

## SOIL FERTILITY STUDIES

### I. THE EFFECTS OF A NAPIER GRASS FALLOW ON SOIL COMPOSITION AND STRUCTURE UNDER CEYLON CONDITIONS

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#### SUMMARY

**T**RIALS were carried out at a number of Departmental Stations to ascertain the effects on the soil of a crop of Napier grass (*Pennisetum purpureum*) grown for a period of three years. The examination of the soil at the start and conclusion of the trials showed that there were appreciable increases in organic matter and nitrogen and that the physical condition of the soil was improved as a result. Soil resistance tests on adjacent grass-fallowed, cultivated and uncultivated land afforded confirmation of the beneficial physical effects on the soil of the cultivation of Napier grass. The application of these findings to rotation agriculture in Ceylon is briefly discussed.

#### INTRODUCTION

It is well recognized that the organic matter status of a soil and its tilth are best maintained by a system of husbandry in which arable agriculture is combined with grassland farming. If this applies to temperate agricultural conditions, it would apply with even greater force in the tropics where climatic conditions are very favourable for the rapid breakdown of organic matter and the destruction of soil tilth. Bulky organic manures such as cattle or green manure are no doubt of benefit to the crops to which they are applied, but as restorers of soil humus and structure, they are much less effective than a temporary ley or grass fallow of at least 2 years' duration. These manures replace the losses of organic matter from, but do not increase its amount in the soil, unless climatic conditions are favourable and heavy dressings are regularly applied. Evidence and support for these views have been furnished by Pieters and Mc Kee (1), Bradford (2), Prince (3) and other workers in the U. S. A., by Theron (4) in S. Africa, Nye (5) in E. Africa, Robinson (6) in Great Britain, Visvanath (7) in India, &c. Experimental data obtained locally confirm some of these findings (8).

In Ceylon temporary leys have not yet found a place in our system of rotation agriculture, but opinion is growing as to the need for such, if soil fertility is to be maintained. One difficulty up to now has been the lack of suitable crops for the purpose. Nye (5) has demonstrated that Elephant

(Napier) grass (*Pennisetum purpureum*) has been largely responsible in E. Africa for maintaining the fertility of soils in that part of the country where this plant is dominant.

