III. Application of Organic Materials and Chemical Fertilizer

1. Effects of Organic Material Application to Heavy Clay Paddy Soil (1974—1977)

Yutaka AKIYAMA
Yutaka ARITA
Prateep VERAPATTANANIRUND
Vichien SASIPRAPA

In order to clarify the effect of organic material application on soil physical and chemical properties and crop yield, field experiments were carried out in the paddy field of heavy clay; from 1974 to 1977 under the following method:

1) Maize and rice were cultivated alternately one after the other in the same field in the dry and wet seasons, respectively;
2) Organic materials, which are available to farmers such as rice straw, rice hull, corn stalks and sawdust, as well as synthesized soil conditioner were incorporated in the surface soil at the middle of December of each year in advance of upland cropping;
3) Plant growth and yield, and soil physical and chemical properties were analyzed during the experimental period.

Materials and methods

1. Descriptions on the soil
   a) Soil physical and chemical properties: The analytical results are shown in Table 1-1.
   b) Parent materials: Semi-recent alluvial deposits.
   c) Drainage: Poorly drained.
   d) Soil classification: Hydromorphic Non-Calcic Brown soils.
   e) Soil series: Manorom series
   f) Soil profile (examined on 28 November, 1974):

Apg	0-15 cm	Dark gray heavy clay (10Y 4/1) with some humus; few dark reddish brown filmy iron mottles (7.5R 3/4); sub-angular blocky structure, massive; few fine pore; very sticky.
A12g	15-25 cm	Olive gray (5Y 4/2) heavy clay; few to common brown filmy iron mottles (10YR 4/4); few manganese concretion; massive, few vertical cracks; very few fine pores; very sticky.
Blg	25-65 cm	Dull brown heavy clay (10YR 4/4); common, distinct brown spotty iron mottles; few manganese concretions; massive; very sticky; wet.

2. Cultivation practice
   (1) Cropping system
   Maize and rice were cultivated one after the other in the same field in dry and wet season, respectively, as shown in Table 1-2.
   (2) Treatment
   Materials applied: Rice straw, rice hull, corn stalks, sawdust, farmyard manure and synthesized soil conditioner. Their chemical qualities are shown in the Table 1-3.

Method and time of the application: Each of the materials was incorporated in surface soil at the middle of December of each year in advance of upland cropping; proper irrigation was made after the application to accelerate their decomposition.

Combination of treatment: 2 different levels for each of 4 organic materials such as rice straw, rice hull, corn stalks and sawdust; 1 level of the other 2, namely, farmyard manure and soil conditioner; and 2 controls as regards with or without fertilizers for upland crops (hereafter the latter will be referred to as non-fertilizer) were considered to be combined. Thus, 12 treatments were disposed to the experiment. Treatments are summarized in the Table 1-4 and Table 1-5.

(3) Layout and plot size

Randomized block design was employed; 12 plots with size of $90m^2$ (15m × 6m) for each were randomized three times, thus, number of plots were 36 in total.

(4) Spacing and Irrigation

Spacing for maize:	75cm × 25cm, 1 plant per hill (53,300 plants/ha)
rice:	25cm × 25cm, 3 plants per hill at the time of transplanting
Irrigation:	Furrow irrigation by means of syphone method

Results

1. Change in total carbon content of the soil after organic materials application

Change in total carbon content of the plots during two years (1974 — 75) are shown in Fig.1-1. The data obtained showed that the newly added organic matter to the soil was decomposed almost completely within the first year, and only a small portion of the organic matter remained in the form of humus to decompose gradually. In most of the plots, the similar trends were observed.

Changes in total carbon of the soil during three years are shown in Table 1-6. The plots to which large amount of organic matter was applied showed only a little increase in total carbon content of the soil after three years. It seemed that this increment of total carbon would be decomposed further. In case of the control plot to which total crop residues produced there were incorporated every year, total carbon content of the soil was maintained nearly constant.

2. Changes in physical properties of soil

(1) Bulk density

Measurements were made for cultivated soil at three different times; during maize cultivation, after harvest of maize and after harvest of rice. Although moisture contents of soil which affected bulk densities varied to some extent by the plots, bulk densities obtained at the same sampling time were compared among the plots.

As shown in Table 1-7 and 1-8, bulk densities of the plots to which organic materials were applied were lower than that of the control. Especially application of organic materials at high levels lowered the bulk density of soil. On the contrary, soil of Nf plot where small amount of crop residues were returned to soil because of the poor growth had comparatively high bulk density.

(2) Moisture retentivity of soil

Moisture properties of soils were mainly determined after the harvest of rice due to the following reasons: a) most of the organic materials plowed in had been decomposed by that time; b) differences of moisture retained by small pores among the plots could be shown clearly because the soil of every plot was packed evenly.

Table 1-9, 10, 11, 12 and 13 show the amount of moisture held under different moisture constants. The maximum moisture-holding capacity and the field capacity increased in the plots where organic matter was incorporated. The increase was mainly due to the increase in the amount of moisture with low pF value; the percentage of unavailable moisture decreased apparently.

Judging from the facts that there was little difference in total carbon content among the plots, such a high moisture retention capacity of the soil incorporated with organic matter may be explained by some changes in the soil structure including bulk density.

The similar trend was observed in dry season while maize was grown as shown in Table 1-14. Table 1-15 shows the comparison of soil moisture content between a control plot and the adjacent CS_s and CS_h plots for 4 seasons of maize. The soil moisture content of the plots where corn stalks were incorporated was generally higher in proportion to the amount of corn stalks incorporated.

(3) Pore space

The percentage of pore space increased by incorporation of organic matter in inverse proportion to the bulk density. Table 1-16 shows the distribution of equivalent diameters of pore spaces which have been calculated from pF — moisture curve. The amount of very fine pore space retaining unavailable moisture decreased while the amount of pore space such as capillary one retaining available moisture increased.

