

The Results of Drainage and Leaching Trials at Peradeniya During 1927.

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IN a previous communication by the writer (1) an account was given of preliminary experiments made during 1926 to study the absorptive powers of Ceylon soils for fertilizers and the losses of the latter by leaching from these soils. It was there indicated that the losses of fertilizers from 6-inch layers of soil due to a total rainfall of 3 inches during 24 hours were, except for the nitrates, hardly appreciable. In continuation of this investigation, a pot experiment was started in December 1926 to determine the amounts and composition of drainage waters from pots filled with soils to a depth of 3 feet, and to each of which fertilizers at the rate of 60 lb. of the fertilizing constituents were added. There were altogether 18 pots, 9 of which were cropped and 9 uncropped. Two pots, one cropped and the other uncropped, were controls. The following fertilizers were added, each to a cropped and an uncropped pot:—Blood Meal, Nitrate of Soda, Nitrate of Potash, Sulphate of Ammonia, Cyanamide, Superphosphate, Muriate of Potash and Sulphate of Potash. The pots were made of galvanised iron. They were cylindrical in form, $1\frac{1}{2}$ feet in internal diameter and $3\frac{1}{2}$ feet high with the base sloping from the circumference towards the outlet pipe at the centre. The drainage waters were collected in galvanised iron cylindrical vessels placed directly under the outlet pipes.

The pots were filled as follows:—A piece of tile was placed over the outlet at the base, and the whole of the latter covered with a layer of gravel. Unsieved soil was then compacted into the pots to a depth of 9 in. from the top, and finally soil, sieved through a quarter-inch sieve, to a depth of 3 in. from the top. The soil was a good loam well supplied with organic matter (7.8%). It is regretted that the pots were filled with soil and sub-soil taken to a depth of $1-1\frac{1}{2}$ feet and mixed together, and not with soil and sub-soil in their natural relative proportions and positions. This has to some extent rendered the results less useful than they might have been, and more divergent from what would have been obtained had drain-gauges or lysimeters of blocks of undisturbed soil *in situ* been used in the experiments. As it is, the two factors responsible for some of the abnormal results obtained from these experiments are (1) the soil disturbance, (2) the mixing of soil and sub-soil in filling the pots. It would take

at least from 4 to 6 years before the soils in the pots could settle down to anything like normal conditions of compactness. An experiment carried out to ascertain the degree of compactness and pore space in the pots showed that only $\frac{3}{4}$ ths of the soil from a hole 1 c.ft. in content could be compacted to the same degree as in the pots, into a wooden box of the same cubic content. The pore space of the soil in the pots is therefore one-third more than that of the soil *in situ*. The crop selected was the ordinary *Hibiscus* as it is a quick-growing perennial. The crop was grown from cuttings, 4 rooted cuttings being planted in each pot at the end of December, 1926. The pots were filled early in November. The manures were spread on the surface of the soil in the pots at the rate of 60 lb. per acre of Nitrogen or Phosphoric Acid or Potash, and forked to a depth of 3 inches, on the 13th January, 1927. Samplings of drainage waters from the pots were made from time to time, depending on the amounts of liquid percolated, the amount of percolate from each pot measured and an analysis made of each of the percolates at every sampling. The methods of analysis were the standard methods adopted for such determinations.

The Amounts of Drainage.

In Table I below are shown the amounts of drainage waters obtained.

Table I.

