SOIL MANAGEMENT IN THE SUBTROPICAL REGION

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Introduction

Under natural conditions, soils of the humid tropics and subtropics are covered by evergreen broad-leaved forests which protect the soil against strong solar radiations and direct raindrop impact and supply abundant amounts of litter on the ground, making the soil surface layer rich in organic matter and plant nutrients. Removal of the vegetation and physical stirring of soil associated with the introduction of crop cultivation inevitably accelerate the decomposition of organic matter and deterioration of soil structure, as well as soil erosion and leaching of plant nutrients, resulting in the rapid exhaustion of soil fertility.

The present studies have been promoted to improve soil fertility with a view to the following three basic aspects, namely, (1) soil management chiefly with organic matter, (2) utilization of legume plants, (3) fertilization of upland soils through locally available materials.

First, Napier grass, a perennial forage crop, was evaluated as a source of organic matter and a rotation system containing Napier grass along with the other main crops of Okinawa was proposed for its high productivity of organic matter.

Second, *Leucaena leucocephala,* a leguminous shrub in the warm region, was chosen to determine the effect of legume plants on the soil fertility of land covered by *Imperata cylindrica.*

Third, coral sand which is available locally was tested as a liming material, since most of the upland soils in the humid tropical and subtropical region are acid with low base status.

Vegetation and soil fertility

A pot experiment with upland rice was carried out using different soils from the neighboring areas of the Okinawa Branch of TARC to evaluate inherent and modified fertility of the soils covered by various types of vegetation. The results are shown in Table 1. It is clear that (1) forest soil was highly productive, (2) in a poor grassland of *Imperata cylindrica,* soil fertility recovered considerably over a period of 10 years after cropping was abandoned, (3) incorporation of Napier grass as green manure was fairly effective in increasing soil fertility, (4) mulching of a large amount of Napier grass had a remarkable effect on the rice yield which was equal to that obtained from the forest soil, and (5) serious reduction of rice yield was observed in the soil of farmland, whereas yield increased in soil with *Imperata* grassland and in farmland soil to which Napier grass had been incorporated.

Despite the presence of poor vegetation namely 0.69 kg of top weight/m^2 and 0.31 kg of root dry weight/m^2 in the *Imperata* grassland, the soil from the grassland showed relatively higher capacity for maintaining fertility. This can be explained by the combined effect of the following factors; plant role in protecting soil against direct solar radiations and raindrop impact, enrichment of soil by plant residues, recovery of soil structure by dense root systems of the grass as well as absence of removal of plant nutrients by crop harvest and of disturbance of soil during the fallow period.

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Table 1 Grain yields (g/pot) of upland rice grown on different soils

Cropping	Soil form	Fertilizer	1974 Yield	1974 Index	1975 Yield	1975 Index	Remarks
Continuous	Farmland	NPK-N	26.0	100	3.5	9	More than 20 years
			3.4	13	2.8	7	after reclamation
	Imperata grassland	NPK-N	33.8	130	44.5	115	10 years after farm-
			9.1	35	11.6	30	land was abandoned
	Napier grass incorporated	NPK	39.4	152	40.8	106	Incorporated at a rate of 40 ton fresh wt/ha
Not continuous	Farmland	NPK	–	–	38.6	100	
	Forest land	NPK-N	–	–	70.4	182	Relatively old
			–	–	62.7	162	secondary stand
	Napier grass mulch	NPK	–	–	72.6	188	Vegetables were grown with heavy mulching of Napier grass in 1974

Improving soil fertility with Napier grass and other materials

1 Growth of Napier grass and fertilizer application

In areas with animal husbandry it is highly possible to include forage crops in the rotation system. The forage crops not only produce roughages but also serve as soil-restoring crops, mulching material or green manure.

By using an appropriate perennial forage crop with higher fertilizer response, a greater effect than that of natural grasses such as *Imperata cylindrica* can be achieved, or the same effect can be attained within a much shorter period of time. In that case, nutrient elements removed by crop harvest from the field can mostly be compensated by the application of chemical fertilizers.

