HARDENING OF PADDY FIELD FOR MECHANIZATION OF HARVESTING

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ABSTRACT

The cropping schedule of rice in the Muda area requires the rapid performance of a sequence of farm operations stretching from harvesting of the off-season crop to transplanting of the main season crop. However, the acute labor shortage in the area makes the rapid performance of these operations difficult. The mechanization of harvesting would be an essential step to the stabilization of double cropping of rice.

Two methods for the hardening of a paddy field in the rainy season to facilitate the operation of harvesters were tested. The drainage of surface water from the experimental fields was difficult because of the unevenness of their surface. Moreover, based on laboratory tests and the analysis of long term rainfall data it was evident that the hardening of a paddy field by drying in the rainy season was not possible due to the limited number of continuous fine days.

It was, however, possible to maintain the soil hardness required for the operation of a medium-sized combine harvester even under inundated field conditions by hardening the field soil through a prolonged dry season fallow and by using a low-ground-contact-pressure tractor equipped wiht a shallow-plowing tiller.

Introduction

The Muda Irrigation Project Area where double cropping of rice was achieved under the first Five Year Plan (1966–1970) accounted for 44% of all the double cropping area in West Malaysia in 1974. For the stabilization of double cropping in the Muda area, it is necessary to alleviate the acute labor shortage that became apparent with the double cropping practice in the area.

According to the cropping schedule proposed by the Muda Agriculture Development Authority (hereafter referred to as MADA), the main season crop (rainy season crop) has to be harvested at the beginning of the dry season, approximately in December. After a sufficiently long fallow period, the off-season crop (dry season crop) has to be transplanted by the end of the dry season, approximately in March. Harvesting of the off-season crop and transplanting of the main season crop should take place from July to September. This period coincides with the rainy season.

However, the cropping schedule has been markedly disorganized due to the acute labor shortage for harvesting. The mechanization of harvesting is thus essential to cope with the labor shortage; however, the weak soil foundation of the paddy fields hampers the promotion of mechanization. Especially, the field soil is soft and weak during the rainy season when harvesting of the off-season crop is scheduled.

The soil of the paddy fields has to be hardened to enable the harvesters to operate satisfactorily. The following two methods were tested in the Muda area from 1974 to 1977: (1) Drying of the paddy fields even in the rainy season; (2) Maintenance of the soil hardness required for the operation of harvesters under inundated field conditions (ANYOJI and THAVARAJ, 1977).

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Rainfall and soil

Annual rainfall in the Muda area is about 2,400 mm. Rainfall from August to November accounts for about 50% of the annual rainfall and this period is called the wet season. Rainfall from April to July accounts for about 36% of the annual rainfall and this period is called the intermediate season. Rainfall from December to March accounts for about 14% of the annual rainfall and this period is called the dry season.

Numbers of fine days and continuous fine days were analysed based on daily rainfall data recorded at 7 rainfall stations from 1955 to 1974. It is anticipated that in December and January of each year there will be 22 fine days and 10 continuous fine days, and 25 fine days and 12 continuous fine days, respectively. These two months coincide with the harvesting period of the main season crop.

In July when harvesting of the off-season crop is scheduled, it is anticipated that there will be 17 fine days and 6 continuous fine days each year. However, most of the off-season crop is actually harvested in August or later. The field conditions for drainage and drying in August are less favorable than those in July.

The Muda area consists of four districts as shown in Fig. 1: the districts I, II, and IV are located along the Straits of Malacca and district III is located on a mountain side. The area is covered mostly with heavy clayey marine soils (WENG, 1972). Table 1 shows the physical characteristics of the Muda soils sample from 89 fields in districts I, II, and IV under inundated field conditions during the cultivation period of the off-season crop. It is very difficult to drain