Treatment	Rainfall	Drainage	
		Uncropped	Cropped
		Inches	Inches
Blood Meal ...	76.6	49.43	28.43
Nitrate of Soda	76.6	48.27	26.58
Nitrate of Potash ...	76.6	51.11	31.80
Sulphate of Ammonia ...	76.6	48.78	30.97
Cyanamide ...	76.6	49.48	30.77
Superphosphate ...	76.6	51.94	34.66
Muriate of Potash ...	76.6	52.15	28.85
Sulphate of Potash ...	76.6	50.48	30.24
Control ...	76.6	47.95	29.2
Average ...	76.6	49.96	32.5
		%	%
Average Drainage ...		65.1	38.6
Evaporation and Transpiration		34.9	61.4

It will be observed that while the average percentage of drainage from the uncropped pots is 65.1 or about two-thirds the rainfall, that from the cropped pots is much less—38.6 or about two-fifths the rainfall. An examination of the detailed data shows that when the rainfall is heavy and continuous the drainage

is about the same from the cropped and the uncropped pots. This is partly due to the low transpiration from the crops when the humidity of the atmosphere is high owing to continuous rain. The average percentage of evaporation from the uncropped pots is 34.9 and of evaporation and transpiration from the cropped pots 65.1. Assuming equal evaporation from both sets of pots owing to soil conditions alone, the percentage of moisture lost by transpiration is 26.5 or about one-fourth the rainfall. It may be of interest to mention here that at Rothamsted the average drainage during a period of 55 years from lysimeters of undisturbed soil is 50.2% for a rainfall of 29.27 inches (2). If these experiments had been carried out on undisturbed blocks of the same soil, the drainage percentage would most probably have been less than what has been obtained. The high drainage percentage can be attributed to (1) the disturbance of the soil, (2) the compactness of the soil in the pots being only three-fourths that of soil *in situ* and the greater pore space, (3) the nature of the soil, (4) the high rainfall, its intensity and uneven distribution, (5) a probable temperature and humidity effect.

An examination of the data shows that there are striking variations in the amounts of drainage obtained from the different pots. These variations are only to be expected owing to (1) the soils in the different pots not being compacted to the same degree in each pot (2) in the case of the cropped pots, the unequal growths of the crop and hence the different amounts of water transpired, (3) the possible effects of the manures. These differences are of great importance, as it will be seen later that the amounts of soluble fertilizing constituents lost are directly dependent on the drainage. Of the cropped pots, it will be noted that the muriate of potash and superphosphate pots have the highest and the control and the nitrate of soda pots the least amounts of drainage. In the case of the cropped pots superphosphate has again the highest drainage and nitrate of soda the least. The low drainage from the nitrate of soda cropped pot might partly be due to the very good growth of the crop in this pot.

The Relation of Drainage to Rainfall and Temperature.

Glancing over Table II. and Fig. 1 it will be observed that in the case of both the cropped and uncropped pots, there is a significant positive correlation between the rainfall and the average drainage during a period. In the former case the correlation co-efficient was +.9344 and in the latter +.7106. These results therefore conform with what has already been found by other workers at Rothamsted, Pusa and Cawnpore, that for any particular place the drainage of water from soils is positively correlated to the rainfall.

Table II.

Last Date of Sampling	Rainfall	Drainage	
		Uncropped	Cropped
		Inches	Inches
29-1	6.09	3.76	4.24
1-3	2.68	1.50	1.24
16-3	4.27	1.83	0.93
23-4	4.91	2.53	0.54
16-5	7.51	6.84	6.10
2-6	6.70	3.72	1.53
24-6	4.13	3.42	1.03
19-7	5.80	3.02	0.46
9-9	4.53	2.75	0.67
30-9	7.54	4.84	2.65
31-10	10.42	8.33	6.07
4-1-28	12.02	7.92	3.88

An examination of the detailed data shows that when the rainfall is heavy and continuous the drainage percentage is high and is greater than when the rain though heavy, falls intermittently. It also shows as previously mentioned, that in the former case, the differences between the amounts drained from the cropped and uncropped pots are much less marked.

With regard to drainage and soil temperature, the data show that there is no direct relationship between the two. The average soil temperature during a period appears however to be affected both by the total rainfall and the distribution of rain during the period or immediately prior to it. The data show that low soil temperatures are obtained when the total rainfall and/or the number of days on which rain fell are great, and *vice versa*.

The Composition of the Drainage Waters.

