REPORT
ON
A TECHNICAL COOPERATION PLAN IN BRAZIL
BASED ON
THE CENTRAL AND SOUTH AMERICA TECHNICAL COOPERATION PLAN

I. Experiment on Mulching Cultivation of Pepper Plant

II. Experiment on Improvement of Agricultural Development System

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A TECHNICAL COOPERATION IN BRAZIL

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I. Experiment on Mulching Cultivation of Pepper Plant

II. Experiment on Improvement of Agricultural Development System

At: Instituto de Pesquisas e Experimentacão Agropecuarias do Norte (IPEAN), Belém, Brazil.

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INTRODUCTION

The author, based on the Central and South America Technical Cooperation Plan, was despatched to Brazil and assigned to the Instituto de Pesquisas e Experimentacão Agropecuarias do Norte (IPEAN) in Belem on two occasions by the Japan International Cooperation Agency as an export on plant husbandry. The first assignment was between 1965 and 1968 while the second was between 1973 and 1976. The outcome of research works conducted during the said period is as reported below classified into the above-mentioned two subjects.

Firstly, a brief explanation will be given on the meteorological condition in the Amazonia Region with special emphasis on Belem, the duty post of the author. The city of Belem stands at the mouth of Amazon River in approximately Lat. 1° S. It is so blessed with light and heat that the luminous intensity amounts to more or less 70,000 luxes in fair weather. As shown in Table 1, the mean maximum temperature stands at 32°C with the mean minimum temperature at 22°C, while the temperature remains high throughout the year without much variation by month. The same thing can be said of the entire Amazonia Region. The annual amount of precipitation is approximately 3,000 mm and the mean monthly amount of precipitation in the six-month rainy season from December to May stands at 350 mm with the monthly maximum of about 500 mm. The monthly average in the six-month dry season is 130 mm with the monthly minimum of about 100 mm. Even during this dry season, rain falls every five to six days and the fact that the aridity stays low in the dry season characterizes Belem and its environs. The western part of Amazonia Region is similar in its rainfall pattern. These two areas are under what is also called the tropical rain forest climate, and the Belem region forms a large pepper-growing area. In the central part of Amazonia Region the amount of precipitation in the rainy season is slightly less than that in Belem, and moreover is quite limited particularly in the dry season so that sometimes there is no rainfall for nearly one month and leaves of wild herbs wither and turn into brown. Nevertheless forests grow without hindrance. Being under the monsoon climate and also what is called the tropical forest climate with its dry season, this part of the Region includes the pepper growing Manaus area as well as Tome-Acų District. Contained respectively to the north and to the south of this central Region small areas where the amount of precipitation in the rainy season is relatively small and the aridity in the dry season is extremely high. These small areas form a shrub-grassland and are also called the tropical savanna where soils are hard and plants of drought resisting shape are found.

From an ecological point of view, some of the meteorological characteristics of the entire Amazonia Region are as follows. Under the influence of abundant light and heat the soil temperature of upland fields is high and the aridity is considerable in the dry season. The record for strong rainfalls in a short period of time during the rainy season is that of 20 mm for 10 minutes and of 29 mm for 30 minutes. Rain drops beat the soil surface strongly and soils become compact. Thus, the amount of soil porosity decreases and also the excessive moisture in the soil remains. On the other hand, water flows out over the soil surface causing the runoff of clay or organic matter accelerating the transformation into sandy soil. This occurs more rapidly when the soil is plowed. It is possible to state that the meteorological condition in the Amazonia Region is severe.

The Amazonia Region can be classified geologically into three; the tertiary huge plain containing most of the main stream and tributary area, the lightly rolling area of mesozoic age strata as well as of paleozoic age strata which lies on both north and south sides of the forementioned huge plain and the alluvial area of guartenary age which develops along the river bank of the middle and lower reaches.

On the tertiary plain Latosol Soils with the parent material of acidic rock develop, and the silicic acid which holds a dominant position in the rock composition dissolves, leaving iron and alumina. The content of soluble base and phosphoric acid is not much, and the clay is of the kaolin group and base absorption capacity is weak. Also organic matter is scarce and the acidity is relatively high. Soils with high base content such as the Terraroxa are distributed in the mesozoic age strata. In the case of alluvial soil, it is affected by the inundation caused by the flooding in the rainy season in the middle reaches and by the high tide in spring or autumn in the lower reaches respectively, but the soil is fertile. IPEAN classified the productivity of these soils by each geological age and expressed it in terms of crop production (Table 2). Accordingly, it is known that the soil of quartenary alluvium is the most productive and the production decrease in second cropping is extremely low, followed by the soil of mesezoic. The least productive is the tertiary soil and the production

Table 1 Temperature and Precipitation in Belem (1923 - 1964) (IPEAN)

Item \ Month	1	2	3	4	5	6	7	8	9	10	11	12	Aver-age
Mean Maximum Temperature (°C)	30.9	30.3	30.3	30.6	31.5	32.0	31.9	32.2	32.0	32.2	32.3	31.9	31.5
Mean Minimum Temperature (°C)	22.5	22.5	23.2	22.8	22.7	22.5	22.1	22.0	21.7	21.8	22.0	22.3	22.3
Amount of Precipita-tion (mm)	335	423	455	379	279	170	150	117	124	106	94	206	2837

Table 2 Crop Production by Soils of Different Geological Age (kg/ha)

Crop	Forest land \ Geological age / Cropping	Quartenary		Tertiary		Mesozoic	
		1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop
Rice - Paddy	Virgin Forest	4,000	4,000	1,200	800	3,000	2,000
- do -	Secondary Forest			800	300		
Corn	Vargin Forest	2,500	2,000	500	300		
Mandioca	- do -			20,000		40,000	

decrease in second cropping in this case is the largest.

In the Amazonia Region, the shifting cultivation method is applied to cultivate annual short-term crops.

In other words, forests are burnt down to plant crops. As for the tertiary soil, the rotated cultivation of rice (or corn) and kidney bean (or cowpea) or rice (corn) and mandioca will continue for two or three years, and then productivity will decline too low for profitable management and the cultivators will shift to other forest land. Thus, when the next cropping is resumed on the same cultivated land, it will be after three to four years for the first time and more than 10 years for the second time. It is noticed that as the frequency gains, the number of years during which the land is lay fallow increases.

During this period of abandonment and fallow, the soil fertility is brought up through the growth of trees and grass --- the utilization of their ash as a fertilizer source.

As explained above, the meteorological condition in the Amazonia Region is severe and can not be considered adequate for the growth of crops. Also, the tertiary soil which occupies most of this area is poor in some extent. Yet, the whole Region is densely covered with forests of large trees except in the savanna area. Under abundant light and heat, the forest crown produces organic matter actively, amounting to 100 to 200 t/ha yearly. The forest soil eases the severe meteorological influence by covering the land surface with the crown, and as a result not only the soil environment but also the physicochemical properties of soil are changed suitably and adequately. That is to say, strong rain in the rainy season beats against the crown and is turned into a drizzle. Some rain is adsorbed by the crown while some is evaporated, thus not all the rainfall reaches the soil at once. Accordingly, there is no decrease in the soil porosity to be caused by the direct impact of rain drops and the saturation of soil moisture becomes less following the slackening of the rainfall. No soil erosion is also expected.

In the dry season, though a tremendous amount of transpiration from the large crown is to be estimated since the solar heat will be strong, the soil moisture remains more abundant than expected. In addition, as the soil evaporation is prevented and the soil temperature stays low, the root is highly active. Forests reproduce branches, leaves and roots. At the same time a large amount of decreased organic matter forms humus year by year by the action of decomposition and utilization of numerous soil micro-organism and small animals, improving the soil condition. Also, mineralized organic matter is absorbed as a nutrition source so as to activate the physiological activity of the forests themselves. This nutrition cycle continues quite rapidly all through the year. This is the mechanism of the development of colossal forests.

The cultivation standards for the pepper plant has not yet been established in the Amazonia Region. Moreover, the root rot disease is rampant. In a pepper plantation, since pepper is to be planted at wide intervals, the area of bare land is sizable, and thus the soil is not in a favorable condition, being exposed to the sun and influenced directly by the severe climate. The cultural improvement will be to put a crop in an adequate environment and to grow it under a condition suitable for its ecological property. The reason why the author adopted the grass mulch method preponderantly as the mainstay in the improvement of pepper cultivation because the grass mulch is more or less equivalent to the compressed crown, and the soil condition to be fostered by it is equal to that of the forest soil, and as such, it was confirmed that the pepper plant will grow properly and soundly.

The agricultural development in the Amazonia Region which forms a sea of forest is under way rapidly. As explained above, a forest is an adequate crop in itself which utilizes the natural energy ingeniously. It had become necessary to produce food by clearing the forest maintaining a good equilibrium and stability in its natural condition. However, various cultural obstacles have to be faced when it is cleared. In order to prevent this, it is necessary to cover a cultivated land with pasture just like what the forest crown does. That is, it is recommendable from a management point of view to run a livestock farming with the pasture and to utilize pasture roots as the nutrition source for crops by rotating between pasture and crop field. This method of development seems to improve the land utilization efficiency and also the labor productivity more than the shifting cultivation method. The advantages and the feasibility of this method are as studied hereunder.

I. EXPERIMENT ON MULCHING CULTIVATION OF THE PEPPER PLANT IN AMAZONIA REGION

(I) Study on the Root System of the Pepper Plant

This study was conducted in 1966 to 1967 at Castanhal Pepper Plantation presented by the Mitsui Trading Co., Ltd. for the advancement of sciences.

1. Cultivation method

Supports were put up as high 2.5 m above the ground and at intervals of 2.5 x 2.5 m after having burnt down and cleared a forest. In January to February (the beginning of the rainy season), the dug-up top soil and the wood ash produced at the time of burning together with burnt scraps and so forth were thrown into cubic planting holes 40 x 60 cm, 40 cm deep. And seedling cultivated in a nursery bed were planted on the east side of the support, so as to avoid the afternoon sun. After planting, subsoil was heaped up around the stock and the drainage was prepared. Relatively young secondary branches were applied for stocks with several nodes and 20 to 30 cm long. They were set on the nursery bed, and after about two months the stock from whose upper nodes a few plumules were sprouting and from whose lower nodes adventitious roots were also growing were planted out. (At present, vinyl bags are designed to be used and the stocks of 30 cm branches with 7 nodes are planted, with the top three plumules above the ground set to grow.) Planting was planned to be carried out ordinary between the beginning (the latter part of December) and the middle (the middle of March) of the rainy season, and accordingly, the root system could develop fully before the advent of the aridity of the dry season. As for the fertilizer application, urea and cake fertilizer were applied generally after the planting, and starting from the second year, fertilizer application holes of the same size as planting holes were dug, adjacent to the planting holes. Weeds collected at the time of weeding, chemical fertilizer and cakes mixed with the top soil removed through the digging were filled into those holes, and on top of it the subsoil was heaped up to the part near the root. The beginning and the end of the rainy season were respectively chosen in general for fertilizer application. The fertilizer was applied into holes dug close to the holes for the previous applications so that the holes would surround the plant. After the plant had been completely surrounded by those holes, a shallow circular ditch was dug around the plant for further application. The amount of fertilizer applied per plant as well as the material used varied to a great extent according to each case. Full consideration was given to the drainage, which consisted of having heaped soil up to the part near the root or forming a drainage canal along the interrow space.

2. Natural condition

The meteorological condition is almost identical to that of Belem which has been described previously. The soil is, as shown in Table 3, of clay loam of Latosol and it is rather more argillaceous than the soil around Belem. Topographically, the farm is flat and lacks in natural drainage.

Table 3 Profile and Chemical Properties of Soil at the Mitsui Pepper Farm - Castanhal

Depth by Stratum		pH		Dissolved with 0.05N HCl (mg)			Soil Profile					
cm		H_2O	KCl	CaO	MgO	K_2O	Soil Texture	Humus	Structure	Gravel	Hardness consisting	Plant root
AP	0-6	5.1	4.1	0.019	0.004	0.0014	Siltclay loam	Poor	Fine granular	None	16	medium
A_3	6-16	5.0	4.0	0.009	0.003	0.0014	"	"	granular	None	19	medium
B_1	16-30	4.9	4.2	0.007	0.002	0.0010	"	rare		None	21	medium
B_{22}	30-60	5.1	4.3	0.011	0.002	0.0014	Clay loam	"		None	21	rare
B_{23}	60-	5.3	4.3	0.009	0.003	0.0014	"	"		None	21	rare

Note: Forest clearing --- 1965
Pepper planting --- in 1966

3. Method for study of root system

The plant-top was cut down at the root on the soil surface, and strings were stretched at right angles into four directions from the root center. Also strings were stretched at right angles from points 1 m and 1.5 m from the center respectively, and were maintained horizontally, thus marking out rectangular blocks around the center, as shown in Fig. 1. The part above the soil surface was classified as the upper stratum due to the mounding. As for the part below the surface, each block was dug and broken one by one to the depth of every 10 cm, using the Enxada and the transplanting spade. When the root appeared, a mark was placed at the depth of every 10 cm without cutting it off and the position was recorded. At the same time, the soil profile was checked and then the survey proceeded to the lower stratum. Finally, the distribution of the root system became apparent and at the same time the root was cut off at a marked point so as to classify the volume of root of each stratum and of each block and to measure the weight by each block after washing and drying.

4. Result of survey and discussion

(1) Nursery stock:

In the case of Fig. 2, the number of node is found to be quite limited. Still, a large number of adventitious roots came out a new from the part of root attached to each node below the surface. From each node above the surface plumules grew.

(2) Differentiation of function of root system:

About one year after the planting, those adventitious roots grown from each node had differentiated enough to be distinguished not only morphologically but also from the viewpoint of distribution range. That is;

a. Nutrient absorbing root system

The adventitious root developed so much as to form main roots and lateral roots, that are relatively thin but with many branched roots and rootlets. Its distribution was in the upper soil stratum. (Fig. 3)

b. Water absorbing root system

Lateral roots were generally few. This root was thick, twisted and elastic, having developed much lenticel and reached out deep into the soil. (Fig. 4)

(3) Root system of one-year plant:

Two plants had been surveyed from March to May (the rainy season) in 1967. The planting hole was made smaller than usual and only cake fertilizer was applied. They grew 2.3 m above the surface on average and a few fruit clusters were grown. The average dry weight of the top was 3.3 kg.