The most popular forage crop for soilage in this area is Napier grass *(Pennisetum purpureum)*. Yields of the grass grown with three-element fertilizer (N P K) and without it (–N, –P and –K) were studied during the period May 1973 – November 1974. Expressed in terms of the percentage to the yield of the NPK plot, yield of –N plot was 26% in an early stage, and decreased to 13% in a later stage, with an average of 21%. Yields of –P and –K plots were 94 and 93% on an average, respectively, without showing a decline in the later cuttings. The total yield of dry weight in the NPK plot was 48 t/ha. Monthly production of Napier grass was almost linearly correlated to monthly mean temperature, indicating the possibility to utilize surplus production in the summer season as mulch or green manure.

2 Napier grass mulch and continuous planting

Decomposition of fresh organic matter on the soil surface is extremely rapid under subtropical and tropical conditions. When Napier grass 50 days of age (with the basal part of stems slightly hardened and a leaf/stem ratio of 1:2) was applied as mulch, only 49% of the stems and 17% of the leaves remained 56 days after the application. All the decomposed materials were supplied as nutrients to the soil. For maintaining the physical effect of the mulch on soil moisture and soil temperature and for erosion control, 200 – 300 ton of the grass in fresh weight/ha are required each year. Therefore older plants should also be used partly with the mulching. It is interesting to note that a large population of worms and other small animals are observed on the soil surface beneath the mulch, suggesting promotion of microbial activities.

Changes in the chemical properties of soil affected continuously by Napier grass are shown in Table 2. In the soil planted to Napier grass the pH value is low due to leaching of exchangeable calcium in the form of calcium nitrate after nitrification of N-fertilizer applied. The readily released nitrogen was increased when half of the grass was incorporated into soil, in particular. Although the base saturation degree decreased because of the uptake by Napier grass, the amount of exchangeable potassium increased a little because half of the grass was returned to the field as mulch.

Table 2 Changes in chemical properties of soil affected by continuous planting of Napier grass

Treatment	pH (H_2O)	CEC (meq/100g)	Exch. – base (meq/100g)					Base sat. (%)	Readily released N (mg/100g)	
			Ca	Mg	K	Na	Total		A	B
Before treatment	5.2	6.8	0.76	0.41	0.22	0.19	1.57	23	1.2	2.6
Grass taken out of field	4.9	7.0	0.52	0.16	0.08	0.15	0.90	13	2.5	3.4
Half of grass returned to the field as mulch	4.5	7.1	0.35	0.22	0.38	0.16	1.12	16	4.4	4.7

Remarks: During 1976.7 – 1979.12
Field in Okinawa Station TARC
A as it is
B adjusted to pH 7

Effect of preceding crop on succeeding crop

As shown in Table 3, effects of Napier grass and various crops (sweet potatoes, peanuts, broad bean and sorghum for 4 years) on succeeding crops were determined with three kinds of treatments, namely no treatment, inorganic materials (40 ton/ha of coral sand) and organic + inorganic materials (40 ton/ha of farmyard manure made of Napier grass + 40 ton/ha of coral sand). It is clearly indicated that Napier grass as a preceding crop brought about higher yield than other crops. The effect of Napier grass was evident in the plot of coral sand application, but not in the plot without treatment and in the case of application of manure combined with coral sand. In other words, the effect of organic matter was negligible in the plots of Napier grass, because Napier grass was returned to the field as a mulching material in one of every two cuttings, and the surface soil became thus rich in organic matter. This result indicates that Napier grass could be advantageously utilized for cropping systems.