(4) Clod size distribution

The clod size distribution was measured after the first harrowing by rotavator after harvesting rice in 1976. As shown in Figure 1-2, fine clods less than 1cm in diameter clearly increased by the application of large amount of organic matter.

(5) Hardness of plow layer

To compare the hardness of soils among the plots, the resistance to intrusion of a conical body was measured by using a conepenetrometer 25 days after harvest of rice before plowing for the next crop. The average values of the resistance were lower in the plots where organic matter was incorporated than that of the control plots as shown in Fig. 1-3. It is concluded that there was a preferable effect of organic matter application on the improvement of hardness of the plow layer. However, there were no clear differences among the values of resistance determined for the subsoils.

(6) Depth of plow layer

The depth of plow layer was also determined simultaneously. Generally, plow layer was differentiated from the subsoil by several criteria such as hardness, structure, distribution of rice roots, etc. However, in practice, the difference in the depth of plow layer among the plots may be mainly due to the difference in resistance to the blades of cultivator. As shown in Figure 1-4, the depth of plow layer increased with the heavy application of organic matter. It resulted from the changes in several soil physical properties such as bulk density, breakability of clods, etc.

3. Changes in soil chemical properties by the application of organic materials

(1) Nitrogen content

The changes in nitrogen content of the soil was determined to clarify the role of organic matter as a nutrients reservoir. As shown in Fig. 1-5, both total and available nitrogen content of the soil increased by the application of organic materials. It suggests that application of organic materials contributes to the improvement of soil fertility.

(2) Reduction of the soil and changes in Fe (II) content

According to the aforementioned data on the total carbon content, organic materials seemed to be decomposed quickly after plowing into the soil. During the decomposition of organic materials in paddy soil, the growth of rice plant may be affected by reduction of the soil or by formation of Fe (II). Change in Eh value of the paddy soil which was treated with organic materials under laboratory conditions were shown in Figure 1-6. The soil treated with a large amount of rice straw or corn stalks was reduced faster than the soils done with other organic materials.

The Eh values were also measured in the field in 1975. The Eh values of plow layer at 35 days after transplanting rice are shown in Figure 1-7 in which the similar trend as the laboratory experiment is observed. Fe (II) which is formed as the results of reduction of the soil was found abundant in the plots where large amount of organic matter was applied. As mentioned above, several factors which might retard the growth of rice were found to have occurred during the decomposition of organic materials. However, the yield of rice was increased from the second year after initiation of heavy application of organic materials as listed in Table 1-20. Therefore, injurious effects of organic materials to the growth of rice plant seemed negligible.

4. The growth and yield of crops

(1) Maize

Maize was grown under irrigation during the dry season. The yields showed the same trend by the treatment for four years (Table 1-18 and 19). Namely, except the farmyard manure applied plot which showed increase in the yield, most of the plots where organic matter was applied especially in a large amount showed poor growth and yields. In these plots, the poor yield seemed to be affected by the poor growth in their initial stage (Table 1-17). The poor growth of maize in some plots to which undecomposed organic matter was incorporated could be caused by nitrogen deficiency, judging from the following facts: i) the color of leaves was yellowish, and ii) an experiment which was conducted in 1977 revealed that the damage which could be caused by heavy application of rice straw was lessened by application of nitrogen.

Maize was sown one month after the incorporation of organic matter; however nitrogen deficiency must have been caused temporarily due to the immobilization of inorganic nitrogen during the decomposition of organic matter added.

(2) Rice

Yield of rice was not affected much by the treatments as was observed in the case of maize. As shown in Table 1-20 and 21, the plots where organic matter was applied (RS, CS and SD) increased the yield since the second year. On the contrary, the farmyard manure plot did not show any increase in the yield, but clearly high yield was recorded in the fourth year. The fact suggested that there was a residual effect of organic matter. That is, the farmyard manure plot could produce bigger amount of corn stalks; therefore the growth of rice successively planted might be strongly affected by the corn stalks incorporated. However, the corn stalks was not incorporated in the fourth year before planting rice, so that the detrimental effect of corn stalks on the growth of rice must have been avoided.

Discussion

The application of organic materials to heavy clay soils resulted in a decrease in bulk density and increase in available moisture holding capacity and depth of plow layer as well as improved tiller workability which was shown by clod size distribution. Judging from the results obtained, it can be said that the purpose of this experiment, to improve physical properties of heavy clay soils through the application of organic materials, has been attained to some extent.

However, the improvement attained within four years of the experimental period was not so prominent. The application of organic materials should be continued. Although it is difficult for farmers under the present conditions to apply organic matter in such large amounts as was done in this experiment, the amount of organic matter available for plowing into the soils surely increases through the practice of double cropping. In this study for example, total amount of rice straw and corn stalk in the control plot reached 8 tons per hectare in 1977.

Organic matter application causes not only an increase in yield due to an increase in the supply of nutrients but also causes a detrimental effect on the growth of crops during the decomposition of organic materials. In this study, organic matter had detrimental effect on the initial growth of maize by causing nitrogen starvation which resulted in yield decrease. The nitrogen starvation caused by the application of organic matter can be avoided by delaying the time of sowing. Application of organic matter had a beneficial effect on the growth of rice, but it was less effective when large amounts of corn stalk were incorporated. It is desirable, therefore, that crop residues are not plowed into the soil before subemerging, but to be applied in the form of farmyard manure after harvesting rice.