Development of root system; Nutrient absorbing root .... The mounding on the part near the root was 10 to 15 cm above the surface level and rootlets reached out horizontally also herein. The longest was 1.3 m.

10 cm below the surface --- The root, the diameter of which at the base was about 3 mm, extended 60 to 70 cm sideways, but most of the roots were within the planting hole.

20 cm below the surface --- the roots were all kept inside the planting hole. Water absorbing root .... Three relatively thick roots developed. One of them stretched downward along the wall of planting hole and then reached out horizontally on the bottom of planting hole 40 cm deep, expanding out of the hole (Fig. 5). The total weight of root system was 619 g on average, the ratio of which by each stratum is as shown in Table 4. 99% of the roots were distributed above the stratum 30 cm below the surface. The value of T-R ratio was 5.0.

(4) Root system of two-year plant:

One plant was surveyed in February, 1967 (the early part of the rainy season). 1.5 kg of castor seed meals, 0.5 kg of fused phosphate, 0.4 kg of ammonium sulphate and 0.2 kg of potassium chloride were applied in total per plant. The plant covered the 2.5 m support all around. Many flower clusters were to be seen and the total weight of the top was 9.25 kg.

Development of root system; Nutrient absorbing root .... Many roots reached out into the mouding. This nutrient absorbing root extended 1.2 m sideways in the straum 10 cm below the surface, 1.0 m in the 20 cm stratum and 30 cm in the 30 cm stratum respectively. That is to say, this root stretched sideways longer in the upper stratum,

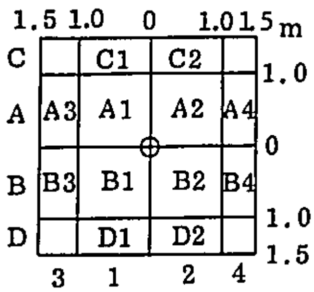


Fig.1 Bird's-eye view of blocks marked on soil surface in Root System Survey

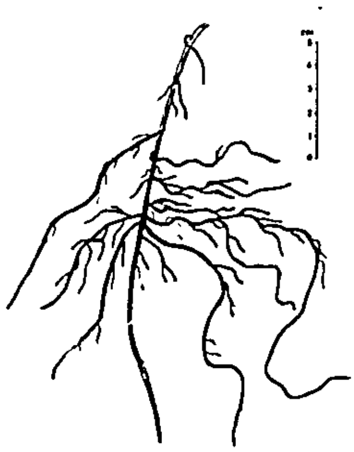


Fig.3-1 Nutrient Absorbing Root (one-year)

Fig.3-2 Nutrient Absorbing Root below the Surface

Fig.2 Rooted and Germinated Seedling

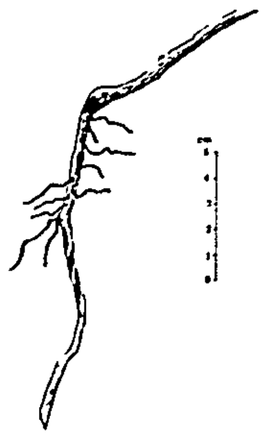


Fig.4-1 Water Absorbing Root (one-year)

Fig.4-2 Water Absorbing Root (60 cm below the surface, four-year)

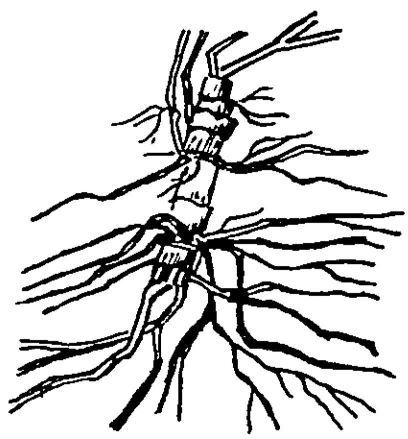


Fig.5 Root System of one-year

Fig.4-3 Lenticel of Water Absorbing Root

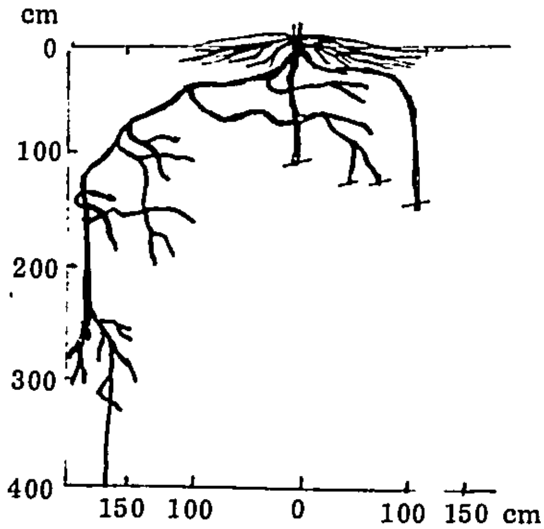


Fig.6 Root System of
Four-year Plant

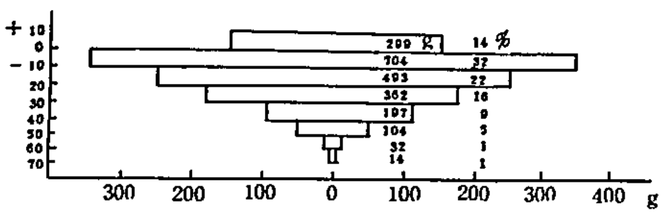


Fig.7 Root Distribution of
Four-year Plant by the
Stratum of every 10 cm

and in the stratum just below the surface it expanded so much as to reach the adjacent plant roots. The growth of many branched roots was observed in a broom shape in the fertilizer application hole. This seems to be because a portion was cut off when the fertilizer application hole was dug and from such parts many branched roots came out a new. Also, the soil hardness inside the fertilizer application hole was 10 to 12 mm and was 19 to 20 mm on its side wall. The planting hole had abundant pore space, which, combined with the richness in fertilizer seems to have accelrated the development of the root.

Water abosrbing root system .... Three thick roots, the diameter of which at the base was approximately 7 mm, were observed to grow from the lower nodes and one thick root from the upper node. The survey was conducted down to the stratum as deep as 50 cm, and the total dry weight of the root system was 950 kg. As for the volume distribution by each stratum, 90% of the total volume was distributed above the 30-cm stratum, as shown in Table 5. The value of T-R ratio was 9.7.

(5) Root system of four-year plant:

Four plants had been surveyed from August to November (the dry season) in 1966. The fertilizer application holes were not dug close to each other, and were smaller and shallower than usual. Before this survey was conducted, the total of 3.5 kg of castor seed meals, 1.1 kg of fused phosphate, 0.4 kg of ammonium sulphate and 0.5 kg of potassium chloride was applied to each plant. Most of the plants surveyed were in the period of maturity and the plants surveyed in November were those after the harvest. The growth was satisfactory and the total dry weight of the aerial part was 26.3 kg on an average.

Nutrient absorbing system;

This system stretched 70 cm sideways at the longest point in the upper stratum above the surface. In the stratum 10-cm below the surface, the longest amounted to 1.5 m and many of the roots extended as long as 50 to 80 cm, being intermingled with the roots of adjacent stock. And some were found to have stretched upward from the lower stratum to this stratum. The deeper it went, the less became the horizontal expanse, and in the stratum 40-cm below the surface, none was observed to reach out more than 1 m sideways. Also the volume of root decreased with depth. In the case of the fertilizer application holes, roots developed so well as to reach its bottom, and some were found to have branched off in a broomy shape as in the case of the two-year plant, some passed through the 10-cm long lifeless branch decomposing and absorbing their contents completely, while other had invaded into the rootstock of weeds. The radial growth of nutrient absorbing roots from its axis was not uniform and the density varied according to the direction. As a result,

Table 4 Distribution of Root System of One-year Plant

(unit: g)

Length \ Depth (cm) / Width	+10		-10		-20		-30		-40		Grand Total
	1	2	1	2	1	2	1	2	1	2	
A	64	67	95	112	17	5	8	6	-	-	
B	35	40	92	21	17	22	8	6		4	
Total		206		320		61		28		4	619
Ratio (%)		33		52		10		5		1	100

Table 5 Root Distribution of Two-year Plant

(unit: g)

Length \ Depth (cm) / Width	+10		-10				-20		-30		-40		-50		Grand Total
	1	2	3	1	2	4	1	2	1	2	1	2	1	2	
C				3	3										
A	38	4	5	223	110	2	75	105	31	47	16	38		5	
B	24	7	3	69	26	3	19	21	5	19		11		16	
D				12	10										
Total		73				469		220		102		65		21	950
Total (%)		8				49		23		11		7		2	100

Table 6 Root Distribution of Four-year Plant

(unit: g)

Length \ Width	+10				-10				-20				-30				-40				- 0		-60	-70	Grand Total
	3	1	2	4	3	1	2	4	3	1	2	4	3	1	2	4	3	1	2	4	1	2	1	1	
C		18	4			22	9			8	4			8	4										
A	12	27	25	2	23	259	99	2	7	107	66	1	7	35	41	1		26	29			2			
B		8	188	13	18	174	95		5	221	72	1	5	221	38	1	5	86	50	1	65	37	32	14	
D			1	1		1	2								1										
Total				299				704				493				362				197		104	32	14	2,205
Total (%)				14				32				22				16				9		5	1	1	100

a fertilizer application hole was discovered which had not been penetrated by roots.

Water absorbing root system;

Some were found to have branched off at the bottom of planting hole and extended downward, and some stretched downward along the support, while others extended seeking appropriate soil structure. As shown in Fig. 6, there were some which stretched diagonally first and then downward, amounting to 4.4 m in total length to a depth of 4 m. The growing points of their roots presented the shape of a bill of a water-bird and were white in color. The total dry weight of the lump of roots was 2.2 kg an average, and 95% of the root volume was distributed above the 40-cm stratum (Table 6 and Fig. 7). The value of T-R ratio stood as high as 12.0.

(6) Root system of three-year plant without fertilizer application:

A plant was surveyed in May (the dry season), 1967. At a plantation near Mitsui Farm, a virgin forest was burnt down and a small planting hole was dug using the Enxada to plant the seedling. In the second year, only cattle manure and wild herbs collected at the time of weedling were applied into a small hole for the first time. The growth of the aerial part was poor and about one half of that of the two-year plant in Mitsui Farm. Its leaves were lusterless and inelastic and assumed an yellow green color. The total dried weight of the top was 4.8 kg.

Nutrient absorbing root system; Being inelastic and frail, the growth of root was extremely poor and the root volume was quite limited. Some did not develop branched roots and rootlets until they reached a mass of cattle manure of a horizontal distance of 80 cm from the plant 20 cm below the surface. Most of the roots could only reach the stratum 30 cm below the surface.

Water absorbing root system; The number of root was small. Some reached out along the support, but the survey was not carried out deeper than 30 cm. The total dry weight of the root was 0.9 kg and the value of T-R ratio was small 5.4.

(7) Summary of survey results:

a. Differentiation of root system;

With the nutrient absorbing root, the closer it was to the surface, the longer it grew sideways. In the case of the two-year plant, the roots stretched sideways as long as 1.2 m in the upper stratum and came into contact with those of the adjacent plant. After two years, the roots got intermingled with those of the adjacent plant. The water absorbing root stretched deeper as it grew, and in the case of four-year plant it reached so deep as 4.0 m.

b. Distribution;

The root volume was larger in the upper stratum and less in the lower one. In the case of the four-year plant, 85% of the total volume was distributed above the 30-cm stratum and 90% above the 40-cm stratum, respectively. The radial distribution from its axis was not uniform in density and roots of some plants did not penetrate into the fertilizer application holes dug around the plant.

c. Soil environment accelrating the development of root;

Roots generally developed well with good permeation of air. In other words, the nutrient absorbing root developed better in the stratum closer to the surface and also in the poose and porous soil of the planting hole and the fertilizer application hole. On the other hand, the water absorbing root stretched long along the support and root of other trees, or in search of appropriate soil structure, respectively.

d. Commencement of elongation of nutrient absorbing root;

The growth of new roots was observed in the latter half of the dry season soon after the harvest of fruit clusters. New roots came out when the soil had enough soil moisture after the harvest.

e. Growing period and value of T-R ratio;

As the year went by after the planting, the value of T/R ratio increased gradually, or in other words, the efficiency of the root function improved little by little. However, this value remained small when manuring practice was erratic.

(8) Problems in cultivation:

The rationality of the traditional method of cultivation is examined hereunder with regard to the survey result, and at the same time some methods or improvement are suggested.

a. Improving air permeability of soil;

Since the root system develops well with good permeation of air, it is necessary to attempt to improve the application of straw or foliage of plant (organic matter). Also due attention is needed to drainage. Fields which have a compact layer in its subsoil and are of poor soil drainage is to be avoided. It is advisable to mound around the plant to prevent the creation of a cavity, so that rain water which runs down the pepper plant is drained off rapidly.

b. Setting fertilizer application holes in a circular Belt around the plant;

Under the supposition that the fertilizer application hole method is adopted, it is necessary to make improvements and prepare a shallow circular ditch around the plant so that all the nutrient absorbing roots can benefit from it. This way, the efficiency of fertilizer application is also increased.

c. Selecting a time immediately following the harvest as one of the fertilizer application periods;

New roots start growing all at once when the moisture condition improves after the harvest. Further, this coincides with the period when the internal nutrients run short. It is commendable to make effects to apply fertilizer promptly after the harvest.

d. Mulching the entire field

The nutrient absorbing roots grow better in the upper stratum, and in the case of two-year or older plants, they expand in the upper stratum over the entire field. In order to improve the function of roots, to lower soil temperature, to maintain adequate soil moisture, to prevent the runoff of top soil and to make a bette condition for benefitting from the functions of soil micro-organism and small animals, it is necessary to mulch the entire field.