In general, the application of organic matter is essential to fields planted with various crops, where plowings are repeated and a large mass of plant materials is removed by each crop. When continuous planting is practiced with only three-element fertilizer, even if the preceding crops are grasses, the pH value declines and a low yield cannot be avoided, as the soils are low in humus, CEC and buffer action. Therefore the supply of liming materials to the fields is always important in the humid subtropical region such as Okinawa. As nutrient uptake from the soil is very high in plots with Napier grass, if the grass is carried away from the field, large amounts of nutrients are lost from the soil. But if the grass is returned to the field as a mulch, nutrients are taken up through the crop to the surface soil from below the deep soil.

Table 3 Effect of Napier grass and various crops on succeeding crops

Treatments	Preceding crops	I. Italian ryegrass 1977.11 Yield (ton/ha)	I. Italian ryegrass 1978.4 Index (No.)	II. Sorghum 1978.4 Yield (ton/ha)	II. Sorghum 10 Index (No.)	III. Broad bean 1978.10 Yield (ton/ha)	III. Broad bean 1979.3 Index (No.)	IV. Sorghum 1979.4 Yield (ton/ha)	IV. Sorghum 10 Index (No.)
No Treatment	Various crops	2.01	100	0.72	100	–	–	–	–
	Napier grass	2.77	138	0.31	43	–	–	–	–
Coral sand	Various crops	5.55	100	6.32	100	0.50	100	5.49	100
	Napier grass	7.21	130	8.21	130	1.26	252	8.73	159
Coral sand + Manure	Various crops	5.67	100	8.37	100	1.01	100	7.54	100
	Napier grass	7.82	138	8.26	99	1.05	104	8.56	114

Remark: I – IV indicate 1st, 2nd, 3rd and 4th crop respectively
Field soil: Yellow soils

Soil improvement and sugar cane

Effects of soil improvement in continuous and rotational cropping of sugar cane are shown in Table 4.

As shown in Table 4, continuous cropping of sugar cane is worse than rotational cropping. Actually no yield was obtained in the plots which had not been improved, but there was a low yield in the improved plots with continuous cropping. On the other hand, sugar cane yielded normally in the rotational cropping group and additional effect of improvement was conspicuous too. This difference in yield was caused by the decrease in the number of tillers due to soil infestation by pests after ratooning. Nevertheless, rotational cropping and application of improvement materials could offset the loss of tillers caused by harmful feeding. It was assumed that the change of environment for the soil pests by rotation is necessary for the control of the pests.

Soil improvement and pineapple

Effect of continuous and rotational cropping, and application of improvement materials to pineapple is shown in Table 5. In both continuous and rotational croppings, production in new planting was higher than production in ratooning, and rotational cropping was better than continuous cropping in both the number and amount of fruits. And the difference between continuous and rotational cropping was found to be larger in ratooning than in new planting. Thus, high production in rotational cropping was achieved by the effect of Napier grass on the preceding crop. Although the effect of improvement appeared in each test group, the effects were different in new planting and ratooning. The reason for the discrepancy is not clear. The weight of pineapple fruit was highest in the plot with application of organic matter combined with inorganic materials (except new planting in rotational cropping) followed by the plot with application of inorganic matter, and lowest in the plot without application of improvement materials. It thus appears that the weight of a pineapple fruit increases in proportion to the amount of improvement materials added.

Table 4 Effect of amendments on continuous and rotation cropping of sugar cane

Group Treatment	Yield of sugar cane (ton/ha)	
	Continuous	Rotation
Control	1.3 (pH 4.8)	61.0 (pH 4.7)
Inorganic matter	23.1 (pH 7.3)	75.5 (pH 7.4)
Organic matter with inorganic matter	34.3 (pH 7.7)	95.8 (pH 7.4)

Remarks: Harvested Mar. 1979
Inorganic matter: fused magnesium phosphate 1 ton/ha, calcium silicate 1 ton/ha, coral sand 40 ton/ha
Organic matter: Napier grass chopped 50 ton/ha