Table 1-1. Mechanical and chemical composition of soil of the experimental field

Horizon	Depth	Particle size distribution Sand	Silt	Clay	Texture	Total Carbon	Total Nitrogen
	cm	%	%	%		%	%
Apg	0—15	15.7	30.4	53.1	HC	1.43	0.114
Alg	15—25	14.8	26.5	58.3	HC	0.92	0.076
Blg	25—65	11.7	22.9	64.5	HC	0.56	0.046

Horizon	pH	CEC	Exchangeable cation m.e./100g Ca	Mg	Na	K	Degree of basic ion saturation
		m.e. 100g					%
Apg	5.8	21.7	8.3	3.4	0.8	0.6	60
Alg	5.3	18.4	9.5	3.6	1.7	0.4	83
Blg	5.5	19.7	14.1	3.4	2.3	0.4	100

Horizon	Available Nitrogen before incubation	increase through incubation	Available P_2O_5
	ppm	ppm	ppm
Apg	28.1	23.2	27
Alg	16.2	9.7	13
Blg	—	—	3

Remarks: 1) soil samples were collected before the first application of organic materials.
2) Available nitrogen is sum of NH_4-N and NO_3-N.

Table 1-2. Cropping system in the experiment

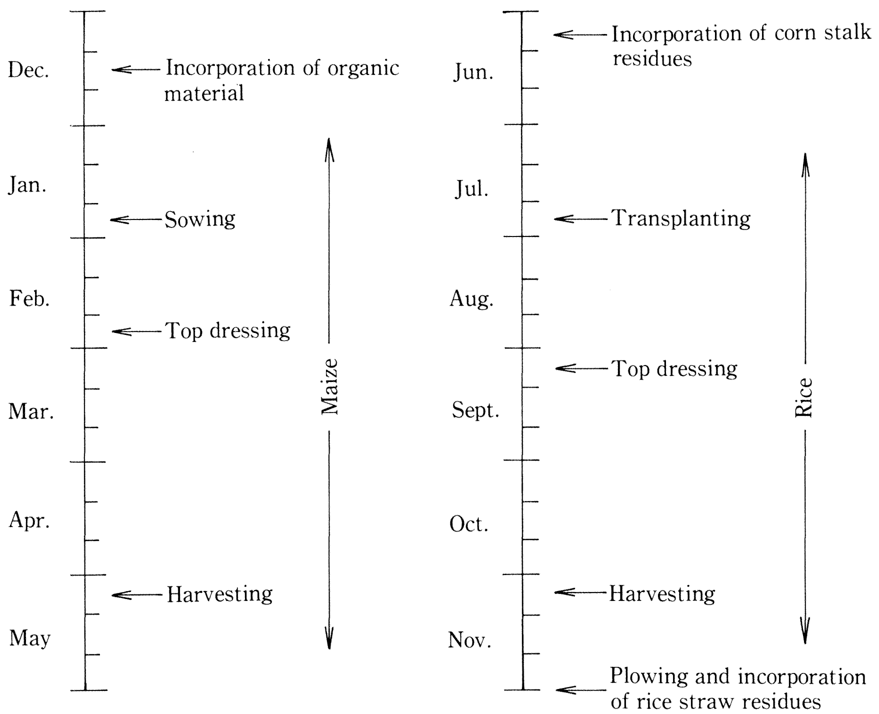


Table 1-3. Chemical qualities of organic materials*

Materials	Total carbon	Total Nitrogen	C/N	Ca	Mg	Na	K
	%	%		ppm	ppm	ppm	ppm
Rice straw	24.1	0.35	68.3	1600	1200	2150	7500
Rice husk	26.5	0.25	107.3	400	180	280	2780
Corn stalk	27.4	1.12	24.5	3200	160	550	15500
Saw dust	29.7	0.14	215.2	1800	100	400	350
Farmyard manure	8.4	1.06	7.9	—	—	—	—
Soil conditioner	3.1	1.21	2.6	800	25	9750	380

* Chemical qualities were determined for the organic materials applied in the second year.

Table 1-4. Experimental design

Plot	Material carried in	amount carried in 1974	1975	1976	1977	Level of organic material application
		t/ha	t/ha	t/ha	t/ha	
Nf	None (No fertilizer for maize)	0	0	0	0	(1)
Cf	None (control)	0	0	0	0	(1)
RS_s	Rice Straw Standard	6	6	6	6 (5.1)	(2)
RS_h	Rice Straw Heavy	18	12	12	12 (10.3)	(3)
RH_s	Rice Hull standard	0.5	3	3	3 (2.7)	(2)
RS_h	Rice Hull Heavy	2.5	9	9	9 (8.1)	(3)
CS_s	Corn stalk Standard	7	7	7	7 (5.3)	(2)
CS_h	Corn stalk Heavy	21	21	21	21 (15.9)	(3)
SD_s	Saw dust Standard	6	6	6	6 (4.2)	(2)
SD_h	Saw dust Heavy	18	18	18	18 (12.7)	(3)
Fm	Farmyard manure	4	30	30	30 (11.7)	(3)
HM	soil conditioner (HAMO)	4	4	4	----	(1)
RS_{hc}	Rice Straw Heavy	—	—	—	12 (10.3)	
Application date		Dec. 12, 1973	Dec. 12, 1974	Dec. 24, 1975	Dec. 14 1976	

Remarks:
1) Figures in parentheses in the column of 1977 show the weight of dry matter.
2) Organic materials were applied and mixed two times by rotary cultivator 40—45 days before sowing maize.
3) Preceding crop residues in the field were plowed into the plots in the experiment of 1974—1976. Namely, only a half amount of rice straw (2.0—2.5 t/ha) produced in the plot was incorporated 40—45 days before sowing mazie. In case of maize, most of the stalk (about 3 t/ha) were incorporated 40 days before transplanting rice. In the experiment of 1977 those crop residues were not incorporated.
4) In the experiment conducted in 1977, HM plots were changed to RS_{hc} plots to know the effect of nitrogen immobilization in the soil on the growth of maize.