(II) Experiment on Effect of Mulching with Organic Matter upon Soil Condition as well as Growth and Yield of Crop

1. Experiment method

The effect of mulching with a few organic matters of different properties and in different volumes upon the soil environment, and the growth and yield were examined. Although the author wished to use pepper plants for this experiment, the cowpea whose growing period is shorter was used instead in order to collect sufficient data on the mulching cultivation of the pepper plant. It was feared that otherwise, the experiment might take too long for completion during the author's period as assignment at the duty station.

The experiment field is of tertiary Latosol, and since the cultivation had been repeated for a considerable length of time on the same land, it was relatively sandy and poor for soil in an area near Belem. Grassland which had been left in follow until the previous year was cleared to conduct this experiment.

(1) Mulching materials applied:

a. Mato grosso foliage (Tripsacum dachtyloides Gram., to be abbreviated as Mg.)

b. Pueraria foliage (Pueraria phaseoloides Leg., to be abbreviated as Pu)

c. Hull (Casca de arroz, to be abbreviated as Ca)

d. Coconut palm shell (Casca de coco, to be abbreviated as Co.)

The volume applied, air dried; 2 kg/m^2 and 4 kg/m^2.

(2) Tested crop:

Cowpea (Vigna sinensis Leg.) Variety -- 40 days

(3) Test area and plot system:

4 m^2, 2-plot system

(4) Mulching and crop cultivation methods:

The soil environment was examined by comparing the mulching plot, where infixed quantities of each material were spread over the entire surface uniformly with the control plot, that is, the non-mulched plot. The survey was started in October (the latter half of the dry season) and was conducted until April (the latter half of the rainy season) in the following year. During this period, the initial depth 7 to 8 cm in case of the mulching matter Mg (4 kg/m^2) was decreased to about 2 cm and as the matter became coarse grained, this test matter was removed. Each plot was then plowed to sow the cowpea, after which the plots were covered again with the same materials. In this way, the growth of crop was studied. The cowpea seeds were sown in plots 40 x 30 cm, four grains to a hill and afterwards, they were thinned and singled.

2. Experiment result and discussion

(1) Soil temperature 5 cm below the surface

a. Transition of time and soil temperature;

Soil temperature measured every four hours is as shown in Table 7-1, with the minimum at 4 o'clock and the maximum at 12 o'clock. In the case of soil temperature at 4 o'clock it was higher, though slightly, at the mulched plot than at the non-mulched plot. Also, the more the materials applied, the higher the temperature. In

Table 7 Effect of Mulching with Various Organic Matter upon Soil Temperature at 5 cm Underground

Item \ Organic Matter \ Q'ty	2 kg/m²					4 kg/m²				
	Mg	Ca	Cc	Pu	Sc	Mg	Ca	Cc	Pu	Sc
1. Soil Temperature of every 4 hours (°C)										
4 o'clock	26.0	24.7	24.2	27.2	24.0	27.0	26.2	24.5	28.0	24.0
8	27.5	27.5	27.2	29.0	28.0	27.5	28.0	27.2	29.0	28.0
12	31.0	33.0	34.2	31.5	39.7	30.0	32.0	31.7	31.5	39.5
16	30.0	33.0	33.5	32.0	38.0	30.0	32.2	32.5	31.2	37.5
20	26.2	26.5	26.5	28.0	27.0	26.5	28.0	27.2	27.7	26.2
24	27.0	26.2	25.0	27.5	25.5	26.5	27.5	26.0	28.2	25.5
Average	28.1	28.5	28.4	29.2	30.4	27.9	29.0	28.2	29.3	30.1
Difference between Max. and Min.	5.0	8.3	10.0	4.8	15.7	3.5	6.0	8.0	3.8	15.5
2. Soil Temperature at 7 o'clock and 12 o'clock for 20 days (May to December)										
7-o'clock Mean soil temperature	27.4	27.5	27.3	28.5	28.0	27.8	27.9	27.0	28.9	27.9
12-o'clock Mean soil temperature	31.4	33.6	34.4	32.6	37.1	30.5	32.8	32.6	31.5	37.0
12-o'clock Maximum soil temperature	33.2	35.0	36.5	34.7	42.5	31.7	34.2	34.7	32.7	42.7
3. Monthly changes in ratio of Temp. in mulching/non-mulched plot on days recording 34 - 36°C in non-mulched plot										
Month October '65	85	91	94	88	100	84	88	90	87	100
April '66	91	97	97	90	100	90	97	94	94	100
May '66	92	97	98	97	100	89	93	95	92	100

particular, the temperature always was higher when foliages rather than hulls were applied. In the case of soil temperature at 12 o'clock, the covered plot showed lower temperature than the non-mulched plot. Furthermore the temperature declined in particular with the application of foliages.

b. Transition of soil temperature during the six months of survey;

The soil temperature was measured once a week at 7 o'clock and 12 o'clock for six months. As indicated in Table 7-2, the 7 o'clock soil temperature stayed from 27 to 28°C without much difference between the mulched plot and the non-mulched plot, while in the case of 12 o'clock mean soil temperature, the plot mulched with foliage showed the temperature of 30 to 32°C and the non-mulched plot 37°C, with a difference of 5 to 7°C. This difference in soil temperature was magnified with the increase in the amount of material applied. The maximum soil temperature stood at 32 to 35°C at the plot mulched with foliage and at 43°C at the non-mulched plot, showing the difference of about 8°C or more. This difference extended to as much as 10°C when a large quantity of materials were applied.

c. Mulching period and soil temperature controlling action;

The effect of temperature control was surveyed with freshly applied mulching as well as on with mulching matter which had become coarse and powdery after long use. The ratio of the soil temperature at the mulched plot as against the mulched plot was obtained for the days when the temperature at the non-mulched plot was equal, and it was judged that the controlling effect was weak when this ratio was low, and conversely strong when the ratio was high. For instance, in the case of foliage as shown in Table 7-3, in October when it was first applied, the value stood at 84 to 88 while in May of the following year it went up more or less to 90 after long use, indicating that the longer the utilization period, the weaker the control effect. In addition, the control effect lasts longer with increase in materials applied.

d. Soil moisture;

A cylindrical soil sampler was driven into the soil to a depth of 3 cm below the surface to collect a sample of soil and the soil moisture was measured by the weight method. The soil moisture according to the number of days passed after the rainfall, as shown in Table 8. When the quantity applied was large, each material could maintain much of the moisture. The moisture gradually decreased as days passed, but comparatively speaking, the foliages could preserve much more moisture than the hulls. On the other hand, the indication of 7 to 8% of soil moisture in the said table is equivalent to 29 to 33% in term of the maximum water-holding capacity, and thus it is not adequate to inhibit the growth of crops to a great extent. As indicated in Table 8-1 and 8-4, some cases where, immediately following the rainfall, the moisture at the mulched plot was less than that at the non-mulched plot were observed. It seems that this can be attributed to the fact that the rainfall reaches the soil surface gradually after saturating the mulching material. The other experiment showed that a dry foliage absorbed twice as much or more moisture as its own weight after a showering treatment lasting one-hour. In the case of a rainfall of great quantity at one time during the rainy season, grass mulching seems to adjust to the condition of abrupt excesses in moisture by keeping back much of the rain water. Considering in addition the soil temperature control effect in dry season mentioned in the previous section, the grass mulch proves effective as the countermeasure during the dry and rainy seasons, and accordingly, mulcing twice a year with grass is to be recommended.

e. Growth of weeds;

Seed-propagating weeds except the perenial plant were removed about every three weeks and their dry weight was measured. As shown in Table 9, the more each material was supplied to cover the plot, the less wild herbs grew. Where the foliage was applied 4 kg/m^2, no growth of wild herbs was observed.

Table 8 Relation between Covering with Different Organic Matter and Soil Moisture

Date \ Material \ Q'ty	2 kg/m²					4 kg/m²					
	Mg	Ca	Cc	Pu	Sc	Mg	Ca	Cc	Pu	Sc	
1. 14/Oct.	10.2	11.9	14.4	13.0	11.3	10.5	9.5	10.8	12.8	11.9	3 hours after the rainfall stop.
30/Oct.	8.3	6.3	4.6	7.3	0.7	7.3	6.5	7.7	8.0	1.3	No rain since 1st rain
1/Nov.	5.2	3.0	2.7	6.2	2.1	6.6	5.6	6.2	6.9	1.3	"
2. 6/Nov.	8.8	10.0	12.1	11.5	8.5	9.4	8.4	7.3	8.5	8.6	12 hours after the rain stop.
7/Nov.	8.5	8.5	7.8	8.4	3.4	9.3	8.5	6.9	8.5	2.7	No rain
3. 27/Nov.	6.8	3.3	2.3	4.4	1.1	7.5	5.9	4.8	6.5	1.5	No rain for a several days
28/Nov.	6.3	3.8	2.2	5.0	1.3	8.3	3.9	2.6	6.7	1.2	"
4. 29/Nov.	10.9	10.6	12.8	12.8	13.8	12.0	10.4	12.7	10.8	13.8	12 hours after the rain stop.

Table 9 Relation between Covering with Organic Matter and Growth Rate of Weeds (air-dried weight g/m²)

Date \ Material \ Q'ty	2 kg/m²					4 kg/m²				
	Mg	Ca	Cc	Pu	Sc	Mg	Ca	Cc	Pu	Sc
10/Nov.	0	9	12	3	14	0	3	5	0	17
10/Dec.	6	34	27	1	68	0	3	8	0	49
Total	6	43	39	4	82	0	6	13	0	66
Treated/Control Plot	7	52	48	5	100	0	10	20	0	100

Table 10 Soil Surface Erosion in Bare Plot (Extent of erosion cm)

2 kg/m²		4 kg/m²	
Extent of Erosion (cm)	Covered Plot around Bare Plot	Extent of Erosion (cm)	Covered Plot around Bare Plot
0.4	Pu Cc	0.7	Cc Mg
1.1	Pu Mg	1.1	Pu Mg

f. Soil erosion;

After six months, the mulching matter was removed to sow the cowpea on the same plot, it was found that the surface of the non-mulched plot was lower than that of the adjacent mulched plot. The lowering of the surface seems to be due to soil compression and soil erosion. Here, it is assumed that it is due to erosion and express its extent by the difference in the surface level between the mulched plot and the non-mulched plot. As shown in Table 10, every non-mulched plot which was surrounded by the treated plots was lowered and in the non-mulched plot adjacent to those plots covered with foliages this tendency was particularly marked. That is to say, the mulched plot particularly treated with foliage, can be said to have prevented soil erosion.

g. Germination rate;

After six months mulching treatment, cowpea was sowed and its growth and yield were surveyed. As known from Table 11, the more the material applied, the higher the germination rate, and this tendency was accelerated if the treatment was with foliage. The germination rate indicated 80 to 90% at the plot covered with foliage (4 kg/m^2), while being 10% at the non-mulched plot.

h. Infection rate;

The ashystem blight (Rhizoctonia bataticola) attacked during the germination period and through the seedling stage. Many of the ungerminated seeds grew radicles in the soil, but were stricken with this disease. Table 11-2 shows, the result of survey on the infection rate about those germinated seedlings. This rate stayed low when much material was applied and when foliage was applied to cover the plot, being 85% at the non-mulched plot against 25 to 30% at the plot covered with foliage (4 kg/m^2).

i. Growth and yield;

Table 11 Covering and Growth of Cowpea

Quantity / Material / Item	2 kg/m²					4 kg/m²				
	Mg	Ca	Cc	Pu	Sc	Mg	Ca	Cc	Pu	Sc
1. Germination Rate (%)	64	24	21	77	13	82	60	22	91	9
2. Infection Rate (%)	44	63	64	23	85	33	59	56	26	87
3. Number of Harvested Plant (10 m^2)	67	27	23	71	19	73	73	25	75	2
4. Stem height (Harvesting Stage) (cm)	14	11	19	12	10	16	15	15	17	8
5. Flowering Time (Day/Month)	31/5	16/6	16/6	1/6	23/6	23/5	2/6	13/6	29/5	-
6. Total Weight of Plant (dry/g/10 m^2)	277	55	129	158	10	514	444	240	510	2
7. Fine Speed Weight (g/10 m^2)	195	37	94	97	6	371	335	178	382	0

The more the material applied,

1) the longer the stem height grew,
2) the earlier it bloomed,
3) the bigger the total air dried weight of plant
4) the higher the production of fine seeds. This was more so especially when the treatment was with foliage.

In conclusion, the mulching, particularly made the soil environment satisfactory, and decomposed organic matter improved the physico chemical properties of the soil and at the same time the balance and the function of soil microorganism, resulting in the healthy growth of crops.

(III) Experiment on Effect of Organic Matters Applied with Different Methods upon Soil Condition as well as Growth and Yield of Crop

The effect upon the soil fertility was compared in the following three cases; to apply the same quantity of gramineous foliage as 1) grass mulch, 2) plowing-in and 3) grass ash. This experiment had been conducted during the dry season from May (the end of the rainy season) to December (the beginning of the rainy season), 1966.

1. Method of experiment

(1) Testing material and method of applying organic matter

a. Crop;

Cowpea Variety -- "40 days"

b. Organic matter;

Organic matter, the Mato grosso Gram. air-dried foliage 4 kg/m^2 was applied as follows.

(a) Grass mulch,

(b) plowing-in

(c) Grass ash (The grass ash obtained from the fixed quantity of organic matter was 450 g/m^2)

(d) no application (control plot)

c. Cultivation and application;

Grass mulch .... Immediately following the sowing of cowpea, the foliage was mulched over the entire plot. It was so designed that only a portion of sowing hole was left uncovered to secure a cylindrical space so as to support the growth of seedling.

Plowing-in .... 15 cm of top soil was removed, the foliage was spread over surface, and after adequate soaking the foliage the soil was returned to the same place.

Grass ash .... After being scattered over the surface, the grass ash was mixed with the soil to the depth of 10 cm.