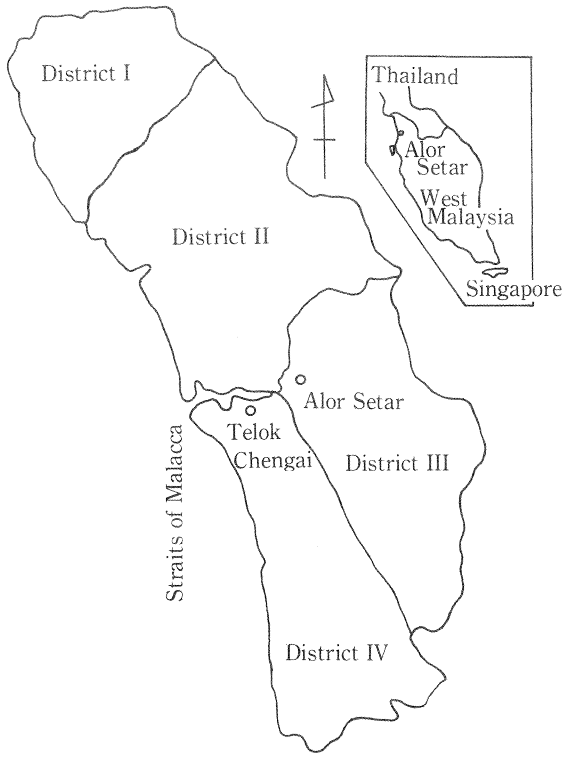

Fig. 1 Location of the Muda area.

Table 1 Physical characteristics of the Muda soil

Item	District I 20 cm depth	District I 30 cm depth	District II 20 cm depth	District II 30 cm depth	District IV 20 cm depth	District IV 30 cm depth	Average 20 cm depth	Average 30 cm depth
Three constituents of soil (%)								
Solid	44.3	46.0	45.7	45.0	43.4	43.7	44.6	44.7
Liquid	53.1	52.6	50.9	51.5	53.6	53.9	52.3	52.3
Air	2.6	1.4	3.4	3.5	3.0	2.4	3.1	2.7
Porosity A (%)	55.7	54.0	54.3	55.0	56.6	56.3	55.4	55.3
Gravity water B (%)	3.2	2.0	3.4	2.5	3.8	2.9	3.5	2.6
(B/A)×100 (%)	5.7	3.7	6.3	4.5	6.7	5.2	6.3	4.7
Specific gravity	2.59	2.61	2.60	2.62	2.53	2.56	2.57	2.60
Dry density (g/cm^3)	1.15	1.20	1.19	1.18	1.10	1.12	1.15	1.16
Atterberg limits (%)								
Liquid limit	79.7	78.0	80.2	84.7	84.9	89.6	81.2	85.4
Plastic limit	31.2	29.2	30.8	30.6	35.6	34.0	32.7	31.7
Plasticity index	48.5	48.8	49.4	54.1	49.3	55.6	49.2	53.4
Particle analysis (%)								
Clay	43	48	47	52	49	52	48	51
Silt	41	38	37	36	41	37	39	37
Sand	16	14	16	12	10	11	13	12
Average values of	16 fields		39 fields		34 fields		89 fields	

water from the Muda soils because the ratio of gravity water to the total volume of soil water is very small.

Soil hardness required for good trafficability of combine harvesters

A very hard soil foundation is naturally required for the good trafficability of large-sized combine harvesters. However, the soil foundation in most fields in this area is soft and weak, especially during the harvesting period of the off-season crop. MADA and the Tropical Agriculture Research Center, Japan jointly developed a medium-sized combine harvester which can be used in most parts of the area where the soil hardness is not suitable for the operation of large-sized combine harvesters.

The ground contact pressure of the medium-sized combine harvester is 0.24 kgf/cm^2. The sinking characteristics of the medium-sized combine harvester into a field are highly correlated with the soil bearing capacity within a depth of 25 cm below the field surface, as shown in Fig. 2. The relationship between the average soil bearing capacity from the ground surface to a depth of 25 cm and the sinking depth of the medium-sized combine harvester is shown in Fig. 3. If the average soil bearing capacity from the ground surface to a depth of 25 cm is higher than 2.0 kgf/cm^2, the combine harvester does not sink or the sinking depth does not exceed 4 cm based on the 95% confidence interval calculated from 33 observations.