Table 1-5. Amounts of fertilizers applied

		Maize		Rice	
		Basal	Top	Basal	Top
		kg/ha	kg/ha	kg/ha	kg/ha
1974	N	50	25	50	25
	P_2O_5	75	0	75	0
	K_2O	50	0	75	0
1975	N	75	50	20	10
	P_2O_5	50	0	25	0
	K_2O	40	0	15	0
1976	N	75	35	20	17.5
	P_2O_5	75	0	25	0
	K_2O	50	0	12.5	0
1977	N	75* 125**	50	20	17.5
	P_2O_5	75	0	25	0
	K_2O	50	0	12.5	0

Remarks: 1) * Applied to every plot except RS_{hc}.
** applied to RS_{hc} plot only.
2) In the Nf plot the fertilizers were applied to rice only.
3) Kinds of fertilizer used.
N : Ammonium sulfate
P_2O_5 : Double super phosphate
K_2O : Potasium chrolide

Table 1-6. Effect of organic material application on total carbon content of soil

Treat.	Nov. 28, 1974	Nov. 26, 1975	Nov. 24, 1976
	%	%	%
Nf	1.37	1.38	1.51
Cf	1.39	1.41	1.38
HM	1.41	1.38	1.47
[(1) mean]	1.39	1.39	1.45
RS_s	1.44	1.40	1.64
RH_s	1.43	1.44	1.44
CS_s	1.42	1.42	1.77
SD_s	1.45	1.52	1.47
[(2) mean]	1.44	1.45	1.58
RS_h	1.50	1.55	1.69
RH_h	1.44	1.56	1.70
CS_h	1.54	1.58	1.77
SD_h	1.48	1.59	1.59
Fm	1.39	1.38	1.69
[(3) mean]	1.47	1.53	1.69

Remarks: Total carbon content of soil at the initiation of the experiment (Dec. 12, 1973) was 1.435.
(1), (2) and (3) indicate the levels of organic materials application (see Table 1-4).

Table 1-7. Bulk density of surface soil determined at maturing sage of maize

Treat.	1974 (Apr. 9)	1975 (Jun. 5)	1976 (May 3)	1977 (Apr. 12)
Nf	1.40	1.38	1.27	1.34
Cf	1.11	1.22	1.22	1.23
HM-RS_{hc}	1.20	1.15	1.24	1.25
[(1) mean]	1.24	1.25	1.24	1.27
RS_s	1.12	1.17	1.17	1.19
RH_s	1.24	1.15	1.26	1.18
CS_s	1.15	1.17	1.16	1.20
SD_s	1.03	1.21	1.15	1.17
[(2) mean]	1.14	1.18	1.19	1.19
RS_h	1.05	1.14	1.14	1.16
RH_h	1.06	1.15	1.18	1.23
CS_h	1.13	1.17	1.06	1.10
SD_h	1.09	1.12	1.09	1.08
Fm	1.16	1.19	1.22	1.17
[(3) mean]	1.10	1.15	1.14	1.15

Remarks: (1) Bulk density determined at the initiation of the experiment (Dec. 12, 1973) was 1.35.
(2) Bulk density were determined for soils of inter-raw space.

Table 1-8. Bulk density of surface soil determined after harvest of rice

Treat.	1974 (Nov. 28)	1975 (Nov. 26)	1976 (Nov. 24)	1977 (Nov. 24)
Nf	1.34	1.33	1.42	1.49
Cf	1.30	1.20	1.24	1.47
HM-RS_{hc}	1.32	1.04	1.23	1.38
[(1) mean]	1.32	1.19	1.30	1.45
RS_s	1.23	1.21	1.29	1.47
RH_s	1.30	1.23	1.26	1.42
CS_s	1.17	1.13	1.25	1.49
SD_s	1.19	—	1.23	1.43
[(2) mean]	1.22	1.19	1.26	1.45
RS_h	1.30	1.13	1.29	1.34
RH_h	1.20	1.17	1.22	1.45
CS_h	1.27	1.05	1.21	1.28
SD_h	1.32	—	1.21	1.42
Fm	1.23	1.21	1.24	1.37
[(3) mean]	1.26	1.14	1.23	1.37

Remarks: (1) Bulk density determined on Dec. 12, 1973 was 1.35.
(2) Bulk density was determined around three weeks after harvest of rice.

Table 1-9. Status of soil moisture observed after harvest of rice

Treat.	Moisture at pF O	Water		
		Gravitational	Available	Unavailable
	%	%	%	%
Nf	31.1	2.5	26.7	70.8
Cf	36.8	4.5	29.0	66.5
HM	36.9	6.2	27.6	66.2
[(1) mean]	34.9	4.4	27.8	67.8
RS_s	37.4	4.9	26.2	66.9
RH_s	37.2	3.5	34.4	62.1
CS_s	37.1	3.5	28.6	67.9
SD_s	37.7	5.0	29.2	65.8
[(2) mean]	37.4	4.2	29.6	65.7
RS_h	36.2	5.0	33.7	61.3
RH_h	39.2	4.3	29.3	66.4
CS_h	40.2	7.0	33.6	59.4
SD_h	39.5	3.8	29.4	66.8
Fm	37.2	2.7	31.7	65.6
[(3) mean]	38.5	4.6	31.5	63.9

Remarks: (1) Gravitational water pF 0—1.5
(2) Available water 1.5 ~ 4.0
(3) Unavailable water >4.0
(4) Determinations were made on Nov. 24, 1976.