Analyses of the drainage waters obtained under the conditions of this experiment show that calcium oxide (lime) and nitrates are found in largest quantities, chlorine in lesser amounts, and potash to a much smaller extent. No appreciable quantities of phosphate or ammonia are found in the leachings. In the case of those constituents leached out in largest quantities, much smaller amounts were found in the drainage waters from the cropped than the uncropped pots. Towards the latter half of the year when the crop had grown well the amounts of fertilizing constituents found in the drainage waters from the former were very small. The amounts of fertilizing constituents in the drainage waters were found to be greater, the greater the drainage and hence the rainfall. This was especially so with the nitrates and lime. Table III. and Figures 2 and 3 will illustrate the above conclusions clearly.

Table III.

Composition of Drainage Waters.

p.p.m. = Average parts per million.

(U) Uncropped
(C) Cropped

Total Solids.

		lbs. per acre.	p.p.m.	Ratio (U/C)
Control	(U)	3906.6	322.8	2.1
"	(C)	1854.0	280.1	

Nitrate Nitrogen.

Ammoniacal Nitrogen.

		lbs. per acre.	p.p.m.	Ratio (U/C)	lbs. per acre.	p.p.m.	Ratio (U/C)
Blood Meal	(U)	505.0	45.1	3.2	.83	.07	.6
Blood Meal	(C)	159.8	24.8		1.39	.22	
Nitrate of Soda	(U)	481.9	44.1	3.8			
Nitrate of Soda	(C)	124.1	20.6				
Nitrate of Potash	(U)	509.8	44.0	3.3			
Nitrate of Potash	(C)	153.1	21.3				
Sulphate of Ammonia	(U)	509.0	46.1	3.5	.64	.06	.6
Sulphate of Ammonia	(C)	145.6	20.8		1.12	.16	
Cyanamide	(U)	547.3	48.8	3.4	.54	.05	.2
Cyanamide	(C)	180.7	25.9		2.85	.49	
Control	(U)	510.5	47.0	2.9	.58	.05	.5
Control	(C)	175.9	26.6		1.15	.17	

Phosphoric Acid.

		lb. per acre.	p.p.m.	Ratio (U/C)
Superphosphate	(U)	.096	.008	.93
Superphosphate	(C)	.10	.014	.93
Control	(U)	.11	.013	.92
Control	(C)	.12	.018	

Lime.

Sulphate of Ammonia	(U)	553.1	50.0	2.7
Sulphate of Ammonia	(C)	203.9	29.1	
Muriate of Potash	(U)	628.6	53.2	3.2
Muriate of Potash	(C)	195.0	29.8	
Control	(U)	589.4	54.3	2.1
Control	(C)	274.9	41.6	

Potash.

Nitrate of Potash	(U)	60.4	5.2	1.5
Nitrate of Potash	(C)	39.4	5.5	
Muriate of Potash	(U)	69.9	5.9	2.3
Muriate of Potash	(C)	30.6	4.7	
Sulphate of Potash	(U)	75.9	6.6	2.4
Sulphate of Potash	(C)	32.0	4.7	
Control	(U)	65.7	6.1	1.4
Control	(C)	46.4	7.0	

Chlorine.

Muriate of Potash	(U)	161.5	13.1	2.4
Muriate of Potash	(C)	68.2	9.8	
Control	(U)	115.2	10.2	1.8
Control	(C)	65.6	9.3	

An examination of the analytical figures obtained for each constituent would appear to point to the following, apart from the general conclusions already referred to.

• **Total Solids.**—The average amount found in the drainage water from the uncropped pot was 2·1 times that from the cropped pots.

Nitrates.—(1) Next to lime these are found in the drainage waters in greatest amounts which are abnormally high.

(2) The amounts of nitrate found in the percolates at each sampling are almost directly proportional to the amounts of drainage, and the rainfall during the period prior to sampling, being greater the greater the drainage and rainfall and *vice versa*.