#### EXPERIMENTAL

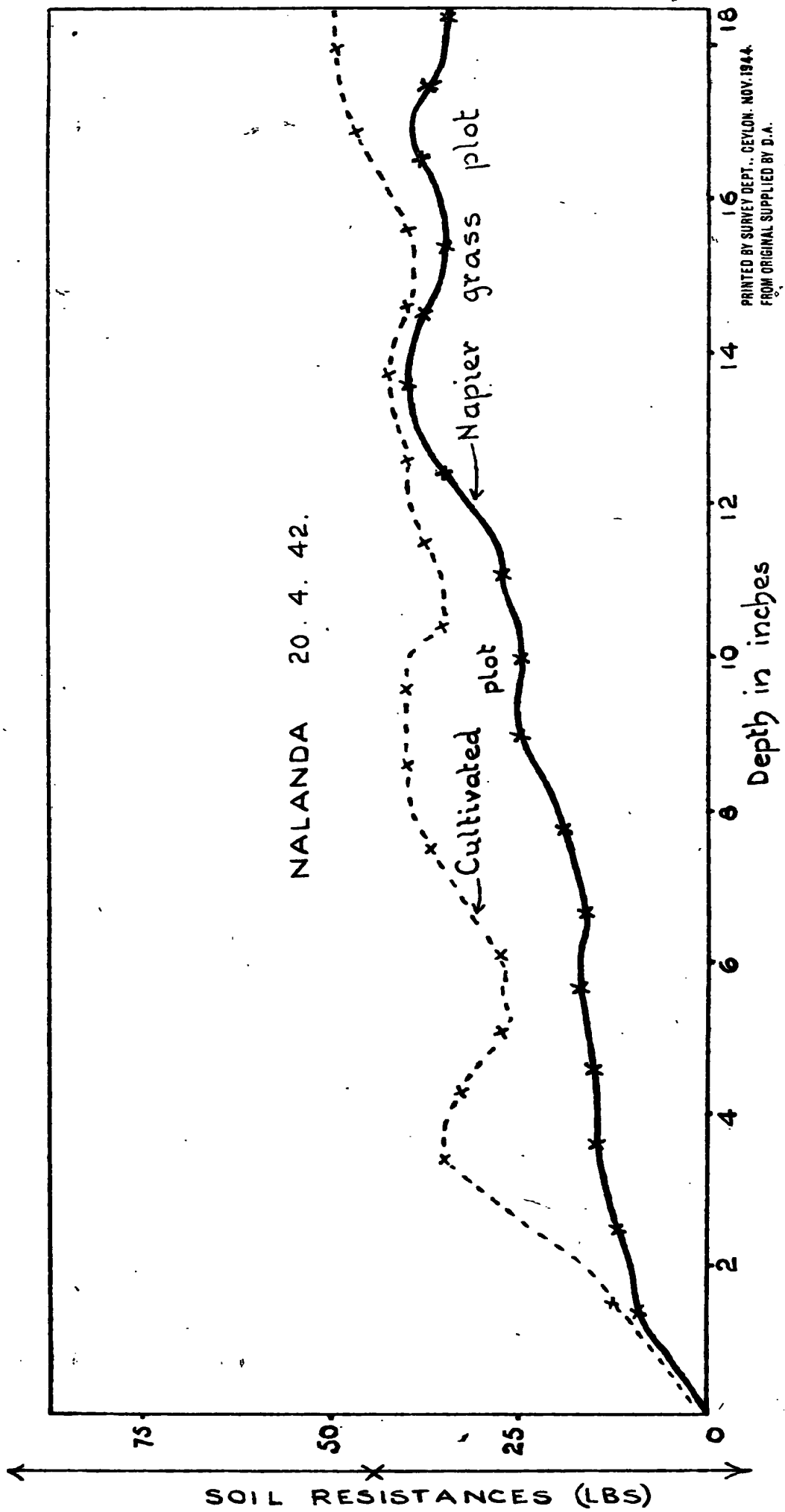
As Napier grass grows well in many parts of Ceylon, it was decided to test out on a number of Departmental Experiment Stations the effects of a 3-year fallow of this crop on soil composition and structure. Accordingly, plots of Napier varying in size from  $\frac{1}{4}$  to  $\frac{1}{2}$  acre were planted between November 1938 and February 1939 at the following stations: Anuradhapura, Maho, Nalanda, Karadiyanaru, Middeniya, Horana and Wariyapola. The plots were sited in a part of the station where the soil was known to be of poor fertility. The soils varied in texture from sand to loams and gravelly loams. At Maho, an additional plot under Napier grass was laid down to which an application of lime at the rate of 2 tons per acre was given prior to planting.

The growth in the plots at Horana and Wariyapola was poor and the crop began to die off two years or so after planting. These centres were, therefore, eliminated from the trials. At the other centres, representative soil samples were taken immediately prior to planting the crop and at the end of each year from planting for three years successively. At the last sampling, soil samples from an area of cultivated land adjacent to or in the close vicinity of the grass plots were taken for comparison. The first and last sets of soil samples were examined for organic matter and nitrogen as well as for soil reaction, maximum water holding capacity, specific gravity, rate of percolation, porosity and moisture equivalent value. The dispersion ratios of a few samples were also determined (9). The methods of analysis adopted were as follows:—nitrogen by the Kjeldhal process, carbon by Walkley & Black's wet combustion method, soil reaction with the quinhydrone electrode, maximum water holding capacity, porosity and specific gravity by Keen and Raczkowski's box method, moisture equivalent by Bouyoucos' procedure, and rate of percolation by Singh's modification of Bouyoucos' method (10).

In order to obtain some measure of the effect of the grass fallow on soil structure, tests were carried out with Culpin's apparatus, at the end of the 3-year period, of the soil resistance of plots under grass fallow and of adjacent cultivated and uncultivated land, at three centres—Maho, Anuradhapura and Nalanda. Unfortunately, as the soil of the Anuradhapura plots was of the gravelly type and the apparatus is not suited for soils of this type, the tests at this centre were vitiated and proved unsatisfactory. The results obtained at Maho and Nalanda are shown in figures I. and II.