Table 1-10. Total pore volume and soil moisture status of soil determined after harvest of rice

Treat.	Total pore space (vol.%)	Soil moisture (vol. %)		
		Gravitational	Available	Unavailable
		%	%	%
Nf	45.4	1.1	11.8	31.1
Cf	52.3	2.1	13.3	30.3
HM	52.7	2.8	12.5	30.1
[(1) mean]	50.1	2.0	12.5	30.5
RS_s	50.4	2.4	12.7	33.3
RH_s	51.5	1.6	16.1	29.1
CS_s	51.9	1.6	13.2	31.7
SD_s	52.7	2.4	13.5	30.5
[(2) mean]	51.6	2.0	13.9	31.2
RS_h	50.4	2.3	15.6	28.6
RH_h	53.1	2.0	14.1	31.7
CS_h	53.5	3.4	16.3	29.0
SD_h	53.5	1.8	14.8	32.0
Fm	52.3	1.2	14.6	30.2
[(3) mean]	52.6	2.1	15.1	30.3

Remarks: Determinations were made on Nov. 24, 1976.

Table 1-11. Contents of soil moisture retained at pf 1.5 which were determined after harvest of rice

Treat.	Bulk density	Moisture at pF 1.5	Three phase distribution at pF 1.5			
			Solid	Liquid	Air	Liquid/Solid
		%	%	%	%	
Nf	1.42	30.2	54.6	42.8	2.6	0.78
Cf	1.24	35.1	47.7	43.5	8.8	0.91
HM	1.23	34.6	47.3	42.6	10.1	0.90
[(1) mean]	1.30	33.3	49.9	43.0	7.2	0.86
RS_s	1.29	35.6	49.6	45.9	4.5	0.93
RH_s	1.26	35.9	48.5	45.2	6.3	0.93
CS_s	1.25	35.9	48.1	44.8	7.1	0.93
SD_s	1.23	35.8	47.3	44.0	8.7	0.93
[(2) mean]	1.26	35.8	48.4	45.0	6.7	0.93
RS_h	1.29	34.4	49.6	44.4	6.0	0.90
RH_h	1.22	37.5	46.9	47.7	5.4	1.02
CS_h	1.21	37.4	46.5	45.3	8.2	0.97
SD_h	1.21	38.1	46.5	46.1	7.4	0.99
Fm	1.24	36.2	47.7	44.8	7.5	0.94
[(3) mean]	1.23	36.7	47.4	45.6	6.9	0.96

Remarks: Determinations were made on Nov. 24, 1976.

Table 1-12. Moisture content at pF 2.0 of soil after harvest of rice

Treat.	Bulk density	Moisture at pF 2.0	Three phase distribution at pF 2.0			
			Solid	Liquid	Air	Liquid/Solid
		%	%	%	%	
Nf	1.42	28.7	54.6	40.7	4.7	0.75
Cf	1.24	34.6	47.7	42.8	9.5	0.90
HM	1.23	33.1	47.3	40.7	12.0	0.86
[(1) mean]	1.30	32.1	49.9	41.4	8.7	0.84
RS_s	1.29	35.0	49.6	45.1	5.3	0.91
RH_s	1.26	34.7	48.5	43.7	7.8	0.90
CS_s	1.25	33.9	48.1	42.4	9.5	0.88
SD_s	1.23	34.8	47.3	42.8	9.9	0.90
[(2) mean]	1.26	34.6	48.4	43.5	8.1	0.90
RS_h	1.29	33.6	49.6	43.3	7.1	0.87
RH_h	1.22	36.1	46.9	44.0	9.1	0.94
CS_h	1.21	36.5	46.5	44.2	9.3	0.95
SD_h	1.21	37.2	46.5	45.0	8.5	0.96
Fm	1.24	34.4	47.7	42.7	9.6	0.90
[(3) mean]	1.23	35.6	47.4	43.8	8.7	0.92

Remarks: Determinations were made on Nov. 24, 1976.

Table 1-13. Available moisture holding capacity of Soil

Treat.	Available	Available pore space	Available pore space /Solid phase
	wt. %	Vol. %	
Nf	8.3	11.8	0.21
Cf	10.7	13.3	0.28
HM	10.2	12.5	0.26
[(1) mean]	9.7	12.5	0.25
RS_s	9.8	12.7	0.25
RH_s	12.8	16.1	0.33
CS_s	10.6	13.2	0.27
SD_s	11.0	13.5	0.29
[(2) mean]	11.1	13.9	0.29
RS_h	12.2	15.6	0.32
RH_h	11.5	14.1	0.30
CS_h	13.5	16.3	0.35
SD_h	11.6	14.8	0.30
Fm	11.8	14.6	0.31
[(3) mean]	12.1	15.1	0.32

Remarks: (1) Soil samples were taken on Nov. 24, 1976.
(2) Available moisture holding capacity was determined as the difference between the field capacity (pF 1.5) and the wilting point (pF 4.0) of soil.

Table 1-14. Moisture content at pF 1.5 of soil at maturing stage of maize

Treat.	Bulk density	Moisture at pF 1.5	Three phase distribution at pF 1.5 Solid	Liquid	Air	Liquid/Solid
		%	%	%	%	
Nf	1.34	29.2	51.5	39.1	9.4	0.76
Cf	1.23	32.3	47.3	39.7	13.0	0.84
HM	1.25	32.6	48.1	40.8	11.1	0.85
[(1) mean]	1.27	31.4	49.0	39.9	11.2	0.82
RS_s	1.19	32.7	45.8	38.9	15.3	0.85
RH_s	1.18	33.6	45.4	39.6	15.0	0.87
CS_s	1.20	32.9	46.2	39.8	14.0	0.86
SD_s	1.17	33.6	45.0	39.3	15.7	0.87
[(2) mean]	1.19	33.2	45.6	39.4	15.0	0.86
RS_h	1.16	36.9	44.6	42.8	12.6	0.96
RH_h	1.23	32.5	47.3	40.0	12.7	0.85
CS_h	1.10	33.7	42.3	37.1	20.6	0.88
SD_h	1.08	34.3	41.5	37.0	21.5	0.89
Fm	1.17	35.7	45.0	41.8	13.2	0.93
[(3) mean]	1.15	34.6	44.1	39.7	16.1	0.90

Remarks: Determinations were made on Apr. 12, 1977.