Table 5 Effect of amendments on continuous and rotation cropping of pineapple

Treatments	Item		Continuous		Rotation	
			Initial crop	Ratoon crop	Initial crop	Ratoon crop
No amendment	Number	per ha	36,270 (100)	7,200 (100)	38,600 (106)	11,870 (165)
	Weight	(ton/ha)	40.81 (100)	8.67 (100)	56.84 (139)	13.27 (153)
	Wt/fruit	(kg)	1.13	1.20	1.47	1.12
Inorganic matter	Number	per ha	36,600 (100)	10,130 (100)	39,270 (107)	13,600 (134)
	Weight	(ton/ha)	48.35 (100)	13.72 (100)	58.01 (120)	16.66 (121)
	Wt/fruit	(kg)	1.32	1.35	1.48	1.23
Organic matter with inorganic matter	Number	per ha	36,930 (100)	7,470 (100)	37,800 (102)	17,730 (237)
	Weight	(ton/ha)	53.18 (100)	10.59 (100)	55.05 (104)	23.92 (226)
	Wt/fruit	(kg)	1.44	1.42	1.46	1.35

Remarks: Harvested Jul. – Sep. 1980
Planted Sep. 1977 (ratooning) and Sep. 1978
Preceding crop in rotation was Napier grass for 3 – 4 years.
Yield of pineapple refers to summer fruit only

Cropping systems and soil chemical properties

Changes in chemical properties of soil during a period of 5 years under various cropping systems are shown in Table 6.

The pH value of the soil in plots without improvement fell below 5 but pH values in improved plots exceeded 7 (except for pineapple) even in a plot where liming had been done 2.5 years ago. The total carbon content of the soil was high in the plots with application of organic matter combined with inorganic materials, naturally, but in the plots with application of inorganic materials the value was lower than that in the plots without application. Among the systems, miscellaneous short-term crops for which the number of plowings were relatively higher had a low total carbon content in the soil and the soils under sugar cane or grass were high in total carbon

Table 6 Changes in chemical properties of soil affected by various cropping systems and soil amendment materials

Group	Amendment	pH (H_2O)	T-C (%)	T-N (%)	C/N	CEC (meq)	Exch-base (meq)					Base sat. deg.	Equ. ratio (per 100g dry soil)	
							Ca	Mg	K	Na	Sum		Ca/Mg	Mg/K
Sugar cane continuous	No amendment	4.7	0.79	0.060	13.2	5.2	0.56	0.23	0.15	0.05	0.99	19	2.43	3.73
	Inorg. matter	7.8	0.73	0.056	13.0	6.6	11.94	1.48	0.26	0.09	13.77	209	7.70	5.69
	Org. + inorg. matter	7.7	0.81	0.064	12.7	6.6	12.75	1.65	0.27	0.08	14.75	223	7.73	6.11
Sugar cane rotation	No amendment	4.5	0.73	0.063	11.6	5.0	0.44	0.23	0.21	0.05	0.93	19	1.91	1.09
	Inorg. matter	7.7	0.63	0.052	12.1	5.4	8.25	1.24	0.19	0.09	9.77	181	6.65	6.53
	Org. + inorg. matter	7.6	0.77	0.065	11.8	6.6	9.44	1.48	0.37	0.10	11.39	173	6.38	4.00
Miscell-aneous crops	No amendment	4.7	0.59	0.056	10.5	4.2	0.31	0.16	0.11	0.05	0.63	15	1.94	1.45
	Inorg. matter	7.2	0.57	0.054	10.5	5.3	7.00	1.09	0.12	0.08	8.29	156	6.42	9.08
	Org. + inorg. matter	7.7	0.74	0.068	10.9	5.8	11.00	1.54	0.24	0.09	12.87	222	7.14	6.42
Napier grass rotation	No amendment	4.5	0.68	0.053	12.8	4.0	0.04	0.14	0.07	0.04	0.29	7	0.29	2.00
	Inorg. matter	7.6	0.63	0.062	10.2	4.9	7.44	1.07	0.15	0.09	8.75	179	6.95	7.13
	Org. + inorg. matter	7.6	0.85	0.076	11.2	6.4	10.56	1.42	0.16	0.11	12.25	191	7.44	8.88
Napier grass continuous	No amendment	4.3	0.77	0.051	15.1	4.3	0.25	0.16	0.05	0.04	0.50	12	1.56	3.20
	Inorg. matter	7.5	0.74	0.051	14.5	5.2	7.19	0.89	0.06	0.07	8.21	158	8.08	14.83
	Org. + inorg. matter	7.5	0.93	0.074	12.6	6.4	8.56	1.24	0.16	0.08	10.04	157	6.90	7.75
Pineapple rotation	No amendment	4.3	0.80	0.064	12.5	4.6	0.38	0.22	0.06	0.05	0.71	15	1.73	3.67
	Inorg. matter	5.0	0.68	0.055	12.4	4.4	0.63	0.60	0.14	0.06	1.43	33	1.05	4.29
	Org. + inorg. matter	5.0	0.76	0.062	12.3	5.9	1.13	0.84	0.25	0.07	2.29	39	1.34	3.36
Pineapple continuous	No amendment	4.5	0.68	0.054	12.6	5.4	0.38	0.29	0.08	0.05	0.80	15	1.31	3.63
	Inorg. matter	5.0	0.71	0.053	13.4	4.9	0.69	0.78	0.17	0.06	1.70	35	0.88	4.59
	Org. + inorg. matter	6.0	0.72	0.063	11.4	5.9	2.31	1.42	0.53	0.07	4.33	73	1.63	2.68