$200\ g/m^2$ of calcium carbonate was applied equally to each plot one week before the sowing, and it was mixed with the top soil. Five cowpea seeds were sowed in each hole at an interval of 25 x 25 cm, and were thinned afterwards and singled. After the first crop the second crop was cultivated in continuation, and the third crop was also attempted. The sowing time was 3rd of May for the first crop, 26th of July for the second and 3rd of October for the third, respectively.

d. Area of each plot and plotting system;

$1\ m^2$ 4-plot system

2. Experiment result and discussion

The result of experiment is as shown in Table 12.

(1) pH (H_2O)

Since calcium carbonate was applied equally, the value of pH immediately following the sowing amounted to 5.8 at the non-treated plot, with the maximum of 7.9 at the grass-ash plot, and others stood at about 7.5. As the cropping advanced, the value decreased and this tendency was quite noticeable at the grass-ash plot, having been lowered down to 6.6 toward the end of the third crop. This value was close to that of the other treated plots. This seems to be due to the rapid leaching of lime and potash of the grass ash.

(2) Furrow evaporation amount

The furrow evaporation was measured, with a glass weighing dish filled with a fixed volume of water. This survey was conducted for the third crop when the soil fertility had declined and the growth of the plant had become thinner, and the evaporation amount was found to be extremely low at the grass-mulched and the plowing-in plots where the growth had been relatively favorable than the other stretched plots. (Table 12-2).

(3) Soil temperature (5 cm underground)

Throughout each cropping, the temperature stayed at a minimum for the grass-mulch plot, followed by the plowing-in plot, the grass-ash, and then non-treated plot. In other words, this indicates that the temperature is more susceptible to the action of grass mulch than to the surface covering action of crop itself. Though the cropping terms were different, at the periods when the soil temperatures at the non-treated plot were similar, it was found that the ratio value between 'treated plot/non-treated plot' stood small in the first crop and large in the third crop. It is to say, that as the growth of the plant falls off, the covering action of plant itself degrades gradually. (Table 12-3).

(4) Soil moisture

The soil moisture was measured with respect to the soil between the surface and 3 cm below. In the case of the first crop, the moisture was at a maximum at the mulched plot, and declined gradually in the order of the plowing-in plot, the grass-ash plot and the non-treated plot. It is apparent that the amount of evaporation from the soil surface where the growth was retarded and the extent of covering was less was much larger than expected (Table 12-4).

(5) Development of root nodule by nodule bacteria

Although growth of thinned plants is not always uniform, the ratio of plant which grew root nodule as well as the dried weight of root nodule per plant were obtained for plants which were thinned out. Equally at each plot, this rate was higher in the first crop than in the third crop and especially at the grass-mulched plot. Similarly in the case of root nodule weight, that from the grass-mulched plot was of the heaviest in whichever crop, then followed by that from the plowing-in plot. The weight was extremely small at the plot without the application of organic matter (Table 12-5 and 6). The application of organic matter seems to have stimulated the activity of soil micro-organism.

Table 12 Effects of Organic Matter Applied with Different Methods on Soil Environment

Item / Date of Experiment	Applying Method	With Lime				Without Lime
		Multh	Plowing-in	Ash	Non-treated	
1. pH (H_2O)						
First Cropping	5/5, 5/15	7.5	7.5	7.9	7.6	5.8
	6/15, 7/12	7.3	7.4	7.6	7.4	5.6
Second "	8/4	6.9	7.0	7.0	6.9	5.5
Third "	12/11	6.4	6.1	6.6	6.6	5.5
2. Furrow Evaporation Amount (cc)						
Third Cropping	10/26	33	32	35	35	35
	11/7	31	31	32	32	34
3. Soil Temperature (5 cm below °C)						
First Cropping	6/15	28.9	30.3	32.5	38.5	38.8
Second "	8/31	30.3	30.3	31.0	31.3	31.8
Third "	10/16 - 10/21	35.4	36.7	37.3	37.2	38.0
4. Soil Moisture (%)						
First Cropping	6/15	7.7	5.3	3.7	2.8	3.1
	6/22	4.6	2.2	1.0	0.3	0.4
Second "	8/31	3.7	0.8	1.4	1.6	1.2
5. Ratio of Plants with bacteria Nodule (%)						
First Cropping	6/6	91	58	79	47	70
Third "	10/18	73	40	25	18	18
6. Weight of bacteria Nodule per Plant (mg)						
First Cropping	6/6	7.1	0.7	4.1	0.4	1.3
Third "	10/18	⧻	⧻	+	+	+
7. Rate of Infected Plant (%)						
First Cropping	6/6	2	20	37	41	50
Third "	10/18	1	0	1	10	28

(6) Disease infection

Plants were infected by sclerotium rolfsii in the first crop and by Macrophomina phaseoli in the third crop, respectively. As shown in Table 12-7, the ratio of infected plants was remarkably less at the grass-mulched and the plowing-in plots. It can be considered that this due to the fact that the balance of soil micro-organisms was maintained because of favorable soil conditions after mulching and that the plants showed steady and healthy growths.

(7) Growth and yield

As shown in Table 13, the stem was particularly long in the grass-mulched plot for the first crop due to a cylindrical space left in the grass mulch at the time of sowing. A part from this, in each cropping, plots where the growth was better, the total plant weight as well as the weight of fine seeds were larger. That is, the production was at a maximum in the plowing-in plot, followed by the grass-mulched plot and in the first cropping the latter accounted for 89% of the former. The production remained still lower at the grass-ash and the non-treated plots. The grass-ash plot signifies the shifting cultivation method plot, thus it is indicating that at this plot there was almost no application of organic matter and nitrogen and moreover, the grass ash applied did not serve to improve the physicochemical properties of soil because of the rapid leaching.

(8) Value of T-R ratio

The value of T-R ratio was obtained by pulling out the root slowly after the harvest and separating the top from the root, and then drying and weighing them (the weight of seed was included in the top). Throughout the crops the value was by far higher in a plot where the growth was satisfactory such as the plowing-in and the grass-mulched plots than in the grass-ash and the non-treated plots. This indicates that the physicochemical property of soil and the function of roots are improved by the application of organic matter.

Table 13 Effect of Organic matter applied with different methods on Growth and Yield of cowpea

Item \ Plot	Liming: Multh	Liming: Plowing-in	Liming: Grass ash	Liming: Non-treated	No-Liming
1. Stem Length at the Harvest (cm)					
First Cropping	28	23	20	14	13
Second "	18	19	14	10	9
Third "	12	13	10	9	7
2. Total Dry Weight of Plant (g/m^2)					
First Cropping	345	389	188	34	34
Second "	75	105	39	11	7
Third "	25	39	16	14	10
3. Weight of fine Seed (g/m^2)					
First Cropping	162	181	89	8	8
Second "	33	51	14	1	1
Third "	7	11	2	1	1
4. Rate of Plant Production Weight against to that of 1st Cropping (%)					
First Cropping	100	100	100	100	100
Second "	20	28	15	13	13
Third "	4	6	2	13	13
5. Value of T/R					
First Cropping	17	19	15	7	5
Second "	18	15	9	8	6
Third "	6	10	5	5	3

(9) Comparison in growth between the grass-ash plot with and without liming. In this test, since lime was added equally to each plot the pH value at the grass-ash plot with the addition of lime amounted at 7.6 to 7.9. To dispel the doubt that the growth in this plot was abnormal, differing from the growth in the grass-ash plot without liming which is almost equivalent to a plot under the burning shifting method, two grass-ash plots were newly created, one with the addition of lime and the other without. The growths were surveyed according to the same methods as in the previous tests.

As is clear in Table 14, though a difference in the value of pH between the two plots can be observed, the growth did not differ at all. This means that this degree of difference in pH value could not cause any major differences in the growth of crop. Therefore, it was concluded that the growth in the grass-ash plot with the addition of lime equals that in the grass-ash plot without lime which is equivalent to a plot under the havitual burning shifting cultivation method.

When discussing the result of this experiment with the effect on production of grass mulch mainly classified into 1) the optimization of soil environment by the mulching and 2) the improvement of physicochemical properties of soil as well as the benefits from the function of soil micro-organism. It is seen that since cowpea is self-equipped with the capacity to cover the soil surface to some extent, its effect on the improvement of physicochemical property of soil is manifested more clearly than its effect on the improvement of soil environment. Accordingly, in the case of cowpeas the production was higher at the plowing-in plot than at the grass-mulched plot. However, in the case of the pepper plant the capacity of soil surface covering by itself is limited and the area of bare land remains wide, moreover, its nutrient absorbing root spreads shallowly, and widely near the ground surface.

Table 14 Growth at Grass-Ash Plots with and without Liming

Item	Plot	Grass Ash without Liming	Grass Ash with Liming
1. pH - H_2O	7/12	6.5	7.5
	8/20	6.5	7.7
	12/11	5.9	6.6
2. Stem Length (cm)	8/14	21	21
3. Flowering Time (month/day)		7/31	7/30
4. Rate of Infection (%)		15	15
5. Total Weight of Plant (dry weight/g/m^2)		123	120
6. Weight of Fine Seeds (g/m^2)		66	64

Note: Sowing Time --- 6/24 Harvesting Time --- 8/28

Therefore, it seems that the covering effect is more manifest than the effect on the improvement of physicochemical property of soil.

The effect of grass mulch on the pepper plant is observed at IPEAN. The fruits productionof the eight-year peper stands at 2.7 kg/plant under the traditional cultivation while at 4.2 kg/plant under the grass-mulching cultivation. In the Amazon Region and the Northeast Region, the implementation of the grass-mulching cultivation is rather rare, but the growth and production at a plantation where this type cultivation is in use are not only higher compared to the nearby plantations under the traditional cultivation, but also the growth is healthy with no or only limited numbers of infected plants (by root rot disease). In addition, there is no indication of disease. According to the observation of the author, the grass mulch surely helps pepper plant grow soundly.

As for the growth at the grass-ash plot, it is noticed that under the burning-shifting cultivation method a gigantic forest is burnt down and the wood ash is utilized as a fertilizer source, but the supply of organic matter and nitrogen is insufficient and the fertilizer component of wood ash is dissolved and lost rapidly. Thus, the improvement of physicochemical properties of soil can not be expected to any extent and on the other hand a lot of labor is required for reclamation (47 men/ha are required to fell down a virgin forest, to burn and prepare it.)

(IV) Experiments on Ecological Characters of the Pepper Plant

The following tests were conducted in 1975/76 to collect the data necessary for the improvement of pepper cultivation.

1. Test on the relation between soil temperature and growth

The growth in the plot where styrene foam was spread on the soil to reduce its temperature was compared with that in the control plot where the natural soil temperature was maintained.

(1) Test method

a. Temperature reducing material:

Noodle-shaped styrene foam was spread to cover the soil surface so that the soil temperature would vary according to the quantity applied.

b. Test plant: Pepper, Singapore variety.

c. Test plot:

The following three plots differing from each other in soil temperature were provided.

(a) High temperature plot:

The test frame in this plot was maintained in the natural condition, with vinyl film spread on the soil surface at suitable intervals to prevent evaporation from the soil.

(b) Medium temperature plot:

Styrene foam was spread on the soil surface at a height of 5 cm.

(c) Low temperature plot:

Sytrene foam was spread on the soil surface at a height of 10 cm, with wooden boards were placed on top of it with a suitable opening provided between them.

d. Test frame:

A bottomless vinyl film frame measuring 50 cm in length and width and 30 cm in depth was set in the ground, with a wooden frame fitted to its upper part to permit stabilizer spreading of styrene foam.

e. Plant in frame:

Each frame had one plant, and four plants were tested for each plot.

f. Cultivation:

Seedling were planted on January 6, 1975 and the test was completed on December 1, 1975. During this period, 5.5 g of urea, 18.5 g of fused phosfate and 11.0 g of potassium chloride were applied per frame on March 25, June 11 and October 23. The plants were watered 2 - 3 times in the high temperature plots as they tended to lack its soil moisture.

(2) Test results and discussion

a. Soil temperature:

The soil temperature at a depth of 5 cm and 10 cm below the soil surface was measured every day between 11:30 and 12:00 starting from June. Table 15 shows the monthly mean and maximum temperatures observed in the test period which coincided with the rainy season.

The overall average temperature in the six-month test period at a depth of 5 cm and 10 cm was 35° - 32°C in the high temperature plot, 31° - 29°C in the medium temperature plot, and 29° - 29°C in the low temperature plot. Thus, the six-month average temperature in the medium and low temperature plots was lower by 4° - 3°C and

6° - 3°C than that in the high temperature plot which registered 35° - 32°C. The maximum soil temperature during test period at a depth of 5 cm was 30°C in the low temperature plot while it recorded 40°C in the high temperature plot.

b. Soil moisture:

The soil moisture in the high temperature plot appeared to be constantly less than that in the treated plots, although the soil surface was covered with vinyl film to prevent evaporation from the soil. The soil moisture measured in the latter part of November was lower in the high temperature plot than in the treated plots. (See Table 16).

c. Growth under different soil temperature:

Table 17 shows the plant growth at about a year after planting.