Table 1-15. Moisture content of surface soil determined during maize growing period

Date / Treat	1974 Apr. 9	1975 Jan. 29	Mar. 10	Jun. 5	1976 May 3	1977 Mar. 21	Apr. 12	Average
	%	%	%	%	%	%	%	%
CS_h	34.5	37.0	30.2	17.9	26.4	21.7	22.3	27.1
Cf	21.6	29.6	26.4	17.7	21.8	19.3	19.5	22.3
CS_s	27.4	32.0	28.8	18.9	25.5	23.2	22.8	25.5

Table 1-16. Pore size distribution

Treat.	Total pore space	Equivalent diameter (mm) > 0.1 (<pF 1.5)	0.1~0.0003	< 0.0003 (> pf 4.0)
		%	%	%
Nf	45.4	5.2	25.9	68.9
Cf	52.3	16.8	25.4	57.8
HM	52.7	19.1	23.7	57.2
(mean)	50.1	13.7	25.0	61.3
RS_s	50.4	9.0	25.1	65.9
RH_s	51.5	12.3	31.3	56.4
CS_s	51.9	13.6	25.4	61.0
SD_s	52.7	16.5	25.6	57.9
(mean)	51.6	12.8	26.9	60.3
RS_h	50.4	11.9	31.3	56.8
RH_h	53.1	13.9	26.4	59.7
CS_h	53.5	15.5	30.5	54.0
SD_h	53.5	13.2	27.5	59.3
Fm	52.3	14.2	27.9	57.9
(mean)	52.6	13.7	28.7	57.5

Remarks: (1) Soil samples were taken on Nov. 24, 1976.
(2) Size of pore was determined by pF — moisture curve.

Table 1-17. Plant height of maize in the early growth stage

(Expressed by percentage based on Cf plot)

Treatment	1974	1975	1976	1977
Nf	46	74	63	63
Cf	100	100	100	100
RS_s	86	98	100	92
RS_h	58	100	89	87
RH_s	92	109	100	90
RH_h	94	98	96	93
CS_s	80	102	95	89
CS_h	63	87	96	79
SD_s	79	94	104	95
SD_h	82	89	94	93
Fm	95	98	106	102
HM	91	103	96	—
RS_{hc}	—	—	—	93
days after sowing	30	26	28	27

Remarks: In 1975, maize was sown three month after application of organic materials.

Table 1-18. Grain yield of maize
(Moisture content 14%)

Treat.	1974[1]		1975[2]		1976		1977	
	Amount	Index	Amount	Index	Amount	Index	Amount	Index
	Kg/ha		Kg/ha		Kg/ha		Kg/ha	
Nf	6	1	750	37	210	13	421	10
Cf	643	100	2,010	100	1,582	100	4,414	100
RS_s	582	91	2,000	100	1,010	64	3,856	88
RS_h	278	43	1,920	96	583	37	2,628	60
RH_s	589	92	2,010	100	1,108	70	3,947	90
RH_h	636	99	2,180	108	1,122	71	3,331	76
CS_s	503	78	1,900	95	1,072	68	3,551	81
CS_h	763	119	1,960	98	860	54	2,137	49
SD_s	464	72	1,890	94	1,167	74	3,317	75
SD_h	494	77	1,780	89	492	31	2,538	53
Fm	817	127	2,120	105	1,862	118	4,829	110
HM	625	97	1,770	88	1,304	82	—	
RS_{hc}	—		—		—		4,564	103
Variety	P B 5		DMR-6		DMR-6		Suwan No.1	

Remarks 1) The crops were damaged by hail storm.
2) DMR-6 was grown in place of PB5 that was ceased to grow at the middle stage of the growth because of serious infection with downy mildow.

Table 1-19. Dry matter production of maize

	1974		1975		1976		1977	
	Weight	Index	Weight	Index	Weight	Index	Weight	Index
	Kg/ha		Kg/ha		Kg/ha		Kg/ha	
Nf	992	19	2,657	49	1,368	32	2,384	21
Cf	5,180	100	5,426	100	4,275	100	11,084	100
RS_s	4,756	92	5,315	98	4,090	96	9,375	84
RS_h	3,047	59	5,216	96	2,832	66	7,197	65
RH_s	4,415	85	5,419	100	4,096	96	9,974	90
RH_h	4,714	91	5,596	103	4,228	99	8,769	79
CS_s	4,046	78	5,190	95	4,125	97	9,134	82
CS_h	—		5,236	96	2,859	67	6,370	57
SD_s	4,320	83	5,274	97	5,174	121	8,640	78
SD_h	3,936	76	5,026	92	2,789	65	7,196	65
Fm	4,779	92	5,547	102	5,520	129	11,956	108
HM	4,787	92	5,278	97	4,598	108	—	
RS_{hc}	—		—		—		10,725	97
Variety	P B 5		DMR-6		DMR-6		Suwan No.1	

Table 1-20. Grain yield of rice
(Moisture content 14%)

	1974[1]		1975[2]		1976		1977	
	Amount	Index	Amount	Index	Amount	Index	Amount	Index
	Kg/ha		Kg/ha		Kg/ha		Kg/ha	
Nf	3,675	92	3,111	88	4,752	100	4,109	94
Cf	3,990	100	3,527	100	4,826	100	4,383	100
RS_s	3,972	100	3,668	104	5,053	106	4,588	105
RS_h	3,985	100	3,735	106	4,952	103	4,860	111
RH_s	3,950	99	3,481	99	4,797	101	4,586	105
RH_h	3,940	99	3,472	98	4,838	102	4,555	104
CS_s	3,764	94	3,632	103	4,575	96	4,584	105
CS_h	3,921	98	3,984	113	4,951	104	4,741	108
SD_s	4,128	104	3,625	103	4,896	103	4,444	101
SD_h	4,035	101	3,821	108	4,828	102	4,848	111
Fm	3,835	96	3,752	106	4,782	100	4,888	112
HM	3,673	92	3,176	90	4,681	98	—	—
RS_{hc}	—	—	—	—	—	—	4,335	99
Variety	RD-1					RD-7		