(3) The losses of nitrate nitrogen from the soil, as a result of the addition of 60 lb. of nitrogen per acre in various forms, if they do occur at all, will be small when compared with the losses from the soil itself which are over 500 lb. per acre. The loss of nitrate from the control pot is as great as or greater than that from the other pots.

(4) It is obviously not possible to determine the different amounts of the added nitrogen lost from the individual pots through leaching, but the analyses show that the amounts and concentrations of nitrate in the drainage waters from both cropped and uncropped pots are greatest from the cyanamide and least from the nitrate of soda pots. It should not however be inferred that similar results would be obtained under all other conditions, nor can it be deduced from the data so far obtained from this experiment that the nitrogen from cyanamide is more easily lost in the drainage water from soils than that from nitrate of soda. But the comparatively smaller quantity of nitrate found in the drainage water from the nitrate of soda cropped pot may be attributed, partly at least, to the low drainage from this pot as a result of the good growth of the crop in it. It is not understood why the concentration of nitrate nitrogen in the drainage water from the cyanamide pots is the highest of all the pots.

(5) The average amount of nitrate found in the drainage waters from the uncropped pots is about $3\frac{1}{2}$ times that from the cropped pots.

The extremely high figures for nitrates in the drainage waters are due to (1) the disturbance of the soil from its natural position and hence the greater bacterial activity owing to the increased aeration and the mechanical disturbance of the bacteria into new quarters where there are fresh supplies of food; (2) the soil and sub-soil not being placed in their natural relative positions in the pot, (3) the high drainage as a result of the high rainfall (76·6 inches) compared with that of temperate countries and

the lower degree of compactness of the soil in the pots as compared with soil *in situ*, (4) high soil temperatures and hence great bacterial activity. The soil temperature ranged from 24°-30°C which is about the optimum temperature range for the nitrifying bacteria (5) the soil being well supplied with organic matter. Though abnormal, these figures for nitrates are not surprising when it is realised that at Pusa (3) as much as 261·5 lb. nitrate nitrogen per acre were lost from the 6 ft. drain gauge of undisturbed soil when the rainfall was 75·7 inches and drainage 28·49 inches as against a drainage of 50 inches in the experiments at Peradeniya. The effect of the transference of soil from *in situ* to the pots in increasing bacterial activity and nitrification of the nitrate already present in the soil, can be gauged from an experiment of the French soil worker Dehérain. (5) He found in the drainage water from pots filled with transported cultivated soil as much as 466 to 664 parts per million of nitrate as against an average of about 45·8 at Peradeniya. He also found that no less than 196·6 lb. per acre of nitrate nitrogen were lost from a hoed fallow plot when the drainage was only 11·5 inches against the average of 50 inches in these experiments. The figures obtained from these experiments should in no way be considered as representing the actual losses of nitrates under normal field conditions as (1) the conditions of the experiment are not normal (2) they are only one year's results. It is essential that the experiment be carried out for at least 4 or 5 years more, before more nearly normal results can be obtained. The actual losses from field conditions would be much less than what these experiments show, though the latter indicate that the losses of nitrate from tropical soils would be greater, probably much greater than those from temperate regions for reasons already stated. It may be useful to refer here to the figures obtained for nitrate losses through drainage waters from drain gauges of undisturbed soil at other places. At Cawnpore in India (5) with an average rainfall of 32·7 inches the amounts of nitrate nitrogen found in the drainage varied from 80-100 lb. per acre per annum for the 6 ft. gauges during 1903-1919 and from 50-60 lb. for the 3 ft. gauges. During later years (1919-1926) the quantity lost was considerably less being 25-30 lb. per annum. Pusa (3) figures for 1906-1910 were 75 and 66 lb. per acre respectively when the average rainfall was 42·4 inches and those of Rothamsted (2) 40 lb. in the earlier years, then 30 and finally 25 lb. in the later years, the average rainfall being 29·3 inches. Reliable data on the losses of nitrate from Ceylon soils can only be obtained if proper lysimeters or drain gauges of soils *in situ* are erected.