(a) The rate of withered plants was 50% in the high temperature plot, 25% in the low temperature plot, and 0% in the low temperature plot. The withered plants were subjected to a microscopic examination after artificial culture, but Fusarium solani f. piperi was not detected partly because of the lapse of a long time after withering. Since the test plants were planted in the dry season, it is believed that their growth was impeded by the high temperature in the seedling stage and was further subjected to damage caused by the salt damage of chemical fertilizers, which eventually led to the withering of some plants. The plant height measured at time of harvesting was 44 cm in the high temperature plot, 55 cm in the medium temperature plot, and 120 cm in the low temperature plot, which clearly indicates that the growth in the low temperature plot was particularly good. Comparison of the best growth plants from the three plots showed in the difference in growth due to soil temperature distinctly. The air-dried weight of the top and the root was low in the high and medium temperature plots and excellent in the low temperature plot. It deserves attention that not only the development of the root system but also the

Table 15 Soil Temperature in Treated Plots at Depth of 5 cm and 10 cm (Measurement conducted from 11:30 - 12:00 hrs. daily)

Month \ Plot		High Temperature Plot		Medium Temperature Plot		Low Temperature Plot		Atmospheric °C
		5 cm	10 cm	5 cm	10 cm	5 cm	10 cm	
June	Average	35.7	33.1	30.8	29.8	29.4	28.6	
	Maximum	38.0	35.0	33.0	31.0	32.0	30.0	
July	Average	34.7	31.7	30.5	29.2	28.3	38.0	
	Maximum	40.0	35.0	35.0	32.0	30.0	30.0	
August	Average	35.1	32.7	31.2	29.8	29.0	28.4	33.9
	Maximum	37.0	34.0	34.0	31.0	30.0	30.0	36.0
Sept.	Average	35.5	32.9	30.9	30.0	29.5	29.4	32.9
	Maximum	40.0	37.0	35.0	32.0	31.0	31.0	34.0
Oct.	Average	35.4	32.3	30.8	29.5	29.3	28.9	32.6
	Maximum	39.0	35.0	33.0	31.0	31.0	30.0	34.0
Nov.	Average	33.4	30.2	29.7	28.8	27.9	27.6	32.6
	Maximum	35.0	32.0	31.0	30.0	30.0	29.0	26.0
Average	Average	35.0	32.2	30.7	29.4	28.9	28.5	33.0
	Maximum	38.2	34.7	33.5	31.2	30.7	30.0	35.0

Table 16 Soil Temperature and Soil Moisture

Item \ Plot	High Temp. Plot	Medium Temp. Plot	Low Temp. Plot
Soil moisture (%)	4.5	7.3	7.6

increase of T-R ratio value was accelerated by the decline of the soil temperature. This indicates that both the development and functions of the root system are impeded in the soil temperatures of uncovered soil, and that the soil temperature must be reduced to ensure adequate growth of the root system.

Table 17 Soil Temperature and Plant Growth at Harvest Time

Item \ Plot		High Temp. Plot	Medium Temp. Plot	Low Temp. Plot
Rate of Withered Plant (%)		50	25	0
Plant Height (cm)	Average	44	55	123
	Maximum	53	90	190
Weight of Aerial Part (g)	Average	16.5	50.3	129.3
	Maximum	20	81	274
Root Weight (g)	Average	20.0	24.0	41.3
	Maximum	21	31	93
Length of Longest Root (g)	Average	22.0	71.7	76.3
	Maximum	25	90	150
Development of Feeder Root		+	+++	++++
T-R Ratio	Average	0.8	2.1	3.1
	Maximum	1.0	2.6	3.0

2. Test on relationship between soaking period and growth of pepper seedling

This test was conducted to start with on pepper seedlings in order to clarify the relationship between the immersion which is often observed during heavy rainfalls and pepper plant growth.

(1) Test method

a. Plant: Pepper Singapore variety

Relatively young sub-main stems with 5 - 6 nodes, about 30 cm in length, were planted in the soil of vinyl bags measuring 16 cm in height and 12 cm in diameter. The rooting was conducted on July 3, 1975, and the cuttings grown to the same size after about 80 days were selected for the test.

b. Test plot:

The test cuttings were put in large wooden frame with running tap water applied in such a way that it would constantly fill the vinyl bags up to the soil surface. The immersion period was set as follows.

(a) 1 day (b) 3 days (c) 5 days

Immersion was started on September 23, and the water temperature was held at about 24°C.

c. Number of test plants:

One plant for each bag, 24 bags.

d. Handling of cuttings:

The cuttings soaked in water for the specified number of days were put in the shade room where the cuttings had been grown, and care was taken to maintain adequate humidity.

(2) Results and discussion

The test results are shown in Table 18.

a. Rate of withered plant:

No withered plants were found in the 1-day immersion plot, but the 3-day and 5-day plots recorded a withering rate of about 15% and 50%, respectively.

b. Growth:

The observation made two months after immersion disclosed that the longer the immersion period, the smaller the number of branches and leaves and the greater the number of withered branches and fallen leaves. In the cutting stage, the nutrients are still retained in the plant and transpiration is limited because the leaf area and number of leaves are small. It is considered that the low withering rate above can be explained by the fact that the water balance within the plant can be maintained even if the water absorption due to immersion declines. If the plant grows in size and placed in an environment exposed to high temperature and bright sunshine, however, transpiration increases sharply to cause an imbalance of water content and accelerate the withering of plants. In the cultivation of pepper, therefore, consideration should be given to adequate drainage.

Table 18 Immersion Period and Growth
(November 25, 1975)

Number of Days Immersed	Withered Plants		Number of Branches	Number of Leaves
	Number	Rate (%)		
1	0	0	2.0	5.5
3	4	17	1.2	4.3
5	7	29	1.0	2.5

(V) Experiment on Buffer Action of Organic Matter

In the aforementioned plowing-in and mulching tests, it was found that the germination rate increased and the disease infection declined with the application of organic matter. The tests described below were conducted to have greater appreciation of the importance of applying organic matter in the agricultural development of the project area.

1. Test on chemical buffer action

(1) Test on relationship between organic matter content of soil and and germination impeding effect of chemical fertilizers

a. Test method:

(a) Plant: Test I - Kidney bean-Julho EEP-358

Test II - Cowpea, 40 days

(b) Soil and chemical fertilizers:

Soils from pasture and natural grass land were used for the test after removing large roots from them. As shown in Table 25 of Test II, the content of organic matter was greater in the pasture soil than in the natural grassland soil. The two soils were put in unglazed pots measuring about 30 cm each in diameter and height and having a capacity of 5 liters. Sand was filled in the lower half of each pot, and the soil mixed thoroughly with chemical fertilizers was filled in the upper half. The chemical fertilizer was composed of N (18), P_2O_5 (23) and K_2O (18), and their dosage per liter of soil was as follows.

i) none applied ii) 2 g iii) 5 g iv) 10 g

(c) Number of seeds sown:

25 seeds per pot, to be thinned to three plants.

b. Result and discussion:

In the first test, the kidney bean seeds showed a low germination percentage of 64% when subjected to the germination test in a glass dish. As seen in Table 19, the germination percentage declined gradually for both soils with the increased dosage of compound fertilizers and recorded zero at the maximum dosage. This decreasing tendency was more pronounced with the soil from natural grassland. The maximum dosage which caused the natural grassland soil to record 0% was one grade less than that at which the pasture soil showed no germination.

The second test presented a tendency similar to that observed in the first test. In the case of the pasture soil, germination impediment started in the 5 g/liter. In the case of grassland soil, however, it started in the 2 g/liter and was heavier in degree. The seedlings contracted a desease which appeared to have been caused by Rhizoctonia sp. It was only in the 10 g/liter pot that all plants in the pasture soil were affected by this disease, but virtually all plants in the natural grassland soil were infected in the 2 g/liter pot. As shown in Table 19, the chemical fertilizer exhibited an appreciable productive effect, but it excerted an adverse effect on germination and increased disease susceptibility.

Table 19 Differences in Growth by Organic Matter and Chemical Fertilizer

	Date of Survey	Soil	Non-fertilized	2 g/ liter	5 g/ liter	10 g/ liter
First Sowing						
Germination Percentage (%)	July 10	Pasture soil	44	28	4	0
		Natural grass-land soil	44	8	0	0
Second Sowing						
Germination Percentage (%)	July 18	Pasture soil	92	92	64	12
		Natural grass-land soil	92	40	8	0
Disease Susce-ptibility (%)	July 26	Pasture soil	0	0	0	100
		Natural grass-land soil	0	80	100	
Flowering Date		Pasture soil	Sept. 4	Aug. 21	Aug. 24	Sept. 15
		Natural grass-land soil	Sept. 4	Aug. 21	-	-
Total Plant Weight (Air dried weight (g))		Pasture soil	14.3	21.3	17.9	9.0
		Natural grass-land soil	13.1	18.4	5.3	-
Fine Seed Weight (g)		Pasture soil	3.8	5.8	3.8	-
		Natural grass-land soil	3.0	6.0	0	-
Number of Test Plants		Pasture soil	3	3	3	1
		Natural grass-land soil	3	2	1	-

(2) Test on relation between organic matter and dosage of chemical fertilizer and germination impediment

The results of Test II-(IV) are quoted.

The fertilizer component was supplied in equal quantities. The germination percentage of cowpea was examined in plots prepared for three different combinations of fertilizers. i.e., application of organic matter only (foliage of Brachiara sp.), application of compound chemical fertilizer only, and combined application of both organic matter and chemical fertilizer. As seen Table 31, the germination percentage was low when only chemical fertilizer was applied and showed a conspicuous decrease with the rise of the dosage. The percentage increased with the decline of the mixing ratio of chemical fertilizers with organic matter, and recorded the highest value when only organic matter was used.

2. Tests on biological buffer action

(1) Test on Relationship between amount of organic matter and disease infection

a. Test method:

The natural grassland soil was used for the test after removing large roots. It was filled in bottomless frames having vinyl film walls stretched on all sides and measuring 50 x 50 x 30, and was mixed thoroughly with the organic matter described below.

128 kg of the soil was filled in each frame which had a capacity of 75 liters. The organic matter mixed with the soil was foliage of Homolepsis aturensis, a gramineous grass, which were cut to a size of 3 - 5 cm. The weight percentage of the organic matter applied to respective frame was as follows.

(a) Test plot - none applied.

(b) -1% (c) -2% (d) -4%

Plant: Cowpea - '40 days'

Planting space: 25 x 17 cm, 6 hill/frame

Seeds sown: 4 seeds/hill

b. Test results and discussion

The first test met with ant damage soon after germination. An overall review of all the three tests indicates that the germination percentage was the lowest in the non-applied plot, becoming higher with the increase of the organic matter. Conversely, the disease infection rate declined with the increase of the organic matter, and dwindled to zero after the amount of organic matter reached a certain level (See Table 20).

Table 20 Relation between Amount of Organic Matter and Growth

Item \ Amount of Organic Matter	Date of Survey	0%	1%	2%	4%
1st Test	(Sowing on July 25, '73)				
Germination Percentage (%)		25	66	79	79
Stem Height (cm)	Aug. 13	11.2	11.6	11.3	12.9
2nd Test	(Sowing on Aug. 15, '73)				
Germination Percentage (%)	Aug. 22	25	50	96	96
Disease Infection Rate (%)	Aug. 28	100	8	0	0
Stem Height (cm)	Aug. 28	-	11.0	12.0	13.0
"	Sept. 10	-	13.5	17.1	17.1
Total Plant Weight (g)	Sept. 14	-	8.0	10.1	12.6
3rd Test	(Sowing on Sept. 17, '73)				
Germination Percentage (%)	Sept. 20	67	89	83	97
Disease Infection Rate (%)	Sept. 25	63	0	0	0
Flowering Date		Nov. 26	Nov. 7	Oct. 31	Nov. 2
Number of Harvested Hills		9	12	12	12
Air-dried Pods Weight (g)		0	1.0	8.5	11.0
Total Plant Weight (g)		2.0	10.5	18.5	20.0

(2) Test on relation between amount of organic matter and disease infection rate

The results of Test III are quoted.

As seen in Table 12, the disease infection rate in the plots applied with organic matter such as mulching and plowing-in plot in the second cropping was extremely low relative to the grass ash plot and non-applied plot. In the third cropping, the rate was high only in the non-applied plot.

The soil in Amazonia Region is generally simple in texture and deficient in organic matter, so that the growth of crops in this area is liable to be retarded by the severe climate. It is believed that application of organic matter will improve the physico-chemical properties of the soil and make the soil environment milder and maintain the balance of microorganism activity thereby contributing to the normal growth of crops, increase of the germination percentage, and reduction of the disease infection rate.

(VI) Studies on Selection and Planting Area required of mulch crop

1. Selection of mulch crop

The efficiency of mulching work can be increased if the mulch crop is planted alternately and adjacent to each one or two rows of pepper plant. The morphological characters to be considered in selecting the mulch crop are described below.

(1) Selection of crop allowing easy mulching work:

A low powered reaper equipped with a pneumatic lifting device is now available on the market.

Regardless of whether this machine is used or manual reaping is conducted, crops suitable are the thin-stemmed Brachiaria, (Brachiaria sp.) a gramineous grass, or the short-stemmed grammineous grasses with extremely long leaf blades such as Mato grosso (Tripsacum sp.) and Capim santo. The crop most commendable at the present stage is Mato grosso because of its large leaf volume.

(2) Selection of crop not impeding growth of pepper:

The selection of grass whose root system and the top grows so actively as to exert an adverse effect upon the growth of pepper in the adjoining row must be avoided. Grasses of this type include Capim elefante and

C. guatemala (C. stands for gramineous grass) which devastate the pepper garden because of the active rooting from each node of stem and the resultant rapid propagation. Pueraria, a leguminous crop, is not recommendable either because its running vine is prone to twine itself around the pepper plant, although it has a high fertilizer resoponse as described later.

(3) Selection of crop with large leaf volume from nematoda-repelling crops

The root rot of pepper plant is caused by Nematoda fungus complex, so that the intrusion of Nematoda must be checked to prevent its occurrence. It is therefore advisable to select the strain with a large leaf volume from the Nemada-repelling species like crotalaria spp., Eupatorium odoratum, etc.

(4) Selection of crop capable of seed propagation from among gramineous crop:

In the project area, legumious crops propagate by seeds but majority of gramineous grasses propagate by stock or stem cutting which entails much labour. It is therefore preferable to select a gramineous crop that can be propagated by seeds.

2. Planting area for mulch crop

As seen in Test II, the soil environment and the physico-chemical properties of soil can be improved to a greater extent by increasing the quality of grass mulch applied. From the viewpoint of management, however, it is desirable to apply mulch in as small a quantity as possible to the minimum area required. Assuming that a minimum of air-dried 2 kg/m^2 grass mulch of pepper garden will be applied twice a year to take measures against the rainy and dry seasons as described previously, the annual air-dried weight requirement of mulch is 4 kg/m^2 (= 13.3 kg/m^2 in terms of fresh leaf weight). Since the annual green production of Brachiaria is generally considered to be 9 kg/m^2, the required planted area of Brachiaria per 1 m^2 of pepper garden is calculated to be 1.5 m^2. In other words, the planted area of Brachiaria must be 150% of the pepper garden area. Therefore, if pepper is grown by single row planting (width - 2.5 m) or double row planting (width - 5.0 m), Brachiaria should be planted in a strip 1.5 times as wide to alternate with the rows of pepper.