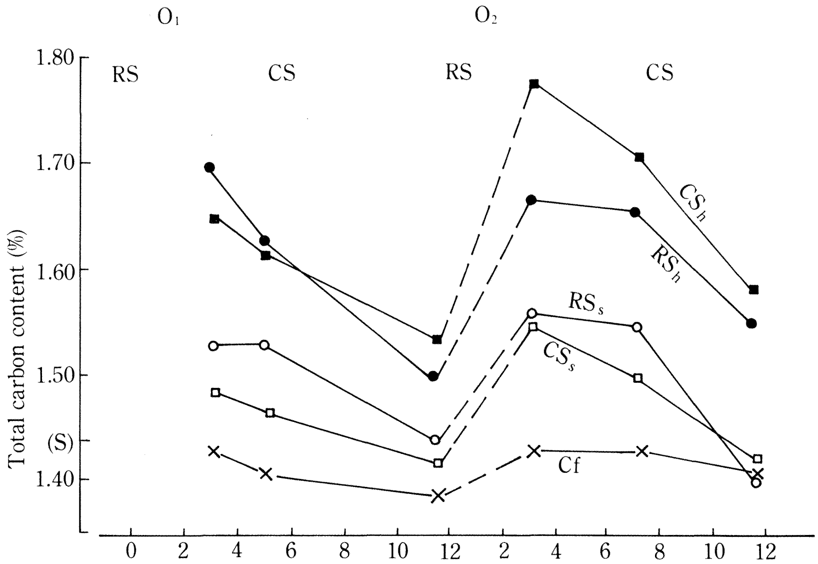
Table 1-21. Dry matter production of rice

	1976		1977	
	Amount	Index	Amount	Index
Nf	9,152	92	7,488	94
Cf	9,901	100	7,953	100
RS_s	10,067	102	8,892	112
RS_h	9,643	97	9,770	123
RH_s	10,189	103	9,048	114
RH_h	9,547	96	9,120	115
CS_s	9,960	101	9,068	114
CS_h	10,668	108	9,800	123
SD_s	10,595	107	8,262	104
SD_h	10,264	104	9,515	120
Fm	10,285	105	10,070	127
HM	9,291	94	—	—
RS_{hc}	—	—	9,073	114

Table 1-22. Annual dry matter production in 1977

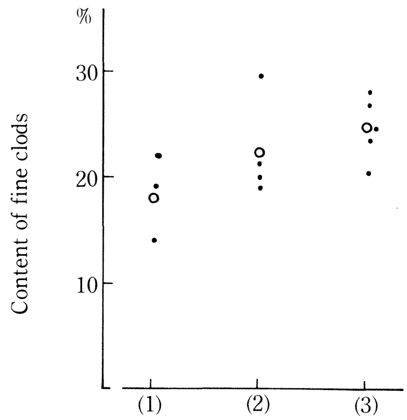
Treat.	Weight	Index
	Kg/ha	
Nf	9,872	54
Cf	19,037	100
RS_s	18,267	96
RS_h	16,967	89
RH_s	19,022	100
RH_h	17,889	94
CS_s	18,202	96
CS_h	16,170	85
SD_s	16,902	89
SD_h	16,711	88
Fm	22,026	116
RS_{hc}	17,830	94

Remarks: Sum of dry matter production of maize and rice.



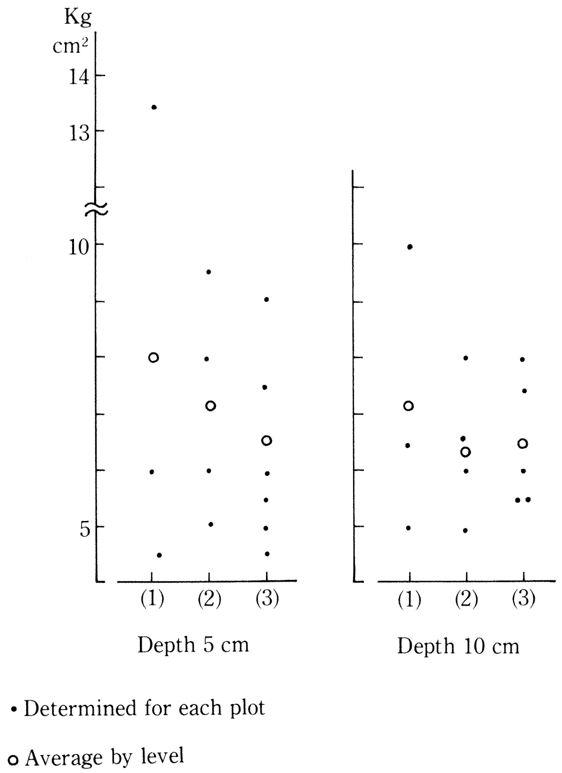
S : Total carbon content of soil determined before the initiation of the experiment
O_1 : First application of organic material
O_2 : Second application of organic material
RS : Incorporation of rice straw residues
CS : Incorporation of corn stalk residues

Fig. 1-1. Change in total carbon of soil after the first and second application of organic material (1974—1975)



Level of organic material application
• Content of fine clods of each plot
o Average by level

Fig. 1-2. Content of fine clods (<1 cm) of soil after first cultivation (after harvest of rice, 1976)



Remarks: (1) The determination was made one month after harvest of rice. Soil hardness was measured by using a SR II — conepenetrometer (cone with a cross section of 2 cm^2).
(2) Hardened dry soil on the surface was removed before the determination.
(3) The results are shown as resistance to the intrusion of the conical body into soil.