When an agricultural machine sinks from 2 to 5 cm, the operation of the machine is rather difficult (KISU, 1966). A value of 2.0 kgf/cm^2 for the average soil bearing capacity from the ground surface to a depth of 25 cm may be used as a minimum target value for increasing the

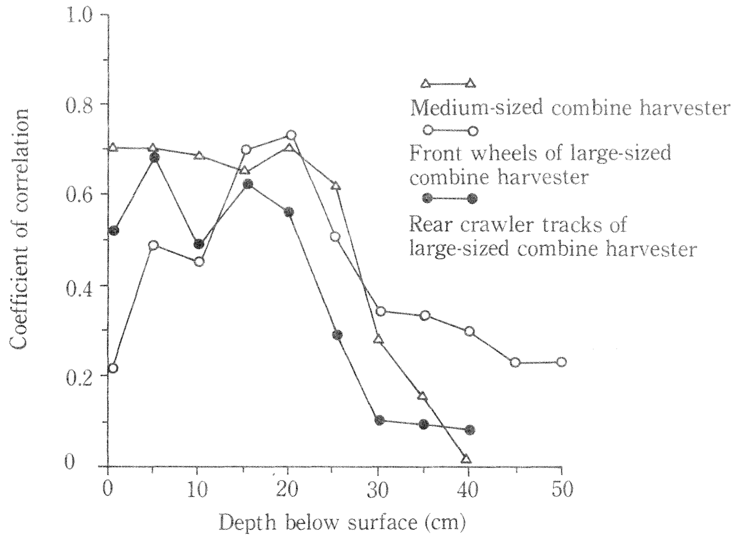

Fig. 2 Coefficient of correlation between sinking depths and soil bearing capacities for each 5 cm depth below the ground surface.

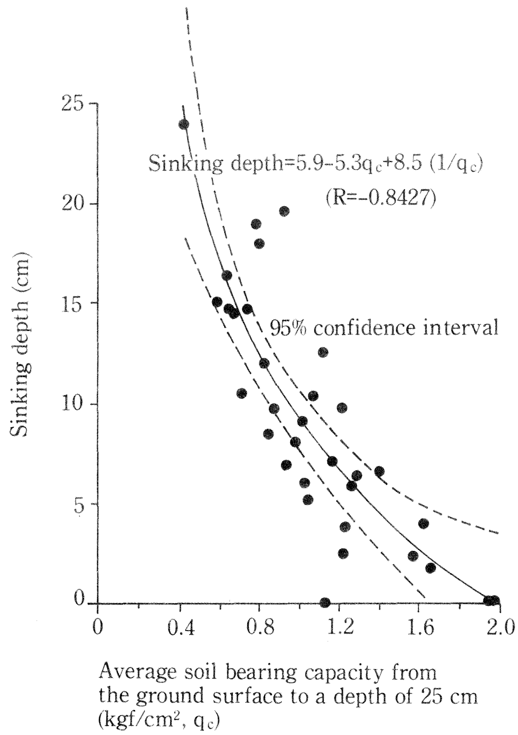

Fig. 3 Relationship between sinking depths of the medium-sized combine harvester and average soil bearing capacities from the ground surface to a depth of 25cm.

soil hardness for the operation of the medium-sized combine harvester.

Increase of soil hardness by drainage and drying

1 Surface drainage

A conventional method to increase the soil hardness is to drain the surface water from a paddy field to dry the soil. Fields No.21 and No.23 at the Telok Chengai Experimental Station were used for the surface drainage tests.

Field No.21 was drained by a pump after puddling was completed. About 50% of the surface on Field No.21 was immediately exposed after pumping. However, the subsequent drainage of the surface water progressed slowly. Even after three days of intermittent pumping, about 25% of the field surface was still under water.

Field No.23 was drained by gravity after puddling was completed. The surface water level of the field rapidly decreased in the first two days and became approximately even with the average field level; however, the subsequent decrease of the water level was slow. About 50% of the field surface was still under water even after four days of drainage. Moreover, about 25% of the field surface remained under water after drainage for eight days.

The existence of surface residual water greatly delays the subsequent drainage of soil water and prevents the increase of soil hardness. It is considered that the field conditions in the Muda area are not suitable for drainage and drying.

2 Drainage of soil water

The surface soil in Field No.21 was packed into a metal container in order to simulate the increasing process of soil hardness after drainage of the surface water from the paddy field. The metal container was 19.3 cm deep and 49 cm in diameter.