3. Fertilizer requirement of pepper plant and fertilizer supply capacity of mulch crop

Table 21 shows the composition of fertilizer elements contained in dry foliage of Brachiaria.

If 3.3 kg/m^2 of dry grass mulch (13.3 kg/m^2 in fresh leaf weight) is to be applied to 1 m^2 of pepper garden, 20.6 kg of dry mulch is necessary to cover each 6.25 m^2 (2.5 m x 2.5 m) around the pepper plant. This is the amount of supplied fertilizer. The annual requirement of fertilizer per plant in each of the yearly stages of growth was calculated on the assumption that the fertilizer response rates for the applied fertilizer were 50% for N, 25% for P_2O_5 and 45% for K_2O (Table 22). It is generally recognized that the productivity of the four-year plant is equivalent to the mean for young and mature plants combined together. It was discovered that the amount of Brachiaria supplied per pepper plant almost equals to the required amount of fertilizer per each four-years pepper plant. That is, though not verified by any fertilizer response test, calculation indicate that the supply and requirement for fertilizer become almost equal when Brachiaria is planted at a rate of 1.5 m^2 per each 1 m^2 of pepper garden.

It is to be noted, however, that suitable management practices should be followed if the production of Brachiaria, which dwindles with the lapse of time, drops below the 9 kg/m^2 of yield in fresh grass weight.

Production of Brachiaria is largely affected by management practices. If intensive management is adopted, therefore, it is possible to reduce the width of its painted row to that of pepper row.

The above description can be generally applied to C. mato grosso.

Table 21 Chemical Composition of Preferable Mulch Crop - Brachiaraia (by Arelino de Oliveira Matos - IPEAN)

Crop \ Composition	N	P_2O_5	K_2O	CaO	MgO	CO
Brachiaria (Pasture land)						
Foliage	0.72	0.426	4.24	0.27	0.42	36.52
Root	0.52	0.279	2.63	0.13	0.12	33.27
Paspalum Maritimum (Natural grassland)						
Foliage	0.68	0.238	3.98	0.39	0.25	35.27
Root	0.69	0.238	3.08	0.10	0.12	34.69

Table 22 Fertilizer Requirement per Pepper Plant by Growth Year (g) (by Chiba et Terada - IPEAN)

Growth Year \ Composition	N	P_2O_5	K_2O	CaO*	MgO*
1st	12.9	18.7	36.2	1.4	4.7
2nd	54.8	41.9	111.3	23.6	6.1
3rd	117.3	77.4	161.3	44.7	7.5
4th	129.3	86.1	169.3	67.8	7.6

* Figures indicated only the absorption quantity.

(VII) Experiment on Planting System of Mulch Crop in Pepper Field

The mulching work can be performed with ease if the mulch crop is grown near the pepper plant.

In the root system survey, it was found that the nutrient absorbing root system developed in a shallow layer below the soil surface, which indicates the possibility of avoiding the root competition between pepper and mulch crop by cultivating the former in raised row and the latter in flat row for intercropping.

This test was conducted to confirm the validity of this cropping pattern.

1. Experiment method

(1) Test plant

Pepper, Singapore variety.

(2) Mulch crop:

Capim mato grosso (Tripsacum dechtyloides Gram.).

(3) Test plot (cropping pattern):

The mulch crop was planted in flat row of the same level in all plots, whereas the pepper plants were planted in the raised row whose height was set as follows.

Plot a) Same level row as the mulch crop (flat row).

Plot b) 20 cm higher raised than the mulch crop.

Plot c) 30 cm higher raised than the mulch crop.

Pepper was planted towards the edge of its row, and the mulch crop was planted at the approximate center of the flat row (See Fig. 8). Further, in order to study the degree of competition between root systems of the two crops in their intercropping, each plot was divided into three sections for single cropping of mulch crop and pepper plant each and intercropping of both. The high raised row was formed by mounding the surface soil from the nearby place, with black soil dressed on top of it to a height of about 3 cm. Black soil was also applied to cover the flat row of mulch crop.

(4) Planting space:

The rows provided in each plot for its division by cropping pattern were 4 m in length and 1 m in width. The intra row spacing was 1 m for pepper plant and 30 cm for mulch crop.

(5) Management practices:

Pepper was planted on January 6, 1975 and mulching crop on May 22, 1975.

Fertilizers were applied only to the pepper plant on May 25, January 11 and October 23, and their dosage per hill was 5.5 g urea, 18.5 g fused phosfate, and 11.0 g potassium chloride. Mulch crop was reaped when it grew to a height of about 1.5 m and was used for mulching the pepper in raised row evenly along their entire length.

2. Results and discussion

(1) Root system development in the intercropping with mulch crop and pepper plant

The root systems of the two crops grown by the above-mentioned cropping pattern was examined on March 4, 1976, on the 15th month after planting. The examination disclosed virtually no difference almost between the 20 cm raised row and 30 cm raised row in pepper plant.

Root system of pepper planted in raised row of intercropping:

Although some morphological differences were noted between the nutrient absorbing root and the water absorbing root, their downward growth could not be established clearly and was noted to distribute to a depth of about 35 cm, slightly deeper than the bottom of the raised row. Some roots were noted to have developed along the raised row slope and extended through the adjoining flat row at a shallow depth, reaching the root bottom of mulch crop (See Fig. 8).

Root system of pepper plant planted in flat row of intercropping:

The root system development was far less active than in the raised row. Specially, the development of branched roots and rootlets were far inferior to that in the raised row. The root system had a length of less than 50 cm, so that it did not intrude into the adjoining row of mulch crop.

Root system of mulch crop in intercropping with pepper plant on raised row:

Some roots of mulch crop were noted to have extended laterally at a shallow depth, crossing over the bottom of raised row and stretching to a point about 30 cm outside the pepper support. Some were found to have intruded upward from the bottom of raised row of pepper plants. Nevertheless, competition with the root system of pepper was observed.

Root system of mulch crop in intercropping with pepper plant on flat row:

The root system developed sideways at a depth of 3 - 10 cm below the land surface, passing through the rhizosphere of pepper freely and extending beyond the 20 cm line outside the pepper support. Thus, it appeared that the root system inhibited, the growth of the pepper root.

(2) Growth of pepper plant and mulch crop:

Mulch crop:

The stock was planted on May 22 after the pepper cutting started rooting and extending. The plant height was measured each month starting from July 14, and the top was cut when it grew to a height of about 150 cm for plant production measurement which was conducted three times until January 21. The figures shown in Table 23 indicate the green top production amount within a row width of 4 m. The production in all the test plots was smaller in amount for the single cropping than for intercropping, which was clearly due to differential soil fertility. This coincides with the results of observation. However in the case of intercropping, the growth of mulch crop adjoining raised row of pepper plant was smaller than that adjoining flat row of pepper plant.

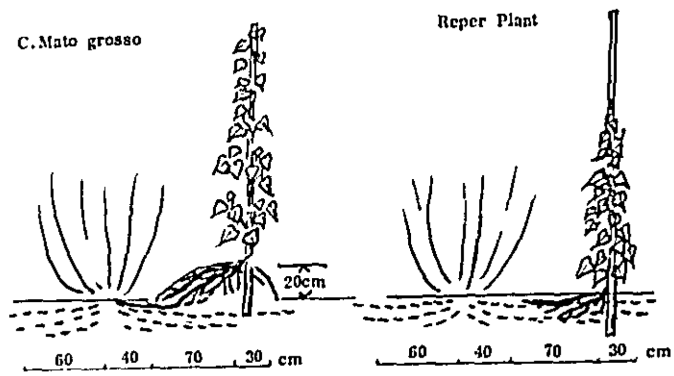
Pepper:

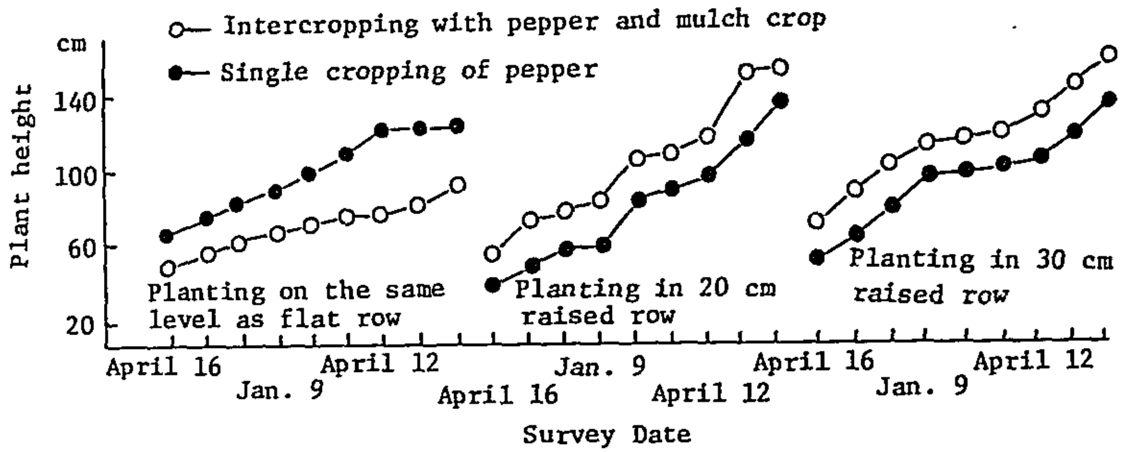
The plant height was measured each month. As shown in Table 23 and Fig. 9, by single cropping pursued just about the same trend in all test plots. However, in the case of intercropping, the growth of pepper planted in flat row was poorer than that in raised rows, moreover the growth of this flat row plot of all other intercropping raised row plots was inferior to that of all single cropping plots. This is probably because the growth in the flat row was inhibited by the intrusion of mulch crop roots. Although the planting density adopted in this test was contracted than the habitual, it is believed that if pepper is planted in 20 - 30 cm high row in the intercropping, it will aboid root system competition from mulch crop in flat row.

Table 23 Plant Height in Intercropping with Pepper Plant in Raised Row and Mulch Crop in Flat Row

Height of Pepper (cm)	Level (flat)				20 cm				30 cm			
	A	B	C	D	A	B	C	D	A	B	C	D
June 6, '75		75		48		39		51		44		65
July 14	92	80	104	54	94	45	122	70	96	60	112	86
July 31	99	85	117	59	105	54	123	75	104	75	115	96
Sept. 1	132	92	153	62	140	58	134	78	107	93	127	110
Oct. 21	143	105	155	67	140	80	177	103	147	94	152	112
(Plant Weight - kg)"	2.5		4.7		2.5		4.5		2.1		2.9	
Nov. 12	105	108	107	68	107	87	128	103	111	94	123	112
Dec. 4	150	123	177	68	153	90	180	110	140	94	173	121
(Plant Weight - kg)"	2.1		3.4		1.9		3.0		2.0		2.3	
Jan. 21, '76	170	123	195	73	180	115	190	145	160	112	195	139
(Plant Weight - kg)"	2.6		4.2		2.6		3.8		2.4		4.2	
March 4	135	123	145	84	138	132	152	147	138	130	172	159
Mean	128	123	144	84	132	132	151	147	125	130	146	159
(Total Plant Weight - kg)	7.2		12.3		7.0		11.3		6.3		9.4	

Note: A : Single Cropping of Mulch Crop
B : Single Cropping of Pepper
C & D : Intercropping with Mulch Crop and Pepper





(VIII) Conclusion

Under the belief that the mulching cultivation of the pepper plant is the most rational method for the Amazonia Region, the advantages of this method had been consistently pursued. At the same time, surveys were conducted to study the ecology of the pepper plant in order to improve its cultivation. As a result, it was found that mulching cultivation of the pepper plant was well adapted to its ecological characteristics. By mulching cultivation, it becomes possible to grow healthy pepper plants under this natural condition. In addition, the method of intercropping with pepper and mulch crops was developed in order to reduce the work of mulching.

Straw or foliage mulching enabled the healthy and vigorous growth of the pepper plant. That is it may justly be said that mulching cultivation is profitable and absolutely necessary for pepper cultivation in this Region.

The amount of mulching material as well as the cultivation area of mulch crop required were investigated.

II. EXPERIMENT ON IMPROVEMENT OF AGRICULTURAL DEVELOPMENT SYSTEM IN AMAZONIA REGION

As stated in the introduction the writer expected as follows. The following agricultural development system was most rational for this Amazonia Region where the climate is somewhat severe and soil fertility is more or less poor. That is, at first agricultural field should be covered by pasture cultivation as soon as the forest is burnt and cleared in order to keep and improve the soil fertility.

This pasture is utilized for live stock husbandry. When the annual crops are cultivated, a part of the pasture is utilized. As soil fertility declines by their successive cultivations moves to an adjacent pasture in which pasture root is applied for fertilizer source. This rotation between pasture field and annual crop field is more profitable than the habitual shifting cultivation system from the view of land utilization and land productivity. The possibilities and advantages of this development system were examined. This test was carried out from 1973 to 1976.

(I) Comparative Test of Soil Fertility between Existing Natural Grass Land and Pasture

In a group field with the same formation and development of soil the comparison of soil fertility between pasture which had been covered with Brachiaria decumbens, gramineae, for three years and grass land (also called the secondary forest) covered with natural plant which had been kept in natural state waiting for recovery of soil fertility for three years also. The soil fertility in this case is expressed by the plant growth and yield of cowpea.

1. The weight of top and root in natural grass land and pasture

Period of Investigation: April 30, 1973 - June 22, 1973

Areas of Investigation:

Top investigated ... 1 m^2 - 3 plots each

Root investigated ... 0.25 m^2 - 2 plots each
1 m^2 - 1 plot each

(1) Predominant plants in both areas

Pasture: Brachiaria decumbens (Fig. 11) is predominant and Cynodon datylon (C. Burro-Gram) Paspalum maritimum (C. Gengibre-Gram) Schrankia leptocarpa (Leg) Ipomea asarifolia (Salsa), etc. are mixed.

Natural Grass Land: Gengibre (Fig. 12) as an example shown in Table 24 is predominant.