Fig. 1-3. Hardness of surface soil

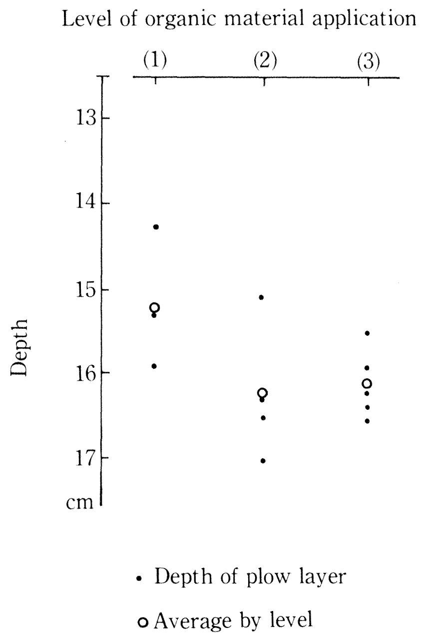
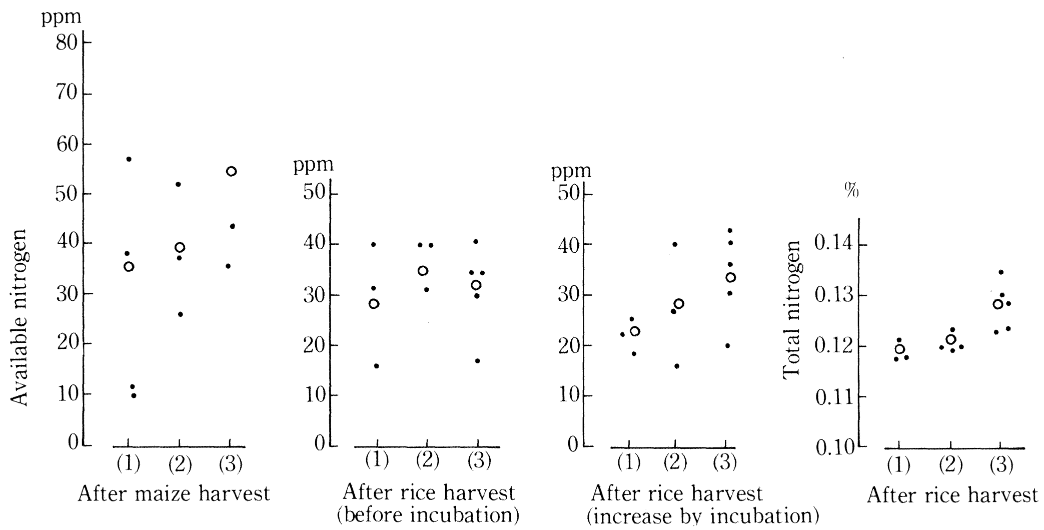


Fig. 1-4. Depth of plow layer



Remarks: • Determined for each plot
o Average by level of organic materials application
(1), (2) and (3) mean the levels of organic materials application.

Fig. 1-5. Total and available nitrogen content of soil (1975)

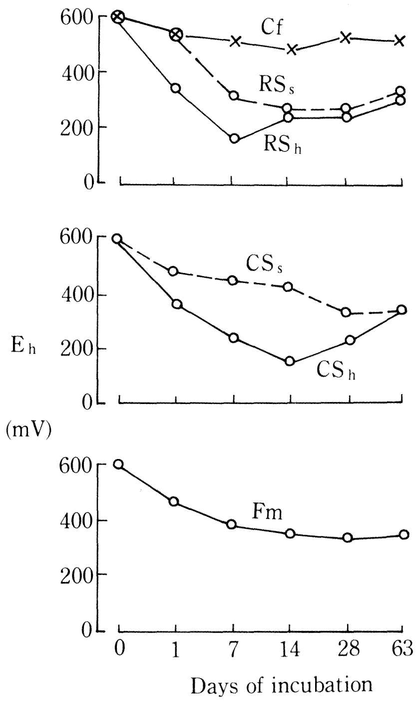


Fig. 1-6. Successive changes in E_h of soil incubated in laboratory (Soil samples were taken 1.5 month after the second application of organic materials — 1975)

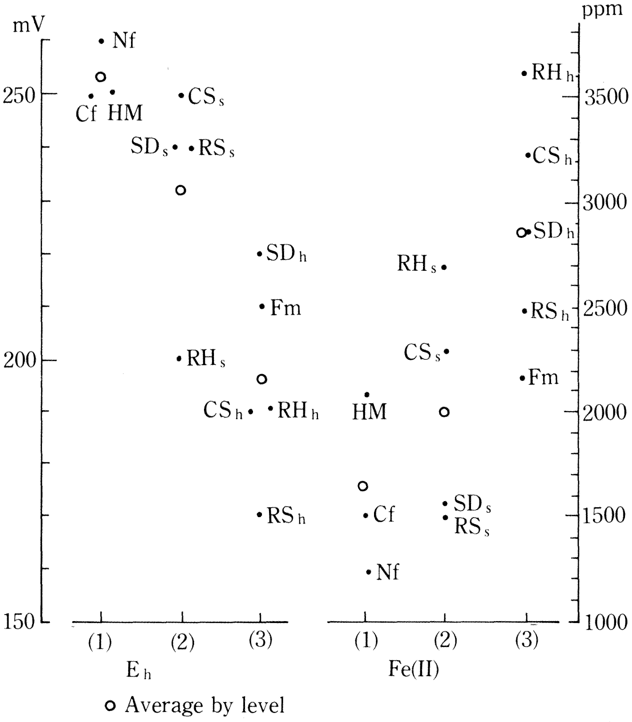


Fig. 1-7. E_h value and Fe(II) content of surface soil determined 35 days after transplanting of rice (1975)