Soil productivity maintenance and cropping system on upland farms of the humid subtropics

Soils of the humid tropics and subtropics are, under the natural condition, covered by evergreen broad-leaf forests which protect the soil against strong solar radiation and direct raindrop impact, and establish abundant litters on soil surface, making the soil surface layer rich in organic matter and plant nutrients. Removal of the vegetation and physical stirring of soils associated with the introduction of crop cultivation inevitably cause a rapid decomposition of organic matter, deterioration of soil structure, serious erosion hazard as well as leaching of plant nutrients, resulting in a rapid exhaustion of soil fertility.

The present study was carried out at the Okinawa Branch Station of Tropical Agriculture Research Center, located in the Ishigaki Island, Okinawa Prefecture, to find out the possible means to improve soil productivity of upland farms by examining the actual state of soil productivity of existing farmland, wild grassland, and forest land, and further to establish a rational cropping system by utilizing crops and materials feasible or available in the isolated island. As a matter of fact, upland farms in the area, where the station was founded in 1970, had been extremely deteriorated due to poor management practices. Therefore it was felt that any field experiment might not properly be carried out unless improving the soil conditions.

State of soil productivity: Table 1 gives yields of upland rice grown in a pot experiment using different soils sampled from the neighboring area of the Station. It is clearly shown that (1) forest soil is highly productive, (2) soil fertility has recovered considerably even in a poor grassland of *Imperata cylindrica* during a period of 10 years after the cultivation was abandoned, (3) incorporation of napier grass as a green manure is fairly effective in increasing soil fertility, (4) mulching of large amount of napier grass gives a remarkable effect; the mulching practiced for only one year gives the yield equal to that obtained from the forest soil, and (5) a serious damage by continued cropping of upland rice occurs with the farm soil, whereas no such damage occurs with the soil of *Imperata* grassland and the farm soil incorporated with napier grass.

The fact that the soil fertility restored in the *Imperate* grassland, though it is poor with 0.69 kg of top dry weight/m^2, can be explained by the combined effect of the followings: plant cover over the soil protecting against direct solar radiation and raindrop impact, enrichment of soil by plant residues, recovery of soil structure by dense root systems of the grass (0.31 kg of root dry weight/m^2), as welll

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

Cropping	Soils from	Fertilizer treatment	1974 Yield	1974 Index	1975 Yield	1975 Index	Remarks
Countinuous	Farmland	NPK	26.0	100	3.5	9	More than 20 years after reclamation
		−N	3.4	13	2.8	7	
	Imperata grassland	NPK	33.8	130	44.5	115	10 years after a farmland was abandoned
		−N	9.1	35	11.6	30	
	Napier grass incorporated	NPK	39.4	152	40.8	106	Incorporated at a rate of 4 tons/10a in fresh weight
Not continuous	Farmland	NPK	—	—	38.6	100	
	Forest land	NPK	—	—	70.4	182	Relatively old secondary stand
		−N	—	—	62.7	162	
	Napier grass mulched	NPK	—	—	72.6	188	Vegetable was grown with heavy mulching of napier grass in 1974

as no removal of plant nutrients by crop harvest and no disturbance of soil during the fallow vegetatoin period.

A method to restore soil fertility: If the *Imperata* grassland is regarded as a type of the fallow, perennial forage crops can be used as a substitute for it, because their effect is of a similar manner as the *Imperata* grassland. By using adequate forage crops with higher fertilizer response, a greater effect than that of natural grassland can be achieved, or the same effect can be attained within a much shorter period. In this case, removal of chemical nutrients by crop harvest taken out of the field can mostly be compensated by chemical fertilizers.

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

Fertilizer response and seasonal production of napier grass: The most popular forage crop for cutting use in this area is napier grass (*Pennisetum purpureum*). Yields of the grass grown with three fertilizer element (NPK) and without each of them (−N, −P, and −K) were studied during a period from May 1973 to November, 1974. In 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% in an average, respectively, without showing a decline in the later cutting. The total dry weight yield of the NPK plot was 48 t/ha.

In a pot experiment, however, yields declined in the later cuttings in −P and −K plots, showing 52 and 12% respectively at the fourth cutting (176 days after planted), because of a limited volume of soil used. These results indicate that if the top of the grass growing in fields is returned directly or indirectly to the soil, the surface layer will be enriched with these elements absorbed by deep roots.

Monthly production of napier grass during a period from March 1973 to April 1975 was examined in relation to monthly mean temperature.