#### DISCUSSION OF RESULTS

An examination of the data of tables I. and II. would show that the effect of the 3-year grass fallow has been (1) *to increase the organic matter and nitrogen contents of the soils*. These increases are definitely significant (see Table II.), and amount to about 17 per cent., on the average, in the case of soil carbon and 15 per cent. in that of nitrogen. On the basis that 1 per cent. carbon will represent about 35,000 lb. of organic matter in an acre of soil to a depth of 6 inches, the average increase in organic matter brought about by growing the Napier grass is approximately 4,700 lb. per acre. This is appreciably greater than what Pieters and Mc Kee (1) report as having been obtained at the New Jersey, Experiment Station, U. S. A. At this Station, a grass sod



of two years' duration increased the humus content by 1,340 lb. per acre. In regard to nitrogen, which in many soil types constitutes about one-tenth the carbon content or about one-seventeenth that of the humus, the average increase obtained in these trials is approximately 200 lb. per acre, which is equivalent to an application of about 1,000 lb. of sulphate of ammonia per acre. -

Another point of importance which emerges from these trials is that while a fallow of Napier grass increases appreciably the organic matter and nitrogen contents of the soil during a 3-year period, the adoption of a system of rotational cropping has resulted merely in the maintenance of the organic matter and nitrogen status of these soils. These findings are in conformity with results obtained elsewhere (1, 11).

Additional data in respect of the beneficial effects of Napier grass on the organic matter and nitrogen contents of the soil are furnished below. They relate to a plot of Napier grass at the Maho Experiment Station which was under the crop for over two years prior to the start of the trials under review and to an adjacent uncultivated plot. It will be noted that the organic matter and nitrogen percentages are higher in the Napier plot in both soil and sub-soil down to a depth of 16 inches.

	Napier grass plot		Adjacent uncultivated plot	
	0-9 in. per cent.	9-16 in. per cent.	0-9 in. per cent.	9-16 in. per cent.
Carbon ..	0.779	0.624	0.741	0.431
Organic matter ..	1.35	1.08	1.28	0.75
Nitrogen ..	0.104	0.076	0.089	0.052

Also of interest in this connexion are the results of the comparative examination of soil samples from a plot at Peradeniya which was under a cover of *Mimosa invisa* for a period of two years and an adjacent grass sod plot.

	Mimosa plot per cent.	Adjacent grass sod plot per cent.
Carbon ..	0.947	1.12
Organic matter ..	1.654	1.94
Nitrogen ..	0.128	0.147
Total exchangeable bases (mgm. equiv. %) ..	3.24	3.65
Reaction (pH) ..	5.73	5.99

These results indicate that from the standpoint of humus and nitrogen restoration in the soil, a grass sod may even be more advantageous than certain types of leguminous covers such as *Mimosa invisa*. Other factors besides this would, however, determine whether a leguminous cover or grass sod should be established under a particular set of agricultural conditions.

(2) *The water-holding capacity, porosity, moisture equivalent and rate of water percolation of the soils have, in general, been improved as a result of the grass fallow, though the improvement in these directions is not marked in some cases.* These results would naturally follow from the increased humus content of and the formation of a "crumb" or granular structure in the soil effected through the agency of the decayed grass roots. The mechanism of the latter process has been lucidly explained by Bradfield (2). Quantitative evidence

has recently been furnished by the Uganda Department of Agriculture in regard to the formation of crumb structure in red loamy soils which had rested under Napier grass, while identical soils treated with cattle manure showed no such effect (13).

(3) *The dispersion ratios of the Napier grass soils from two of the centres are somewhat lower than those of the original soils.* This would indicate the formation in the soils of water-stable aggregates which would be, even for a time, more resistant, to erosion than the original soil particles, when the areas revert to arable cultivation. The additional benefit of liming in this respect is seen in the case of the Maho soil.

(4) *The improvement in the physical condition of the soil which is effected by the Napier grass fallow is clearly seen from diagrams I. and II.* which show the comparative soil resistances, at different depths, in the Napier grass plots and in adjacent cultivated and uncultivated land. At Nalanda, the soil resistance is considerably less in the Napier grass plots than in the uncultivated plot at all depths below about 1 inch down to 18 inches. At Maho, while the differences are not so marked between the Napier grass and cultivated plots, they confirm that the beneficial effect of the grass in respect of soil consolidation is not merely superficial but extends down to as much as 18 inches. These tests also demonstrate that cultivation reduces appreciably the resistance of the Maho soil to a depth of about 8 inches. As a close correlation between soil resistance and crop growth has been established (12), the importance of any agricultural practice which reduces soil resistance will be realized.