Some results of practical value are clearly demonstrated by these experiments. They show that large amounts of nitrate nitrogen would be made available to crops by judicious and care-

ful soil cultivation provided there is sufficient nitrogen and organic matter in the soil, and that the excessive cultivation of soil is uneconomic owing to the depletion of the lime, nitrogen and organic matter reserves of the soil.

Lime.—(1) Lime is found in the drainage waters in greatest amounts and is evidently in the form of nitrate of lime.

(2) The amounts of lime found in the leachings are dependent on the drainage and the rainfall, in the case of both cropped and uncropped pots.

(3) The effect of fertilizers on the amounts of lime found in the drainage waters is not apparent owing to the soil disturbance and the different degrees of compactness in the pots. The loss from the control is less than that from the muriate of potash pot owing to the high drainage from the latter, and greater than that from the sulphate of ammonia pot.

(4) The average amount lost from the uncropped pots is 2.7 times that from the cropped pots.

The high losses of lime are due to (1) the high drainage, (2) the increased production of carbon dioxide and hence greater solubility of the calcium carbonate in the soil owing to the increased aeration and high soil temperatures.

Potash.—(1) The amounts of potash present in the drainage waters are much smaller than those of nitrate and lime and are dependent on drainage and rainfall to a lesser extent than the latter.

(2) The concentration of potash in the drainage waters is much the same as of those from cultivated fields at Rothamsted.

(3) The average amount found in the drainage water from the uncropped pots is about twice that from the cropped pots.

Chlorine.—(1) The amounts of chlorine present in the drainage waters are dependent on drainage and rainfall.

(2) The loss of chlorine from the muriate of potash pot is greater than that from the control. This is probably due to the greater drainage from the former as well as to the chlorine lost from the fertilizer itself.

(3) The average amount lost from the uncropped pots is about twice that from the cropped pots.

Ammonia.—(1) Only very small amounts of nitrogen as ammonia are found in the drainage waters.

(2) The drainage waters from the cropped pots contain greater amounts of ammonia than those from the uncropped pots.

Phosphoric Acid.—Only minute traces of phosphoric acid are found in the drainage waters from both the cropped and the uncropped pots.

The above results indicate that the effects of soil disturbance on the amounts and concentrations of drainage waters are considerable, and such as to render the latter much higher than what would have been obtained from drain gauges of undisturbed soil *in situ* as those at Rothamsted, Pusa and Cawnpore. It is likely that if the soil had been left to settle in the pots for 3 or 4 years at least before the experiment was started, more nearly normal results would have been obtained.

References.

1. A Preliminary Investigation on the Absorption of Fertilizers by Ceylon Soils—A. W. R. Joachim, Department of Agriculture, Bulletin, No. 75.
2. Soil Conditions and Plant Growth—E. J. Russell, pp. 245 and 354.
3. Records of Drainage in India—J. W. Leather, Memoirs, Department of Agriculture, India, Chem. Series, Vol. II., Part I.
4. The Soil—A. D. Hall, pp. 223 and 265.
5. Drainage Waters at Cawnpore—H. N. Batham, Mem. Dept. Agri., India. Chem. Series, Vol. VIII., No. VIII.

Discussion.

MR. KEILLER said that he would like to confirm from his own little experience, the findings of Mr. Joachim. He thought that there was a good deal of exaggeration in people's minds as to the rate of loss of nitrates under Ceylon conditions. That was one point which Mr. Joachim did bring up. They knew that there was no chemical action which fixed nitrates in the soil and there was no physical mechanism, except a little absorption and the surface tension effect which prevented nitrates being washed off, and having a little knowledge of those two they would think that it is washed off. As Mr. Joachim had pointed out, where they had a good crop, the loss of nitrate was much less than if they had a bad crop.

There was on the other hand, the retentive effect of the growing crop itself, as Mr. Joachim's findings had proved. He had experienced further that the growth in rubber from nitrate applications annually was better than the growth from any other fertilizer he had used by way of comparison, or that of the unmanured control plot.