(2) Weight of plants in both areas:

The top was divided into the green part and the part of withered leaves, and the root was divided into 10 cm layer each down to 30 cm and were weighed respectively. As indicated in Table 25, both parts are equal in the total air-dried weight of plant. But the top of plants from pasture land is equivalent to 70% of that from the natural grass land. The root weight of the pasture plant is greater, equivalent to 135% of the natural grass land plant and deeply distributed. Further, on the surface of the pasture land there are large amounts of heaped humus which is beyond comparision with that on the natural grass land.

2. Comparison of soil fertility between natural grass land and pasture

(1) Testing method:

a. Applied crop for testing:

Cowpea-Vigna sinensis --- '40 days'

b. Test plot:

Non-fertilizing plot

Fertilizing plot-Fertilization was made only at the first cropping as a basal application.

c. Plot area & plot system:

4 m^2 3 plots system

d. Cultivation method:

After the top was mowed and carried off, the following measure was taken:

Fertilization:

Calcium carbonate, 200 g/m^2 (Natural Grass land) 100 g/m^2 (Pasture), was spread on the surface of the ground and mixed thoroughly down to the depth of 10 cm from the surface.

Table 24 An Example of Vegetation of Natural Grass Land by Secao Botani - IPEAN

	Air-dreid Weight (g/m^2)	Rate (%)
*Paspalum maritimum-Gram	714	52
Homolepis aturensis-Gram	305	23
Borreria verticilata-Rubia	130	10
Borreria latifolia-Rubia	160	11
Others	47	4
Total	1,351	100

* call Gengibre

Table 25 Weights of Top & Root in Natural Grass Land and Pasture

Item / Plot	Natural Grass Land Air-dried (g/m^2)	%	Pasture Air-dried (g/m^2)	%	Pasture/Natural Grass Land (%)
Top - Green part	659	51	413	47	63
- Withered part	627	49	474	53	75
Sub-total:	1,286	100	887	100	69
Root 0 - 10 cm	956	96	1,054	78	110
10 - 20 cm	22	4	233	17	1,060
20 - 30 cm	13	1	65	5	500
Sub-total:	991	100	1,352	100	136
Total	2,277		2,239		98

Table 26-1 General View of Growth in Each Cropping

1st Cropping	3/6/'73	19/9	Rain distribution good. Germination in good order. Favorable growth.
2nd Cropping	22/10/'73	3/1	Germination good. Frequent rain after flowing caused bad ripening on both non-fertilized and fertilized plots, in Pasture, fertilized plots grew vines showing spindle growth.
3rd Cropping	28/6/'74	2/9	Germination good, symptom of lack of micro elements shown. Many plant unable to flower, especially in natural grass land.
4th Cropping	21/10/'74	30/12	Germination good. Frequent rain after the middle stage of growth, caused bad ripening.

Compound chemical fertilizer (N-18, P_2O_5-23, K_2O-18) 55.5 g/m^2 was given in the fertilizing plot.

Planting distance: 50 x 25 cm 4-seeds per hill, thinned out to 2 plants.

(2) Results and discussion:

The first cropping was sown on June 3rd, and the cropping was continued as long as weather conditions permitted it.

Growth of each cropping:

The growth in each cropping in both test areas was as follows;

As shown in Table 26-1 the growth of 1st cropping which was sown in the beginning of dry season, i.e., 3/June was favorable in both areas under good climate whereas the 2nd cropping sowed at the end of dry season i.e. in October was not favorable due to the heavy rainfall in the beginning of rainy season. The growth of advanced term cropping declined to show the symptom of micro element deficiency and many plants lacked flowers, and were finally affected by fusarium solani, soil fungus, (Table 26-2-10) as indicated in Table 26-2.

a. The amount of total plant weight and seeds in both nonfertilized and fertilized plots in both areas is the highest in the first cropping, and as the term cropping advanced, it gradually declines, showing that the decomposition of the organic matter (root) in the soil is very rapid and is absorbed by the crop.

b. In the non-fertilized plots, the productivity in the pasture is considerably higher than that in the natural grass land by approximately three times in the first and the second croppings.

Table 26-2 Growth in Natural Grass Land & Pasture

Item Cropping \ Test Plot	Natural Grass Land			Pasture		
	Non-fertilized	Ferti-lized	Average	Non-fertilized	Ferti-lized	Average
1. Total air-dried plant weight g/10 cm^2						
1st cropping	986	4,799	2,893	2,906	5,917	4,412
2nd "	763	2,443	1,603	2,466	3,432	2,953
3rd "	371	275	294	455	830	643
4th "	-	-	-	184	404	294
2. Seed weight g/10 cm^2						
1st cropping	393	2,299	1,346	1,420	2,803	2,112
2nd "	276	1,049	663	915	1,433	1,174
3rd "	93	75	84	133	288	211
4th "	-	-	-	29	119	74
3. Rate of total air-dried plant weight to that of 1st cropping						
1st cropping	100	100	100	100	100	100
2nd "	77	51	55	85	58	67
3rd "	32	6	10	16	14	15
4th "	-	-	-	6	7	7
4. Rate of seed weight to that of 1st cropping %						
1st cropping	100	100	100	100	100	100
2nd "	70	46	49	64	51	56
3rd "	2	3	6	9	10	10
4th "	-	-	-	2	4	3
5. Rate of pasture/natural grass land in total air-dried plant weight %						
1st cropping	100	100	100	295	123	153
2nd "	100	100	100	323	140	184
3rd "	100	100	100	145	301	219
6. Rate of fertilized/non-fertilized in total air-dried plant weight %						
1st cropping	100	487		100	204	
2nd "	100	320		100	139	
3rd "	100	88		100	182	
4th "	100	-		100	200	
7. Ignition loss %						
Before cultivation of 3rd cropping	2.80	2.73		4.50	4.16	

Item Cropping \ Test Plot	Natural Grass Land			Pasture		
	Non-fertilized	Ferti-lized	Average	Non-fertilized	Ferti-lized	Average
8. Seed weight/total plant weight %						
1st cropping	40	48	46	49	47	48
2nd "	36	43	41	37	42	40
3rd "	30	27	29	29	35	33
4th "	-	-	-	16	29	25
9. Beginning of flowing (day/month)						
1st cropping	17/8	9/8	13/8	16/8	9/8	13/8
2nd "	29/11	26/11	28/11	27/11	27/11	27/11
3rd "	10/8	11/8	11/8	14/8	11/8	12/8
4th "	-	-	-	*	9/12	*
10. Diseased plant percentage (%)	**					
3rd cropping - 2/9	92	92	92	86	80	83

* The day when flowering plant reached 1/3 of the total plants was defined to be the beginning of flowering, but this was not reached.

** Infected by Fusarium solani f. phaseoli.

c. In the fertilized plots of the pasture soil the total plant weight is greater than that of the natural grass land in each cropping, in the first cropping for instance, that of the natural grass land is 5 kg/m^2 against 6 kg/m^2 of the pasture. However, the fertilizer response rate (fertilized/non-fertilized) of the pasture is on the contrary considerably lower until the 2nd cropping than the natural grass land. That is, in the 1st cropping the natural grass shows 500% against 200% for the pasture. But the extension of the retention period of high production by fertilizing cannot be expected as in case of non-fertilizing.

d. The rate of the seed weight/total plant weight expresses the physiological function of plants. This rate declines with the advance advance of cropping. With the decrease in soil organic matter, physiological function of the plant declines gradually, and the plant is unable to form flower buds or to mature seeds gradually.

e. The ignition loss is regarded as the amount of soil organic matter, and when this amount was examined before the cultivation of the 3rd cropping, it was less in the fertilized plots than in the non-fertilized plots in both area. It means that the chemical fertilizer increases production considerably but at the same time, increases the consumption of organic matters.

f. The production of cowpea is quite high in pasture soil which in rich in organic matter. However, it is thought that as the decomposition of the organic matter is quite rapid, the period of retention and the duration of high production is short. It is safe to consider that the production until second cropping will pay from the viewpoint of economical management and the two croppings of cowpea which has short growth period of about 2 months are equivalent to one cropping of annual crops with long growth period in general.

Higher production by the application of chemical fertilizer can be expected, but the extension of the period of retention and duration of higher production can not be anticipated. Also in this area it is said that chemical fertilization can not make good returns economicaly for annual crops generally.

(II) Comparative Test of Soil Fertility between Newly Established Natural Grass Land and Pasture

Natural grass land and pasture was newly cultivated in the natural grass area which had been used for Test I, and their soil fertility after a year of growth was investigated. In this test, a few kinds of pasture grass were newly added, and also the fertility of plowing-in a part of the top was examined.

1. Testing method

(1) Crop for soil fertility test: Cowpea - '40 days'

Tested pasture: Brachiaria (abbreviated Br.)
Stylozanthes (St) Pueraria (Pu)

(2) Area used & plot system: Same as Test I.

(3) Cultivation method:

Calcium carbonate 200 g/m^2 (23/May) and a compound chemical fertilizer (N-18, P_2O_5-23, K_2O-18) 55.5 g/m^2 (29/May) was given.

(4) Planting time and space:

Br (31/May) St (5/June) Pu (12/June)

Br - 50 x 50 cm St - 50 x 30 cm Pu - 50 x 50 cm
Cowpea - 50 x 25 cm

(5) Test plot:

After a year of growth following establishment.

a - The top was mowed and carried off.
b - Plowing-in: Foliage of the final amount mowed was plowed in.

2. Results and discussion

(1) Growth of pasture:

Except for the pasture St, each pasture grew normally. The amount of the raw foliage mowed during a year is as shown in Table 27. But the natural grass area was mowed in the final mowing time only.

The amount of each pasture mowed was approximated equal to the result of IPEAN. The reason for the small amount of St in the 3rd mowing was due to the fact that the plant was mowed near the root in the 2nd mowing time, resulting in the appearance of too many withered stocks.

(2) Soil fertility of natural grass land and pasture

Table 28 indicates the growth and yield of cowpea in each plot under the two sections, namely that with the top removed and with it plowed-in. The plants in the Br plots of two sections were earlier in flowering time and higher in stem height than in other plots because the soil physico-chemical condition in the Br plot was favorable. In the plowed-in section, all plots except for the St plot had spindle growth. It is, especially conspicuous in the Pu plot and the reason is considered to be the increase of organic matter plowed in which has higher nourishment and is easy to decompose.

Further, in all plots of plowed-in section the disease Fusarium solani f. phaseoli was absent almost (Table 28-2-4) whereas it must be noted that almost all plots in the 3rd cropping of Test I were affected by the same disease owing to the decreased soil fertility by repeating croppings.

a. Total plant weight and seed weight in every plot are the highest at the first cropping and gradually decline with the repetition of croppings. The value of seed weight/total plant weight ratio which is the indication of the physiological function of plants was reduced with the advance of the cropping. These are the same as Test I.

Table 27 Mowed Amount of Pasture

Green weight - kg/10 m^2

Kinds of Grasses \ Times to mow (Date)	1 8/Oct.	2 12/Feb.	3 31/May	Total
Top removed section				
Brachiaria (Br)	20.6	22.4	8.6	51.6
Stylozanthes (St)	13.0	25.1	0.7	38.8
Natural Grass *3			28.4	28.4*1
Top partially plowed-in section				
Brachiaria	34.4	33.5	17.8*4	85.7
Stylozanthes	23.6	23.7	0.6	47.9
Pueraria	16.8	20.6	11.8	48.4
Natural grass *3			28.7	28.7*2

*1 Young tree 2.9 kg included

*2 Young tree 1.6 kg included.

*3 Predominant plant is Gengibre.

*4 Amount plowed-in.

Table 28-1 General View of Growth in Removed and Plowed-in Section

Term Cropping \ Item	Sowing time (day, month)	Harvest time (day, month)	Growth
1st cropping	27/6/'74	2/9	Growth was normal.
2nd "	21/10/'74	30/12	Heavy rain in middle & latter growing stage disturbed the ripening.
3rd "	9/6/'74	21/8	Growth was normal. Ants attached all over the plowed-in section and production amount was calculated by conversion on the basis of non-attacked plant.

Table 28-2 Growth of Carried-off and Plowed-in Sections

Item Cropping \ Test section	Carried-off section			Plowed-in section			
	Br	St	Natural grass	Br	St	Pu	Natural grass
1. Beginning of flowing	(day, month)						
1st cropping	11/8	14/8	13/8	19/8	19/8	16/8	19/8
2nd "	6/12	8/12	7/12	6/12	13/12	7/12	9/12
3rd "	19/7	*	*	18/7	*	*	*
2. Stem height (cm)							
1st cropping	22	20	19	43	30	40	44
2nd "	26	23	28	33	23	31	26
3rd "	10	10	10	12	10	11	10
3. Growing extent of spindly growth and new leaves after harvesting							
1st cropping	0	0	0	++	0	++++	+++
4. Rate of diseased plant %							
1st cropping				7	0	2	5

*1 Indicates the height up to the first flower bud.

b. The total air-dried plant weight and seed weight, in both removeed and plowed-in section, throughout each cropping is the highest in the Br plot, i.e., the soil fertility of the Br soil is higher than that of natural grass land. In the case of plowed-in section, the Pu plot is equal to the Br plot in the first cropping, but after the 2nd cropping the production degree declined considerably and became quite small in comparison with the Br plot. That is, as the foliage of Pu is quite easily decomposed and the high production duration is short, it is inferior to Br.

c. The cause of low production in the St plot is due mostly to the failure of the 2nd mowing as stated above, but another reason seems to be that the grass shape of this plant is straight and the leaf is so small that the soil surface can be seen through the plant. This caused soil erosion.

d. The ignition loss in each plot was investigated at a fixed time. There was a positive correlation between this and the average total plant weight of both croppings interposing the investigation time. (Fig. 10). In this area the amount of the soil organic matter is an important factor in controlling production.

In sum, it is true even in the case of a short cultivation period of the pasture that the Br soil is superior to natural grass land soil in plant productivity. When foliage is plowed in, Pu soil has high production in the first cropping, but its duration is short so that it is inferior to Br. Furthermore, there is a positive correlation between the amount of organic matter in the soil and the plant production weight, which indicates that organic matter is a crucial factor in plant production.