Remarks: Soil sampling: 4 areas per plot
Value in the table is mean of values in each area
Depth of plowing (0 – 25 cm)
Date of sampling: May 1980
Improvement application date: August 1977 – May 1978
Amount of inorganic matter applied
- Sugar cane group: fused phosphate 1 ton/ha, calcium silicate 1 ton/ha, coral sand 40 ton/ha
- Pineapple group: calcium silicate 2 ton/ha
- Other groups: coral sand 40 ton/ha

Amount of organic matter applied
- Sugar cane group: Napier grass chopped 50 ton/ha
- Pineapple group: manure 20 ton/ha and mulch 20 ton/ha
- Other groups: manure derived from Napier grass 40 ton/ha

Soil in the field belongs to Yellow soils (Toeinishi series) which received alluvial material from adjoining areas at higher altitude.

contents. CEC was high in the plots with organic matter combined with inorganic materials too, but the values did not always parallel total carbon content of the soil. Total nitrogen content of the soil failed to show a definite trend except that it was high when organic matter was applied in combination with inorganic materials. The C/N ratio was high in the group of Napier grass, and low in the group of miscellaneous short-term crops. Exchangeable Ca and Mg contents of the soil were highest in the plots where organic matter had been applied along with inorganic materials, followed by the plots with application of inorganic materials, and lowest in the plots without application. Among the soil groups, the sugar cane soils had high values of exchangeable Ca and Mg whereas low values were recorded in the group with Napier grass. Potassium content was high in the plots where organic matter had been applied as well as in the group with Napier grass. The high potassium content in the former was derived from manure of Napier grass, and that in the latter derived from large amounts of potassium absorbed by Napier grass. No consistent changes in Na content of the soil were detected. Base saturation degree showed 100% in plots with improvement except in the pineapple plots, and pineapple soil showed low base saturation degree due to the acidic condition required for the cultivation of choice pineapple. Ca/Mg (ratio of equivalent) was above 6 in the plots with improvement except for the group with pineapple, and it tended to show excessive values. Mg/K unbalance was observed in the plots without improvement within the Napier grass group.

As a result, it is suggested that the adjustment of soil reaction including the application of organic matter is necessary to keep soil in suitable cation balance, and sugar cane and Napier grass can contribute to the enrichment of soil in organic matter.