MR. T. EDEN.—I have listened to what Mr. Joachim has said with very great interest and there are a number of points arising from the data presented in this paper, which, if they are confirmed by subsequent work, should lead to results of practical importance. I would confine my attention entirely to the question of loss of nitrogen. In the first place, Mr. Joachim said that the nitrate losses are as great in the control as in the manured plots. He ascribes this to the high organic matter content of the soil. The importance of this finding can, to my mind, be more adequately judged if the emphasis is altered and we say that the data show that the losses from manured plots are no greater than from the control.

The second point is that in respect of nitrate loss. Nitrate of soda, sulphate of ammonia and blood meal acted alike in these plots. (The small differences which appear to occur are not large enough to have any significance until confirmed by statistical examination.) This means that even on the uncropped soil, the readily available and soluble nitrate has not been lost to an extent greater than its less available neighbour, sulphate of ammonia, or the alleged slow-acting blood meal.

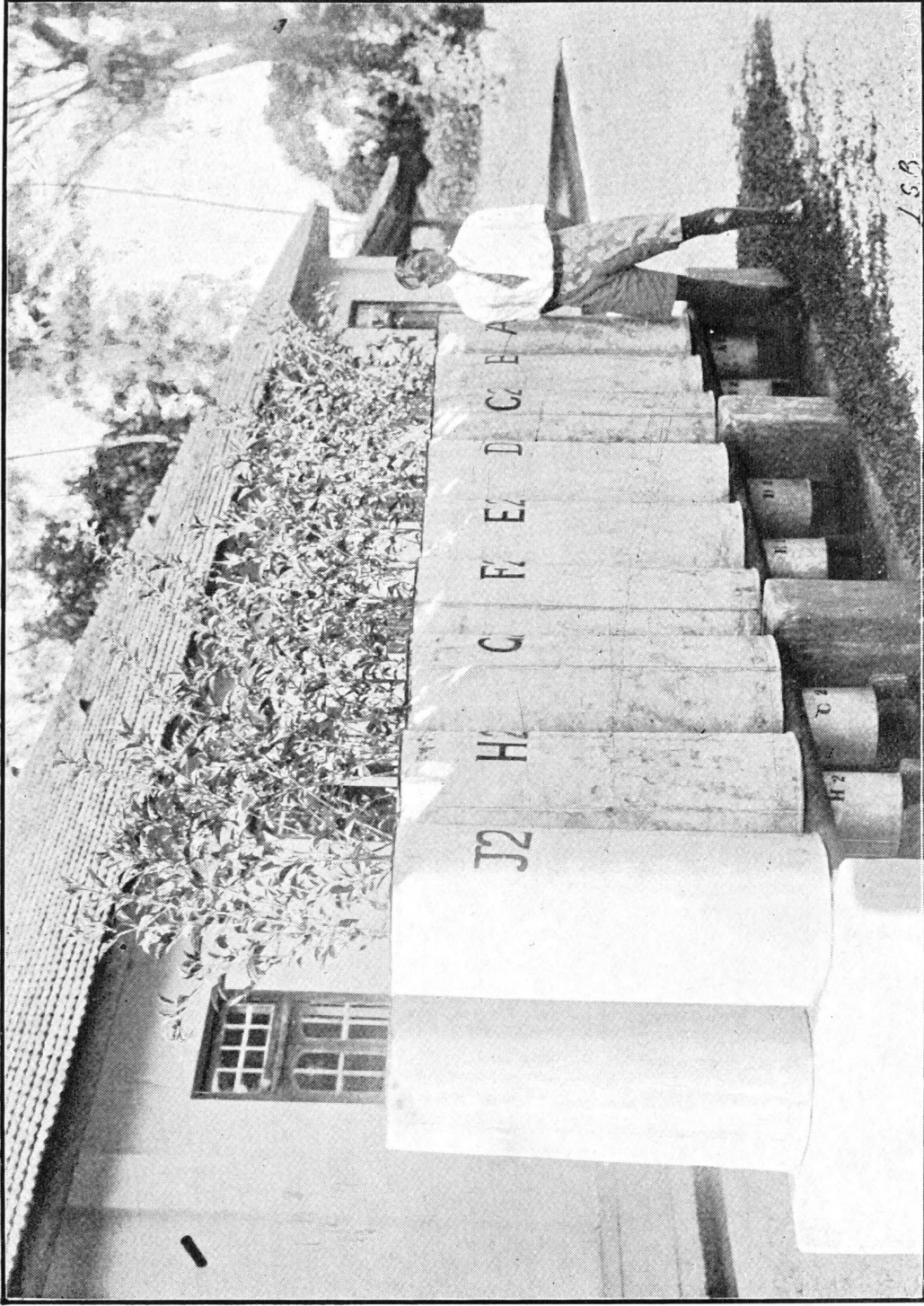


Photo by L. S. Bertus.

Showing Pots Used in Leaching Experiment. The Pots in front are Uncropped. Crop at a Late Stage of Growth.

Yet if nitrification and leaching were the only factors concerned, a differential effect might have been expected. The solution to this problem is offered by regarding the nitrogen changes in the soil as being part of a complete cycle which includes both the breaking down and the building up of complex substances. The nitrogen lost in drainage is the balance between what is produced by degradation of higher forms on the one hand, and what is re-assimilated by the micro-organic population or used by higher plants on the other hand.

The two processes of breaking down and building up by way of micro-organic protoplasm go on side by side.

The figures under review suggest that such a process has been taking place, so that the loss of added nitrate and ammonia has been checked by their being brought into the "synthetic" portion of that nitrogen cycle. The agency which makes this conservation possible is the organic matter.