(5) *There are no appreciable changes in soil reaction resulting from the growth of the Napier grass except in the case of the plot at Maho which was limed in addition, and which, in consequence, shows a higher pH value.*

In order to ascertain the bearing of these observations on the exchangeable base changes in the soils, determinations of total exchangeable bases were made on the original and final soil samples from Maho and Nalanda. The results are tabulated below :—

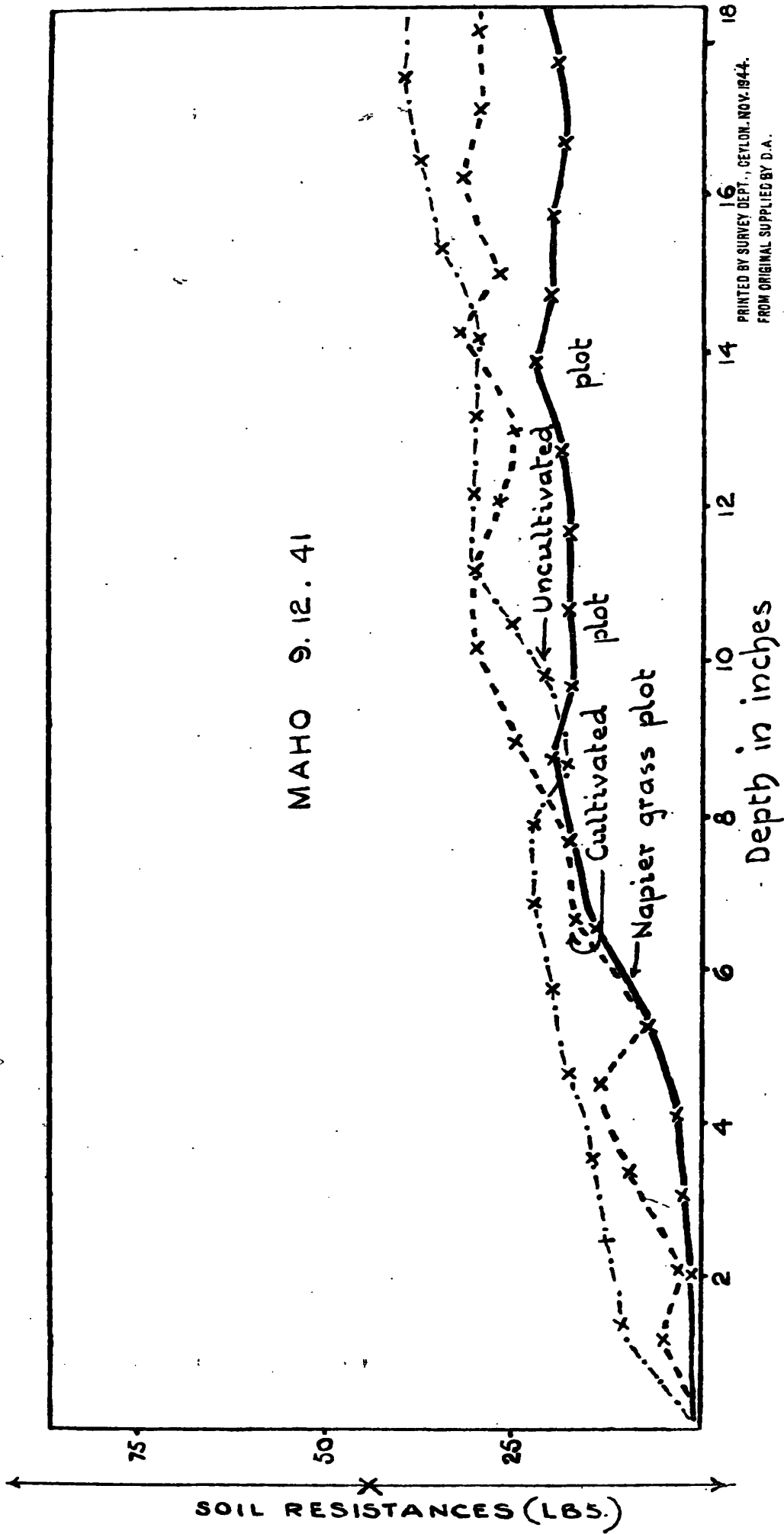
			Initial soil		Napier grass soil Mgm. equivalent per cent.
Maho	..	..	8.8	..	9.2
Nalanda	..	..	10.4	..	14.3

It will be seen that while the increase in base content was appreciable at Nalanda, it was only slight at Maho. The buffer capacity of the Nalanda soil is apparently higher than that of the Maho soil, to judge from the pH data.

