, a carbonaceous material capable of acting as the energy food supply for the rotting organisms, but providing no nitrogen. Accordingly the nitrogen in the culture solution was commandeered, and the result was acute nitrogen starvation caused by an unsuitably high carbon-nitrogen ratio. The seedling has barely passed the cotyledon stage, and has put out only one dwarfed foliage leaf that contrasts markedly with the normal healthy growth where available nitrogen was obtainable. The second photograph shows what were originally three of the nitrogen starved seedlings some time later than the date of the first photograph. A has received no subsequent treatment, but B and C have been given doses of nitrogen to modify the carbon-nitrogen ratio. C received twice as much nitrogen as

* Not reproduced.

B. It is plain that this additional nitrogen has rectified the conditions, and that there is no doubt that nitrogen starvation, caused by the means described, was the controlling factor in the poor growth of the seedling subject to the filter paper treatment.

TABLE I.

Composition of various materials with respect to Carbon and Nitrogen.

	Material	Carbon per cent	Nitrogen per cent	Ratio C/N
1.	Leaf of tea prunings	43·65	2·52	17·3
2.	Manna grass	45·29	1·68	26·9
3.	Dadaps	45·39	4·06	11·2
4.	Tephrosia vogelii	45·08	3·92	11·5
5.	Tares	40·1	3·01	13·3
6.	Mustard	39·9	1·51	26·4
7.	Straw	40·9	0·32	127·8
8.	Bloodmeal	41·5	11·1	3·7
9.	Groundnut cake	44·9	7·92	5·7
10.	Farmyard manure	30·9	2·15	14·4
11.	Compost (Single sample)	18·72	1·77	10·6
12.	Indore Compost (Howard)	—	—	10·8-16·5

TABLE II.

Nitrogen in various portions of the Tea Plant

		Per cent
Bud and first leaf	...	4·84
Second leaf	...	4·47
Third leaf	...	4·07
Foliage leaves	...	3·48
Flush	...	4·09
Pruning wood	...	0·85

PRACTICAL APPLICATION OF THE CARBON-NITROGEN RATIO

Admitting then that a certain amount of care is necessary in choosing materials for putting into the soil, what criteria should be adopted in making the choice ? Well, for the type of material that would naturally suggest itself for use as green manure, it happens that the carbon content is tolerably constant; so that a fair idea of changes in the carbon-nitrogen ratio can be had merely by considering changes in the nitrogen composition. Table I gives a selection of carbon and nitrogen contents and their ratios for a series of substances. It thus follows that a material poor in nitrogen is unsuitable for direct incorporation in the soil. The older the plant, or portion of the plant, the less its nitrogen content, as can be seen from Table II which gives a selection of figures for tea leaves, and the woody portions of prunings. Normally, in a shade tree, the leaves and flexible green branches will have a suitable nitrogen content. In bush crops the period just before flowering will give the optimum average figure for nitrogen. You will notice how low in nitrogen pruning wood is, and hence how unsuitable for forking in. Wood is unsuitable for another reason. Its tissues are highly lignified and this lignin is very resistant to microbial attack. Being so intimately associated structurally with the other tissues, it acts as a preventative factor in the course of decomposition. Not long ago a correspondent in the daily Press, who was more rash than the proverbial angels, suggested that sawdust offered an unlimited source of material for composting. In passing therefore it may be as well to remark that for the two reasons outlined above, namely high carbon-nitrogen ratio and the presence of abundant lignin, wood in quantity is quite unsuitable. The correspondent did not divulge what process had enabled him to produce a powdery substance in twenty-four hours; he assumed that its powdery nature was evidence of humification. Sufficient to say that reduction to powder is not a valid criterion, and I am afraid that in the use of wood, there lies a rich reward neither for the agriculturist nor for the proud sponsor of the secret method.

In agricultural terms then we may say that green leafy material is suitable for direct green manuring, that woody and pithy tissues are definitely out of the question, and that straws or the standing foliage of plants producing seed which have accumulated in that seed nitrogen withdrawn at the expense of the vegetative tissue, are generally unsuitable for direct green manuring. If used, they are likely to have the "filter paper effect."