Investigation at Rothamsted and in America show that within limits the ratio of carbon to nitrogen in the soil is 10. That leads to my third point which is that without an adequate supply of organic matter the conservation of even added nitrogen (that is, as apart from what the organic matter itself supplies) is impossible.

Given a soil rich in humus, then within the range of fluctuation possible to the carbon nitrogen ratio added nitrogen can be preserved by the process of biological assimilation and gradual release. Given, on the other hand, a soil poor in humus, added nitrogen will be lost in drainage, because in the absence of the energy supplied by the organic matter, assimilation cannot take place. These data then suggest that in the practical field a number of points should be tried out. Where green manuring is carried on intensively and organic matter is consequently well supplied, these results suggest that losses would not be greater using the more soluble sulphate of ammonia at Rs. 9/- a unit than with the so-called less available blood meal at Rs. 24/- a unit of nitrogen.

If this is the case, if this conservation of nitrogen can be demonstrated in the field, it provides an added reason why green stuff should find favour on estates in Ceylon. In this connection it is interesting that not only the classical experiments but modern ones also at Rothamsted point to a higher level of efficiency from a judicious use of artificial and organic matter than from either by itself. In parenthesis it may be mentioned that the contribution of organic matter to a soil by organic manures like blood meal is negligible, being on a 500-lb. application about 1—50 per cent.

These points, I believe, are important enough to warrant not only a continuance of these leaching trials, but full investigation on the field side. These latter would have to be accurate and comprehensive, and it is hoped that work at present in hand at Nuwara Eliya will provide a sound basis for such experiments when the time is ripe for their accomplishment.

HIS EXCELLENCY THE GOVERNOR.—I thank Mr. Joachim on your behalf for the very instructive paper which he has just read and I believe that these results are the labour of careful calculations. I have had the opportunity of seeing the useful work carried on by Mr. Joachim here, and I hope that those of you who are interested in this will put it to practical experience.

His Excellency then called upon MR. T. H. HOLLAND to read his paper entitled "Experiences in the use of creeping cover crops in tea cultivation with special reference to *Indigofera endecaphylla*."