#### PRACTICAL CONCLUSIONS

It is clear that a Napier grass fallow is of appreciable value in increasing the organic matter and nitrogen contents of soils and in improving soil tilth and structure. Under local conditions a 3-year period of fallow is suggested as a desideratum, which is also the recommendation of the Department of Agriculture, Uganda. Certain objections would, however, be urged against the adoption of the practice. These are : (1) that an appreciable part of the land in a holding will be non-productive, so far as economic crops are concerned, for a 3-year period. This is inevitable if it is conceded that soil fertility decline is rapid under tropical conditions, and that the best means of restoring this fertility is the introduction, as in temperate regions, of a temporary ley or grass fallow in the rotation. The proportion of arable to

MAHO 9.12.41



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grass land or ley would depend on the local soil and climatic conditions and the rotation adopted. The ideal, however, would be a system of alternate cropping in a 3-year cycle, one half the rotation area being under arable crops and the other under grass or leguminous fallow. A modification of the system would be the cultivation of such an extent of fodder crops on the farm as would supply enough cattle manure to be applied in heavy dressings to the arable crops. This would necessitate the rearing of much larger numbers of cattle on the farm than is normally the case, and would probably be less satisfactory from the standpoint of soil fertility maintenance than a grass or leguminous fallow. The choice of crop is a matter for experiment. These trials indicate that Napier grass is very suitable for achieving the desired objective in respect of soil fertility. It has several advantages over pasture grasses and many leguminous covers—it is easily established in many parts of the Island on all but gravelly soils, has a relatively deep and extensive root system, is hardy and fairly long-lived, makes a dense growth which kills out most weeds, and supplies a large quantity of useful fodder per unit area. It is possible, however, that some other crop may be found which would prove even more satisfactory than Napier. But till such time, Napier grass can be recommended; (ii) that the labour involved in planting and clearing would not be available when it is required. This difficulty should not prove insuperable to a resourceful farmer. The clearing of the crop would be a real difficulty unless burning is adopted. This would entail loss of organic material which could well be utilized for composting. Even if burning were done, the removal of the grass stumps and mat of roots by hand would be a formidable task, but if tractor-drawn implements are used the difficulty would be solved; (iii) the difficulty of preventing the crop from being damaged by cattle. This can easily be surmounted by proper fencing.

#### ACKNOWLEDGEMENTS

The thanks of the authors are due to the several Divisional Agricultural and station officers for having made this investigation possible.

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TABLE I.