Table 28-3

Item cropping \ Section plot	Carried-off section			Plowed-in section			
	Br	St	Natural Grass	Br	St	Pu	Natural Grass
1. Total air-dried weight (g/10m²)							
1st cropping	868	678	800	2,261	1,216	2,366	1,613
2nd "	489	351	500	1,202	267	685	548
3rd "	618	298	405	468	260	275	308
2. Seed weight (g/10m²)							
1st cropping	460	325	415	878	413	733	495
2nd "	223	112	214	514	39	235	185
3rd "	240	80	130	138	50	55	73
3. Rate of total air-dried plant weight against that of 1st cropping (%)							
1st cropping	100	100	100	100	100	100	100
2nd "	56	52	63	53	22	29	34
3rd "	71	44	51	21	21	12	19
4. Rate of seed weight against that of 1st cropping (%)							
1st cropping	100	100	100	100	100	100	100
2nd "	48	34	52	59	9	32	37
3rd "	52	25	31	16	12	8	15
5. Rate of seed weight/total air-dried plant weight (%)							
1st cropping	53	48	52	39	34	31	31
2nd "	46	32	43	43	15	34	34
3rd "	39	27	32	29	19	20	24
6. Rate of pasture/natural grass on total air-dried plant weight (%)							
1st cropping	109	85	100	140	75	147	100
2nd "	98	70	100	219	49	125	100
3rd "	153	74	100	152	84	89	100
7. Rate of pasture/natural grass on seed weight (%)							
1st cropping	111	75	100	177	83	148	100
2nd "	104	52	100	278	21	127	100
3rd "	185	62	100	189	68	75	100
8. Ignition loss (%)							
Oct./'74 - before 2nd cropping	3.69	3.06	3.12	4.50	4.24	4.42	4.34
Feb./'75 - before 3rd cropping	3.54	3.21	2.99	3.73	3.45	3.53	3.52

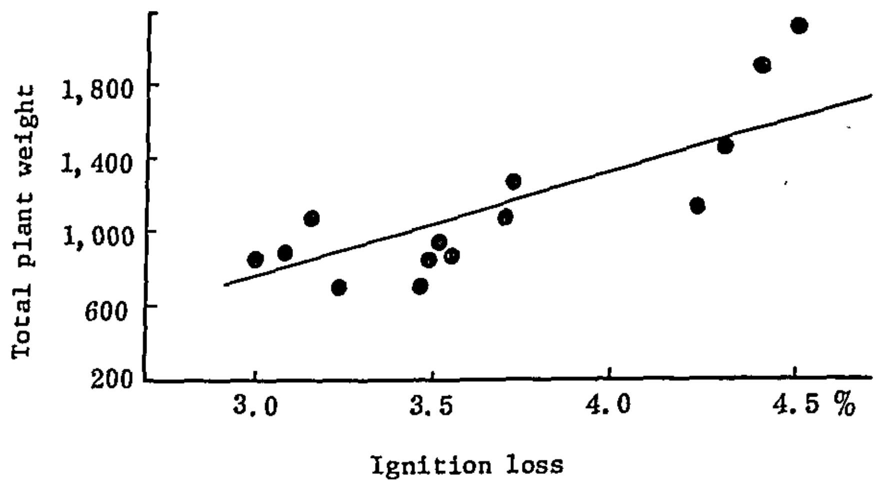


Fig. 10 Relation between ignition loss and total plant weight

(III) Studies on Recovery of Soil Fertility with Pasture "Brachiaria"

The soil after the cultivation of Brachiaria has higher productivity than that of natural grass. This is due to the excellent quantity, quality and distribution of roots in the soil. The number of cultivation years of Br needed for retaining ordinary crop production is examined as it relates to the number of rotation years between the pasture field and the crop field.

1. Test for recovery of soil fertility in desolate field

In the natural grassland which was one of the experiment field for test I and the soil fertility has been desolated by three consecutive croppings of cowpea, two test plots were set up, namely one was the natural grass plot left as it was and another the Brachiaria plot newly. The soil fertility of these two plots was examined according to the grade of plant (cowpea) growth.

(1) Testing method

a. Test plot: Natural Grass plot, Br plot

b. Area for test plot and testing plot system:

1 plot $4m^2$, Two plot system

c. Test treatment:

After the Br stocks were planted on Jan. 16, '75, the Br plot and the natural grass plot were left as they were for eight months. Afterwards, the top of each plant was mowed and taken away and cowpea was cultivated.

(2) Results and discussion

a. The predominant plant in natural grass plot had already changed from Gengibre to the grasses of Sebastiana sp and Mollugo sp and Waltheria sp (Table 29).

In the amount of top mowed, Br plot was air dried 7.0 kg/10 m^2, while that of the natural grass plot was 4.2 kg/10 m^2, which are very small in comparison with the green Br 86 kg/10 m^2 and the green natural grass 28 kg/10 m^2 after one year's growth in the newly cultivated plot (Test II). It depended on the poor soil fertility of desolate field.

b. The total plant weight and seeds of cowpea in the Br and the natural grass plots are as seen in Table 29. As for the total plant weight in the Br plot, it is about 520 g/10 m^2 which in equivalent to 133% of the natural grass plot 370 g/10 m^2. Though plant growth in unfavorable, Br soil is known to be more productive than the natural grass soil similar to the previous tests.

2. Soil fertility of Brachiaria pasture with different number of cultivation years

(1) Confirmation of result on soil fertility

The relation between the number of years of cultivation of Br and soil fertility was examined by the past results. The history of the test section - Table 30 referred to here is as follows;

Test II (carried off) 1 year: The pasture was cultivated for one year, the top was mowed and carried off and then cowpea was cultivated.

Test II (plowed-in) 1 year: The pasture was cultivated for one year and the top was mowed and the final amount of mowed top was plowed-in and then cowpea was cultivated.

Test II (carried off) 2 years: At the same time as the above test the pasture was planted and after two years' growth the top was mowed and carried off and then cowpea was cultivated. The sowing time of cowpea was a year later than in the above test, and simultaneous with the third cropping of the above test.

Test I (removed) 3 years: Each of pasture plot and natural grass plot had been cultivated separately for three years before the commencement of this test. The top was mowed and carried off and then cowpea was cultivated as mentioned above.

Table 29 Top Weight mowed of Brachiaria & Natural Grass after Eight Months Growth and the Plant Production of Cowpea in each Plot

Plot	Top mowed of pasture	Growth of Cowpea - Air dried g/10m^2				
	Air-dried weight kg/10m^2	Total plant weight	Seed weight	Seed/total plant weight (%)	Steam height (cm)	Ratio of Br/Natural grass in Total Plant weight
Brachiaria	7.0	521	267	49	19	133
Natural grass	4.2 (grass) 3.4 (tree)	392	148	38	19	100

Table 30 Total Plant Weight of Cowepea in Pasture and Natural Grass Land Soils with Different Number of Cultivation Years (air dried weight g/10m^2)

Plot / Cropping	Test II (carried-off) 1 year		Test II (plowed-in) 1 year			Test II (carried-off) 2 years		Test I (carried-off) 3 years	
	Br	Natural gross	Br	Pu	Natural gross	Br	Natural gross	Br	Natural gross
1st cropping	868	800	2,261	2,366	1,613	1,210*	993	2,906	986
2nd "	489	500	1,202	685	548			2,466	763
3rd "	618	405	486	275	308			455	371

* Sowing time is same as the 3rd cropping in other plots of Test II.

(2) Result and discussion

The longer the number of years Br is cultivated, the higher the soil fertility (plant growth of cowpea) becomes in the same field, and the high productivity is retained as longer as two croppings of cowpea. In this test, the top was removed under the assumption that it would be used for livestock fodder, leaving the root only as nutrient source for crops. It is considered that the number of cultivation years for a pasture required to maintain the standard productivity level for crops is at least three years in accordance with the observation of growth state of cowpea in the field.

(IV) Experiment on Effect of Application of Organic Matter and Chemical Fertilizer on Growth of Crop

The effect of chemical fertilization is considerably high, but it is thought that as it is expensive, it is not economical for general annual crops. Recently, this fertilization has been wide spread for cash crops such as the pepper plant. However, various problems have taken place. To make preparations for chemical fertilization in the future, the influence of this fertilization on the growth of crops was investigated, comparing with the application of organic matters.

1. Testing method

(1) Fertilizers applied for testing

Organic matter: Brachiaria foliage, its chemical component is as shown in Table 21.

Chemical fertilizers: Urea (N-45%), Fused Phosphate (P_2O_5-19%, CaO-30%, Mg-18%) Potassium Chloride (K_2O-60%)

(2) Test plot

In the total amount of main elements of fertilizer supplied, two general divisions of 100% and 50% were made and single applications and combinations of both organic matters and chemical fertilizers are distributed as follows:

Plot Number / Material	Plot of fertilizer application								
	100% section					Control	50% section		
	1	2	3	4	5	6	7	8	9
Chemical fertilizer	100%		25	50	75	0	50	-	25
Organic matter (Brachiaria foliage)		100	75	50	25	0		50	25

(3) Fertilizer amount

The 100% as the standard fertilizing amount was determined at Br dried 480 g/m^2 in the 1st test and Br dried 311 g/m^2 in the 2nd test respectively, and the fixed amount of fertilizer was calculated from element quantity rates of Br and the chemical fertilizer respectively.

(4) Applied crop for testing: Cowpea - '40 days'

(5) Plot area: 1 x 2 m = 2 m^2, 3 plots sytem

(6) Plant space: 50 x 25 cm

(7) Sowing and harvest times: Work schedule of test plot

Work schedule of test plot

Work / Test	Plot-in	Chemical fertilizing	Sowing	Harvest
1st time	2/6/'75	6/6/'75	9/6/'75	28/8/'75
2nd time	26/9/'75	26/9/'75	30/10/'75	15/1/'76

2. Results and discussion

- The investigation results are shown in Table 31.

(1) Rate of Germination:

In the first test, with a single use of chemical fertilizer, the rate of germination is very low, especially in the case of 100% chemical fertilizer. In the case of mixed use with organic matter, the more the amount of the chemical fertilizer, the lower the rate of germination. Moreover, in the case of a single use of organic matter, it is higher; and the higher the composition rate of organic matter, the higher the rate of germination becomes. In the second test this tendency was not clear.

(2) Beginning of flowering:

In the first test, it was observed that as the rate of germination increases flowering begins earlier.

(3) Growth and yield:

In the 100% chemical fertilizer plot of the first cropping as the germination was disturbed heavily, total plant weight was amended by the conversion with normal growth plants. The total plant weight in the first test is only a little higher in the 100% chemical fertilized plot compared with the 50% plot and in the case of mixed fertilizing, it is higher than that a single application of organic matter and chemical fertilizer respectively. Also, in the second test, in the case of 100% fertilized amount, there is the same tendency as in the first test and total plant weight and seed weight follow the same trend.

As the soil in this area is poor in the degree of base saturation and the amount of organic matter is also small the salt damage of chemical fertilizers is apt to occur. Application of organic matter removes this problem, and, mixed fertilization with organic matter increases the effect of fertilization in comparison with a single application of chemical fertilizer.

Table 31 Relation between Fertilization of Organic Matter and Chemical Fertilizer and Growth of Cowpea

Test plot / Item	100% section					Control	50% section		
	1	2	3	4	5	6	7	8	9
1st time: Growth									
1. Rate of germination (%)	17.2	77.6	52.6	31.3	26.6	82.3	43.8	82.8	36.5
2. Beginning of germination - June-date	17	14	14	16	16	14	16	14	16
3. Beginning of flowering - July-date	22	16	17	18	18	17	19	18	19
2nd time: Growth									
1. Rate of germination (%)	78	84	92	67	70	80	75	84	83
2. Beginning of flowering - Dec.-date	12	12	11	9	9	13	12	10	11
3. pH (H_2O) - 19/12	4.9	4.8	4.8	4.8	4.8	4.5	4.8	4.0	4.3
1st time: Plant growth									
1. Air-dried total plant weight ($g/10m^2$)	3,680	3,275	4,190	4,030	4,150	2,895	3,125	3,170	3,125
2. Seed weight ($g/10m^2$)	1,575	1,470	1,880	1,925	1,915	1,330	1,450	1,400	1,395
3. Seed weight/total plant weight (%)	43	45	45	48	46	46	46	44	45
2nd time: Growth									
1. Air-dried total plant weight ($g/10m^2$)	1,175	1,145	1,295	1,495	1,535	590	1,000	1,010	1,035
2. Seed weight ($g/10m^2$)	625	620	790	825	815	205	475	565	600
3. Seed weight/total plant weight (%)	53	54	61	55	53	35	48	56	57

(V) CONCLUSION

In this experiment it was concluded that the Brachiaria Pasture (gramineae) improved soil fertility beyond comparison with natural grass land. Though the soil whose fertility became poor by repeating croppings, soil fertility was recovered to maintain the standard growth of annual crops by a minimum of three years' Brachiaria cultivation. On one had, even in the soil reclaimed with short years' pasture cultivation, pasture roots were decomposed so rapidly that the normal production of cowpea, whose growing period is short at about two months, could not maintain more than two croppings. Even if pasture foliage and chemical fertilizer were applied in addition the production of the crop was raised higher but the period of high yield could not be extended longer than the two croppings of cowpea as mentioned above.

It may be said that two croppings of cowpea are similar as one or two croppings of common annual crops in one year from the viewpoint of growth period and consumption of soil fertility.

Shifting cultivation in this area requires much heavy labour to clear the forest at each reclamation time, and at the same time, not only the efficiency of land utilization but also land productivity are lower.

According to the data mentioned above the following agricultural development system in this area is rational and profitable, that is as soon as the forest is cleared, the field should be covered with pasture and livestock husbundary should take place.

At the time of annual crop cultivation a part of pasture is assigned to this crop for one or two croppings in one year. When the soil fertility is exhausted by these cultivations, the annual crop field is shifted to an adjoining part of the pasture.

In this improved system the annual crop field after one year cultivation is shifted to Brachiaria pasture for three years cultivation.

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