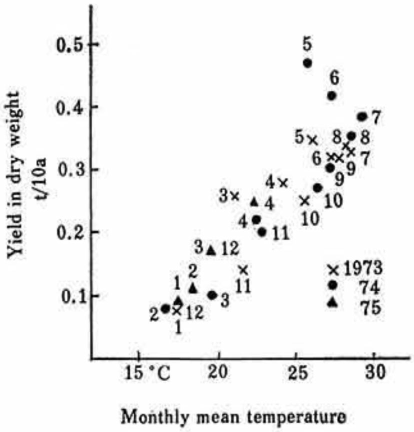


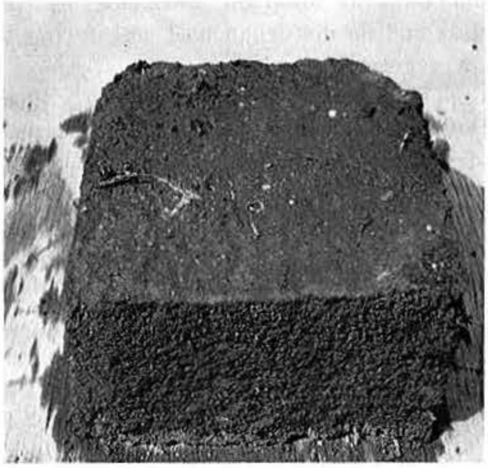
Fig. 1. Monthly production of napier grass as correlated to montly mean air-temperature

As given in Fig. 1, monthly production is almost linearly correlated to monthly mean temperature, indicating the possibility to utilize surplus production in the summer season as mulch or green manure.

Effectiveness of napier grass mulch: Decomposition of fresh organic matter on the soil surface is extremely fast under subtropical and tropical conditions. When napier grass of 50 day old (with basal part of stems slightly hardened and leaf/stem ratio of 1 : 2) was applied as mulch, only 49% of stems and 17% of leaves remained at 56 days after the application. It implies the nutrient supply to the soil. For maintaining physical effect of the mulch on soil moisture, soil temperature and for erosion control, 20–30 tons of fresh weight per ha are required a year. Therefore older plants should also be used partly.

Remarkable effect of the napier grass mulch is given below as an example. In percentage to the fruit yield of papaya of the fertilized plot, the unfertilized plot yielded 49%, but the fertilized and mulched plot yielded 134%, and the mulching alone without fertilizer gave 102%. Plate 1 shows a surface layer profile of the soil kept under the mulch. Apparently the soil has an improved structure and accumulated organic matter in contrast to the soil without mulch. Interesting is that a large

Kept under mulch



Left bare without mulch

Plate 1. Surface layer profile of the soils with or without napier grass mulch

population of worms and other small animals is observed on the soil surface beneath the mulch, suggesting of the promoted microbial activities too.

Conclusion: Napier grass mulch was found extremely effective in restoring soil productivity, in protecting soil against direct solar radiation and raindrop impact, and in controlling soil erosion. In the tropics and subtropics, forest has such an important role. Effective substitute for the forest should be found out in developing permanent agriculture in these regions. The present paper proposes the rotation system based on perennial forage crops, in this case napier grass, and the utilization of forage crops as mulch or green manure for that purpose.

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Difference in the distribution of *Cercospora* between Brazil and Japan

Cercospora is a genus name of fungus, well known as pathogens for many kinds of crops. Fungus *Cercospora* is host-specific or host-genus-specific, and is widely distributed all over the world. Especially, it is abundant in tropical and subtropical zones.

In Brazil, P. Hennings, E. Rangel, A. Maublanc, etc. reported new species of *Cercospora* in the early 20th century. This seems to be the beginning of study on *Cercospora* in Brazil. In 1934 and 1936, C. Chupp and A. S. Muller reported on the genus, describing 123 species collected in Brazil[6,7]. In 1945, A. P. Viégas published "Alguns Fungos do Brasil—*Cercosporae*" as one of the series of his taxonomic work[8]. He described 102 species of the genus including 28 new species with precise illustrations.

Cercosporae in Japan have been thoroughly studied by S. Katsuki on almost all the specimens collected in Japan[2,3,4,5], and a monograph of Japanese *Cercosporae* was published in 1965[2].

In the United States, C. Chupp published "A monograph of the Fungus genus *Cercospora*" in 1953, by compiling all *Cercosporae* reported in the world, and making synonyms clear by checking almost all type specimens[1]. According to his classification, 1,419 species were confirmed. After that, many new species were identified year after year.

The writers summarized *Cercosporae* already reported in Brazil, and also identified some new *Cercosporae* collected by them in Brazil for the period of 2 years from February 1974 to March 1976. The present preliminary report deals with the difference in *Cercospora* distribution between Brazil and Japan. Brazilian *Cercosporae* are summarized in Table 1 in comparison with those in Japan, one of the farthest countries from Brazil. The table indicates that 261 species are distributed in Brazil, and 235 speices in Japan. Among them, only 73 speices are common in both countries.