	Maho				Anuradhapura				Middeniya				Karadiyanaru				Nalanda			
	Initial	Napier unlimed	Napier limed	Control (cultivated)	Initial	Napier	Napier	Control (cultivated)	Initial	Napier	Napier	Control (cultivated)	Initial	Napier	Napier	Control (cultivated)	Initial	Napier	Napier	Control (cultivated)
Date of sampling	2.11.38	—	8.12.41	—	26.10.38	28.12.41	28.12.41	9.12.41	8.1.39	10.1.42	10.1.42	10.1.42	2.2.39	18.2.42	18.2.42	10.1.42	2.2.39	18.2.42	18.2.42	10.1.42
Depth of sampling (average)	—	—	0-8 in.	—	—	0-6 in.	0-6 in.	0.6	—	0-9 in.	0-9 in.	0-9 in.	—	—	—	—	—	—	—	—
Gravel and stones %	1.5	1.0	5.0	2.4	20.7	20.3	22.0	0.8	—	2.28	2.26	2.33	—	—	—	—	—	—	—	—
Texture index number	—	—	13.3	—	—	18.8	—	16.9	—	35.7	39.2	37.6	—	—	—	—	—	—	—	—
Soil type	—	Sandy loam	loam	—	Gravelly loam	loam	—	Loam	—	—	—	—	—	—	—	—	—	Loam	—	—
<b>Physical Characteristics</b>																				
Apparent specific gravity	1.47	1.39	1.42	1.43	1.43	1.41	1.39	1.44	1.40	1.44	1.47	1.47	1.49	1.46	1.49	1.49	1.33	1.33	1.33	1.33
Real specific gravity	2.33	2.22	2.29	2.23	2.22	2.20	2.37	2.26	2.28	2.26	2.33	2.33	2.35	2.23	2.26	2.26	2.27	2.38	2.38	2.33
Porosity %	40.1	42.3	42.9	38.1	40.8	41.8	40.6	39.2	35.7	39.2	37.6	37.6	35.7	38.5	34.2	34.2	44.3	46.3	46.3	44.4
Maximum water holding capacity %	33.8	41.5	38.7	34.9	36.6	38.1	37.6	29.9	27.0	29.9	28.9	28.9	24.2	26.8	23.0	23.0	40.8	42.4	42.4	40.0
Moisture equivalent (Bouyococ) %	13.7	15.8	14.6	12.2	15.9	16.3	11.1	12.5	10.9	12.5	10.9	10.9	6.5	9.0	6.4	6.4	16.2	16.0	16.0	15.9
Rate of percolation (minutes)	24	24	21	23	27	19	46	16	—	16	26	26	7.0	4.5	4.5	24	22	22	23	23
Dispersion ratio	21.2	17.1	10.7	17.8	—	—	—	—	—	—	—	—	—	—	—	—	11.5	8.5	8.5	10.9
<b>Chemical Analysis</b>																				
Moisture %	1.47	1.91	1.91	1.58	1.84	2.11	1.96	1.16	0.91	1.16	1.13	1.13	0.38	0.77	0.45	0.38	2.25	2.53	2.53	2.12
Loss on ignition %	3.22	3.91	3.66	3.17	4.09	4.21	4.11	3.96	3.34	3.96	3.61	3.61	1.51	2.04	1.75	1.75	3.48	3.72	3.72	3.46
Organic matter %	1.23	1.64	1.57	1.19	1.62	1.69	1.59	1.12	1.00	1.12	1.02	1.02	1.19	1.43	1.31	1.31	1.45	1.79	1.79	1.45
Carbon %	0.71	0.95	0.91	0.69	0.91	0.98	0.92	0.66	0.58	0.66	0.59	0.59	0.69	0.83	0.76	0.76	0.84	1.04	1.04	0.84
Nitrogen %	0.071	0.091	0.089	0.076	0.094	0.096	0.090	0.058	0.049	0.058	0.056	0.056	0.05f	0.062	0.058	0.058	0.075	0.086	0.086	0.080
Carbon/nitrogen ratio	10.0	10.47	10.21	9.08	9.24	10.21	10.21	11.38	11.84	11.38	10.53	10.53	13.53	13.39	13.10	13.10	11.21	12.09	12.09	10.50
Reaction (pH)	6.5	6.6	7.1	6.5	5.6	5.6	5.7	6.0	6.0	6.0	6.0	6.0	5.5	5.6	5.4	5.4	6.5	6.6	6.6	6.4

TABLE II.

	Carbon			Nitrogen		
	1 Initial Per Cent.	2 Napier Plot Per Cent.	3 Cultivated Plot Per Cent.	1 Initial Per Cent.	2 Napier Plot Per Cent.	3 Cultivated Plot Per Cent.
1. Maho ..	0.71	0.93	0.69	0.071	0.090	0.076
2. Anuradhapura ..	0.94	0.98	0.92	0.094	0.096	0.090
3. Middeniya ..	0.58	0.66	0.59	0.049	0.058	0.056
4. Karadiyanaru ..	0.69	0.83	0.76	0.051	0.062	0.058
5. Nalanda ..	0.84	1.04	0.84	0.075	0.086	0.080
Means ..	0.752	0.888	0.76	0.068	0.078	0.072
Differences of means ( <i>d</i> ) ..	(2)—(1) 0.136	(2)—(3) 0.128	(3)—(1) 0.008	(2)—(1) 0.010	(2)—(3) 0.006	(3)—(1) 0.004
Standard error of mean differ- ence (S.Ed) ..	0.034	0.038	0.017	0.027	0.002	0.002
$t = \frac{d}{\text{S. Ed}}$ ..	4.0	3.37	0.5	3.7	3.0	2.0
Odds for $n = 4$ ..	Between 50 & 100:1	About 50:1	<2:1	50:1	Between 50 & 20:1	<10:1