THE ALTERNATIVES: GREEN MANURES VERSUS COMPOST

There is a school of thought led by Howard and Anstead, that will not admit that any green manures are suitable for direct incorporation in the soil. In this connection I will ask you to study the last column of Table I in a little more detail. It is admitted generally, and by the adverse critics of green manuring in particular, that a ratio of 10 to 1 for carbon-nitrogen is ideal for the purposes of plant nutrition. Of the first four materials listed in that table, all of which are in common uses as producers of organic matter in Ceylon, two, namely, dadaps and tephrosia, representing our main types of green manure, are as near to the optimum value as one is likely to get in an imperfect world; whilst tea pruning leaf is not far removed, relatively speaking. For comparison I have shown in the last line the range of ratios given in Howard's "Waste Products of Agriculture" for finished compost. Manna grass stands in a different class. It thus appears that the contention that green manures and pruning leaf in Ceylon have a carbon-nitrogen ratio which renders them quite unsuitable for direct incorporation as green manures in the soil, is not valid. The cost and trouble involved in composting our loppings is therefore unwarrantable since the object of composting is to produce a suitable carbon-nitrogen ratio. Used as one constituent amongst others of higher ratio I have nothing to say against them, provided they were not taken from amongst the tea but are grown on waste land.

The foregoing discussion leads naturally to the case where composting has a contribution to make. Where materials such as manna grass are available, the carbon-nitrogen ratio must be adjusted before application is made. It will be adjusted in the properly made compost heap by fermentation which dissipates the surplus carbon as carbon dioxide whilst preserving the nitrogen. Item number 11 in Table I shows how much lower in carbon content an average compost is than the raw material from which it is made.

I mentioned earlier in this lecture that the carbon-nitrogen ratio of finished compost represents an equilibrium point which can be approached from both sides, *i.e.*, by loss of carbon or by loss of nitrogen. The practical application of this is that to attempt to manufacture a specially rich compost is to defeat the ends for which compost is conceived. I have encountered several composts made solely or almost solely from refuse teas. Apart from the fact that refuse teas can be used direct, in the compost heap they are liable to lose their excess nitrogen in the attainment of the equilibrium, and so the process is unsatisfactory on two counts.

THE USE OF MULCHES

Passing now to a different though a related topic, various people, especially in dry zones, have made a practice of using manna grass as a direct mulch over the surface of the soil. I believe this to be an excellent plan, and results on coffee have shown enhanced yields from this practice. Mere observation shows that it maintains soil moisture better than any attempt to produce a so-called dust mulch by cultivation, and that in times of heavy rain it checks erosion. From the point of view of moisture conservation I found it extensively used in Assam on nursery beds. In Assam, where seed is sown in the dry season, frequent watering is not practised, and the nurseries have to subsist on scattered rains helped out by this protective device. The mulch must therefore not be so thick that light rains cannot penetrate. The point of contact with my subject is that, bearing in mind the carbon-nitrogen ratio of 27 for manna grass, it is advisable, when such a mulch is eventually forked in, to plan that the mulch is incorporated with a normal dose of artificial manure.

CONSERVATION OF NITROGEN

One of the reasons for green manuring is to form a cycle of changes whereby readily available nitrogen, which cannot be immediately used for nutrition of the major crop, is locked up in green manure vegetation, returned to the soil, and then gradually released. Throughout the whole of this discussion it should have been evident that the only method for conserving nitrogen in the soil is by linking it with carbon. In past years this fact was tacitly assumed as the basis for the advocacy of organic artificials. In these materials carbon was linked with nitrogen, and the availability was thereby thought to be greatly decreased in comparison with inorganic fertilizers. To a large extent the availability of the nitrogen in these manures depends on their carbon-nitrogen ratio. It is interesting therefore to see where they stand. I have included in Table I two examples, bloodmeal and groundnut cake, and for comparison farmyard manure. Both the organic artificials are well on the low side of the ratio; they cannot, as is frequently done, be classed with farmyard manure. Their nitrogen is really quite readily available, which explains why the cropping curves, following the use of organic manures, are so similar to those for inorganic manures. Without entering further into the respective merits of organic and inorganic manures, which, except in this respect, is outside my subject today, these facts must be borne in mind before too much importance is attached to the slow but steady supply of nitrogen in organic fertilizers. On the evidence available, green manuring or composting, under the special circumstances where it is an economic proposition, offers the best means of conserving nitrogen in the soil.

In conclusion, I have taken a single important hypothesis, confirmed by actual experiment in laboratory and field, and have tried to show that it has a distinct and practical bearing on the methods you are already adopting to increase the organic matter in the soil and conserve its nitrogenous food value. There are those who think that the application of science to cropping problems only makes confusion worse confounded. That is untrue except in the realm of their own minds. I hope I have been able to show that the scientific approach clarifies the situation, and links together what at first seem to be irreconcilable viewpoints.