Table 1. Number of *Cercospora* species distributed in Brazil and Japan

Host family	Distributed in		
	Brazil	both Brazil and Japan	Japan
Compositae	16	7	17
Euphorbiaceae	18	3	9
Gramineae	8	6	8
Leguminosae	31	6	19
Malvaceae	12	5	5
Rosaceae	9	6	11
Solanaceae	12	5	10
Other 24 families	63	35	62
Labiatae	5	0	3
Moraceae	4	0	6
Other 17 families	32	0	30
Bignoniaceae	7	0	0
Juglandaceae	3	0	0
Other 28 families	41	0	0
Caprifoliaceae	0	0	5
Vitaceae	0	0	3
Other 32 families	0	0	47
Total 114 families	261	73	235

Crops have been introduced to each country directly or through other countries. Probably, diseases might be spread together with introduced crops. For example, *Xanthomonas citri* on orange was carried to Brazil by seedlings. In Table 2, *Cercospora* species on main crops common to both countries are summarized. In this Table, 38 species are found common to both countries. This number, is more than half of 73, which is the number of species common to both countries as mentioned above. These species are considered to be introduced together with crops, by seedlings, seeds, etc. Most of these species are common not only in Brazil and Japan, but also in most of the world, such as *C. oryzae* on rice, *C. kikuchii* on soybean, *C. canescens* and *C. cruenta* on bean and cowpea, *C. arachidicola* and *C. personata* on peanut, *C. citrullina* on

Table 2. Distribution of *Cercospora* species on main crops common to both Brazil and Japan

Crops	Distributed in		
	Brazil	both Brazil and Japan	Japan
Rice	1	1	1
Corn and sorghum	2	1	2
Italian millet	1	1	1
Potato	1	0	1
Sweet potato	3	2	2
Chinese yam	4	3	5
Soybean	1	1	2
Bean and cowpea	4	2	2
Peanut	2	2	2
Tomato	0	0	1
Eggplant	1	0	2
Pepper	2	1	1
Watermelon	1	1	1
Brassica spp.	1	1	1
Radish	1	0	0
Nasturtium	1	1	1
Asparagus	1	1	1
Burdock	0	0	1
Lettuce	1	1	1
Carrot	1	1	1
Celery	1	1	1
Parsley	1	0	0
Beet and spinach	1	1	1
New Zealand spinach	1	1	1
Okra	3	2	2
Orange	1	1	1
Persimmon	1	1	2
Apple and pear	1	0	0
Quince	1	1	1
Peach	2	2	2
Loquat	0	0	1
Raspberry	1	1	1
Fig	0	0	2
Pomegranate	1	1	1
Chestnut	1	0	0
Tobacco	1	1	1
Mulberry	2	0	1
Tea	1	1	2
Sugarcane	2	2	3
Sesame	1	1	1
Peppermint	1	0	0
Castor bean	1	1	1
Total	54	38	54

watermelon, *C. asparagi* on asparagus, *C. apii* on celery, *C. beticola* on beet and spinach, *C. nicotianae* on tobacco, *C. koepkei* and *C. vaginae* on sugarcane, *C. sesami* on sesame, *C. ricinella* on castor bean, etc.

However, even on crops common to both countries, some *Cercospora* species which are specific to each country could be found. These were *C. zeae-maidis* in Brazil (hereafter referred to B) on corn, *C. concors* in Japan (referred to J) and *C. solanicola* (B) on potato, *C. cordobensis* (B) on sweet potato, *C. carbonacea* (B), *C. contraria* (J) and *C. hiratsukana* (J) on chinese yam, *C. caracallae* (B) and *C. vanderysti* (B) on bean, *C. fuligena* (J) on tomato, *C. deightonii* (J), *C. solani-melongenae* (J) and *C. melongenae* (B) on eggplant, *C. unamunoi* (B) on pepper, *C. cruciferarum* (B) on radish, *C. hibicina* (B) on okra, *C. kakivora* (J) on persimmon, *C. mali* (B) on apple and pear, *C. bolleana* (J) and *C. fici* (J) on fig. *C. castaneae* (B) on chestnut, *C. mori* (J), *C. moricola* (B) and *C. morina* (B) on mulberry, *C. chaae* (J) on tea, *C. taiwanensis* (J) on sugarcane, *C. menthicola* (B) on peppermint, etc.

Besides the crops mentioned in Table 2, there are still more plants common in both countries, and *Cercospora* species specific to each country were found on them, such as *C. calendulae* (B) on pot marigold, *C. gerberae* (B) on Transvaal daisy, *C. wistariae* (B) on wistaria, *C. populina* (J), *C. salicina* (B) and *C. salicis* (B) on willow, etc.

In view of the different host plant distribution, it is natural that different *Cercospora* species were found on host plants not common to both countries, because the fungus is host-specific. However, regarding the fungus species on host plants common to both countries, it can be said that 1) in spite of the existence of many common host plants, only a limited number of the fungus species are common to both countries, 2) most of these common fungus species seems to be associated with the transportation of plants, and 3) even on the common plants there are many species specific to each country.

Thus, the results obtained indicate that microflora of *Cercospora* in Brazil is, perhaps, originally different from that in Japan, and the species common to both countries might be introduced by the transportation of plants.

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