Effect of legumes on soil fertility

An experiment to analyse the effect of *Leucaena leucocephala* on the productivity of *Imperata cylindrica* grassland was carried out. A stock of the legume had been planted to each plot of *Imperata cylindrica* grassland measuring 6 x 5.5 m, since 1974.

The results are shown in Fig. 1. The grassland with the legume yielded twice as much as the control (*Imperata cylindrica* grassland) and the quantity of nitrogen absorbed increased threefold in comparison with that of the control, with an estimated nitrogen transformation of about 90 kg N/ha/year. The result indicates that it would be advantageous to utilize legumes to develop fertile grassland.

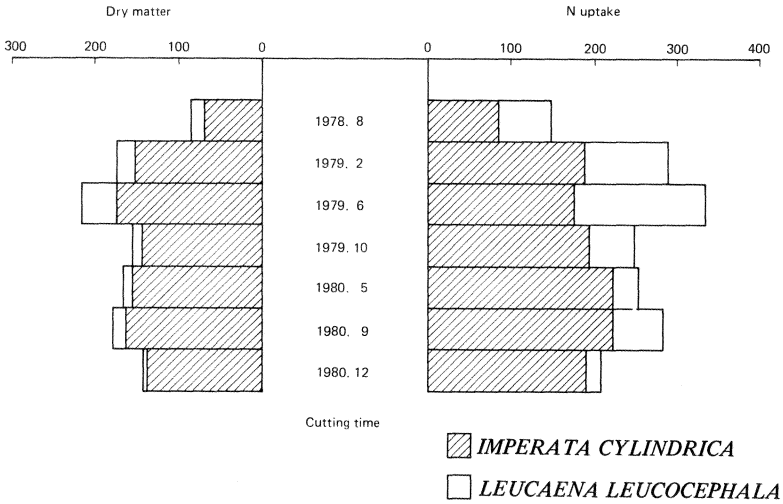

Fig. 1 **Effect of *Leucaena leucocephala* on *Imperata cylindrica* grassland.**
*** Index with the control as 100**

Utilization of coral sand

When mineral soil is to be ameliorated by liming, there is a possibility of overliming because of the small buffer action of the soil. Then coarse coral sand which is harmless even if applied in large amounts would be suitable.

On the other hand, it is difficult to obtain commercial amendments for neutralizing soil acidity in a remote island, because the transportation cost is high.

Coral sand can be found in the tropical and subtropical zone of the Pacific Ocean. The distribution of particle size in coral sand varies with the area dredged up. Half of the particles are usually less than 2 mm in diameter, and the average size of a particle is 0.5 – 1 mm, with very few being less than 0.1 mm. The coral sand tested here included particles of more than 2 mm in size which remain in the original form of coral and shell as well as their mixing material. As coral sand is highly porous on the surface, it is considered that neutralization of soil acidity with fine particles, is rapid but coarse particles may have a slow effect on soil acidity. Thus coral sand with particles of various sizes should be used to induce different responses to soil acidity. In order to increase the duration of the effect, material high in the coarser fraction should be used. Seven days after application of particles of coral sand less than 0.5 mm in diameter, the soil pH rose about ½ unit compared with the effect obtained with commercial lime, but after 100 days, the increase exceeded ½ unit. (Fig. 2) Thus, coral sand is slowly neutralizing soil acidity with a longer residual effect than commercial lime. Then, in mineral soils in which the buffer action is low, large amounts should be applied as basic materials for soil improvement. It was suggested that where the soil is apt to deteriorate due to difficulty of management, after grassland is established, soil acidification and decrease of lime in soil could be avoided through the application of large amounts of coarse particles of coral sand when the grassland is already established.

Coral sand, being soluble in N/2 HCl or acetic acid, is a carbonate containing about 50% of CaO and 1 – 3% of MgO, several minor elements and 0.5 – 1% of SrO, as presented in Table 7. Chemical composition of coral sand is very similar to that of commercial liming materials, except for the strontium content which is higher than that of the commercial ones. In the sea where the temperature of the water is higher, Mg contents are high because of abundant remains of foraminifera. Therefore, it has been observed that the Ca/Mg equivalent ratio is lower in high temperature areas. The difference of contents among various particle sizes is small, and Ca/Mg equivalent ratio ranges between 10 to 20. A large amount of silica sand derived from the land is contained in the fine particles of sand in the neighboring coast where the rivers flow into the seas.

As coral sand is coarse and reacts slowly, usually, large amounts can be applied at a time. Fertilization with coral sand was effective in increasing the yield of Napier grass, Rhodes grass, sugar cane, sorghum, barley, groundnut and swiss chard. The persistence of its effect was longer than that of commercial lime. The effect of coral sand on Rhodes grass and swiss chard is shown in Table 8.

The yield of Rhodes grass and swiss chard in the plots to which coral sand was applied increased more than in the control plot as a result of the application of commercial lime for neutralizing soil acidity and supply of calcium nutrients.

Determination of pH and base saturation degree of soils from the Rhodes grass field used in the liming experiment was carried out and the results are shown in Fig. 3. Under Rhodes grass to which a sufficient amount of fertilizers had been applied, the pH of the plow layer (0 – 15 cm) which was adjusted to pH 6.5 with liming returned to the initial value of 4.9 within eleven cuttings during 1.5 years. Difference in base saturation degree betwen the values in 1978 and 1980, 1.5 and 3.5 years after liming respectively, indicated that the large amounts of calcium applied in the plow layer had moved down to the deeper layers.

Table 7 Ca, Mg contents of coral sand depending on kinds and locality

Item		CaO (%)	MgO (%)	Ca/Mg (meq ratio)
Coral sand location	Okinawa island	51.4	1.93	19
	Miyako island	49.1	2.24	16
	Ishigaki island	51.0	2.52	15
	Yonaguni island	47.7	3.45	10
Kinds of coral sand*	Branched coral	55.4	0.124	320
	Blocky coral	55.4	0.165	240
	Shell	54.8	0.070	560
	Foraminifera	47.5	5.10	6.7

Remark: * The majority consisted of branched and blocky coral.

Table 8 Effect of liming materials on crop yield

Treatment	Yield of Rhodes grass (dry matter) 1st – 2nd year		3rd year		4th year		Yield of swiss chard (fresh matter) 1st year	
	Harvested 9 times		Harvested 6 times		Harvested 6 times		Harvested 3 times	
	ton/ha	Index	ton/ha	Index	ton/ha	Index	ton/ha	Index
No lime (pH 4.9)	38.6	100	27.4	100	12.0	100	24.0	100
Lime 7.7 ton/ha (pH 6.5)	36.8	95	28.8	105	18.5	154	45.5	190
Lime 60 ton/ha (pH 7.5)	40.4	105	34.5	126	27.6	230	51.0	213
Coral sand 45.5 ton/ha (pH 6.5)	42.4	110	31.1	114	25.8	215	64.1	267

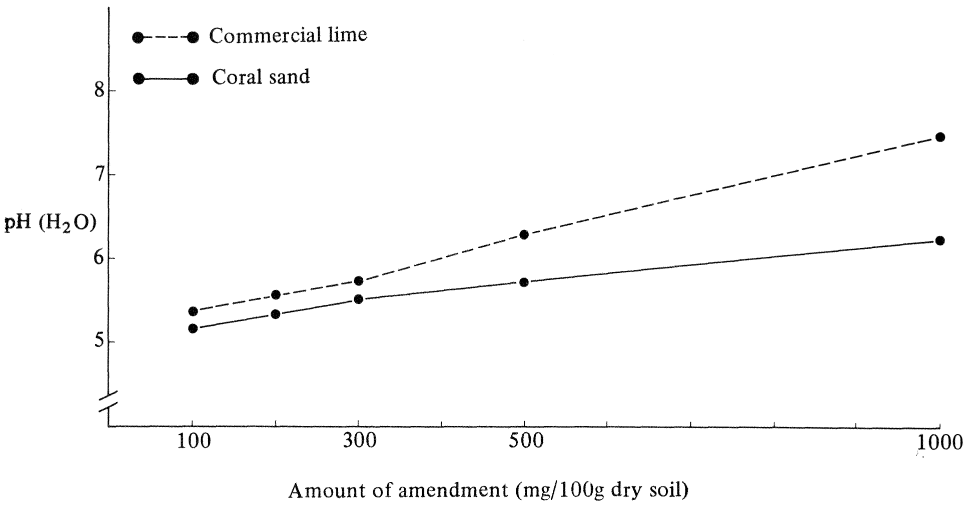

Fig. 2 Effect of the amount of amendments on soil pH.

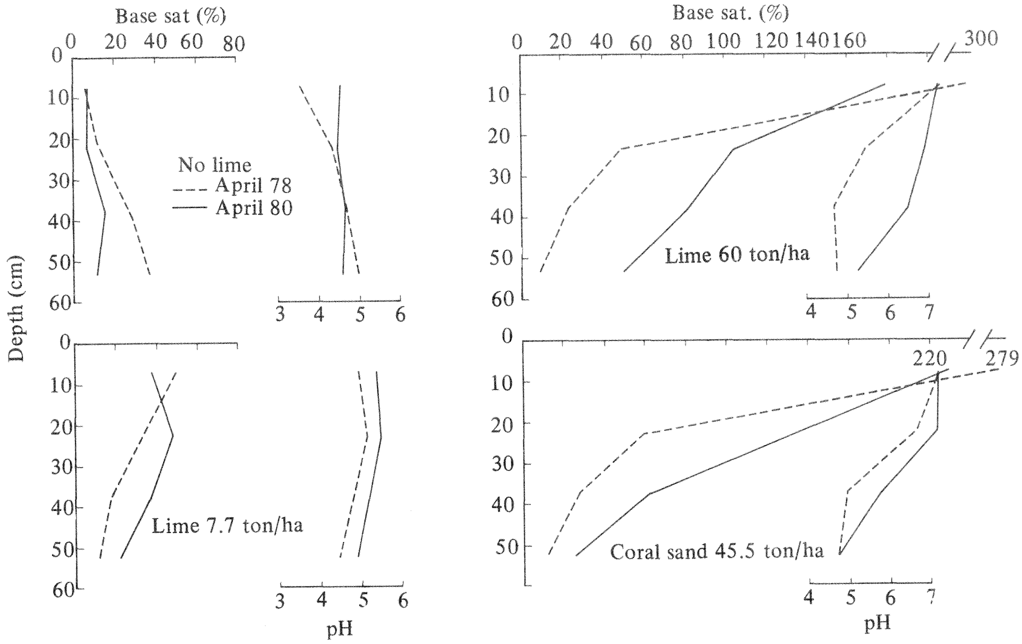

Fig. 3 Base saturation and soil pH (H_2O) in April 1978 and April 1980.

Reference

HAKOISHI T., IWASAKI, S. and TSUKIDATE, T. (1976): Soil productivity maintenance and cropping system on upland farms of the humid subtropics *JARQ* **10 (4)**, 212-214.

Discussion

Watanabe, I (IRRI): How much land is needed to grow Napier grass so as to achieve a production of organic matter enabling to increase crop production?

Answer: Napier grass, which gives a good response to fertilization, produces about 30 ton/ha of dry matter (about 200 ton/ha of fresh weight) in four cuttings each year under proper fertilization. The higher the temperature, the higher the dry matter production (production usually decreases from December to March when mean temperature is less than 20°C). Application rate of 50 ton/ha of fresh Napier grass is equivalent to the amount produced in ¼ha.