About 1,620 cc of soil water was drained from the soil sample by infiltration. The infiltrated water accounted for 6.7% of the total volume of soil water under the initial conditions. Assuming that the soil sample was saturated with water under the initial conditions, the rate of 6.7% expresses the ratio of gravity water to the porosity. Based on the surface area of the soil sample, the 1,620 cc of the drained soil water corresponds to a depth of 7 mm of water, which is equivalent to one day's pan evaporation in the dry season. Since the ratios of gravity water to the porosity of the Muda soils are 6.3% and 4.7% for the soil at a depth of 20 cm and 30 cm, respectively, it is suggested that gravity water does not affect significantly the increasing speed of soil hardness.

When the soil bearing capacity of the field surface reached a value of 3.0 kgf/cm^2, the average soil bearing capacity from the field surface to a depth of 25 cm was 2.0 kgf/cm^2 in the field survey. The accumulated pan evaporation required to increase the soil bearing capacity of the surface of the soil sample up to a value of 3.0 kgf/cm^2 was approximately 50 mm when the soil water was drained by evaporation alone, as shown in Fig. 4. When the soil water was drained by evaporation and infiltration, the accumulated pan evaporation was about 45 mm, as also shown in Fig. 4.

In July when the harvesting of the off-season crop is scheduled, about 10 fine days are necessary to evaporate a depth of 45 mm of water and about 11 fine days are necessary to evaporate a depth of 50 mm of water, as shown in Table 2. However, it is anticipated that each year there will be 7 continuous fine days and that once in two years there will be 10 continuous fine days. Even if the surface water were to be completely drained from the paddy field, it would be very difficult to increase the average soil bearing capacity from the ground surface to a depth of 25 cm by more than 2.0 kgf/cm^2.

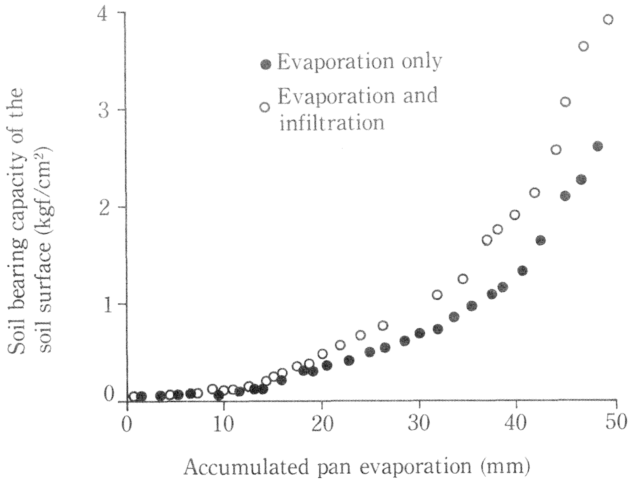

Fig. 4 Relationship between soil bearing capacity of the soil surface and accumulated pan evaporation.

Table 2 Number of days required to evaporate water at various depths

Month	1	2	3	4	5	6	7	8	9	10	11	12
Continuous fine days												
Frequency 1.0	12.4	11.7	10.4	6.8	6.4	6.6	7.6	6.5	5.1	4.8	5.8	9.8
Frequency 0.5	25.1	21.0	17.0	10.6	8.4	9.5	10.3	8.4	7.4	6.3	7.4	14.8
Daily evaporated water (mm)	6.6	7.4	7.1	6.2	5.8	5.0	4.7	5.4	4.8	4.7	4.3	4.7
Number of days required to evaporate water at various depths												
45 mm	6.8	6.1	6.3	7.3	7.8	9.0	9.6	8.3	9.4	9.6	10.5	9.6
50 mm	7.6	6.8	7.0	8.1	8.6	10.0	10.6	9.3	10.4	10.6	11.6	10.6
55 mm	8.3	7.4	7.7	8.9	9.5	11.0	11.7	10.2	11.5	11.7	12.8	11.7
60 mm	9.1	8.1	8.5	9.7	10.3	12.0	12.8	11.1	12.5	12.8	14.0	12.8

Prevention of the attenuation of the drying effect during the dry season by improving the plowing method

No distinct plowsole was found on the diagram of the cross-section of soil hardness of a paddy field in the Muda area, as shown in Fig. 5. It is assumed that there is a relationship between the cross-section of soil hardness and the type of plowing machine that can be used.

Field No.21 at the Telok Chengai Experimental Station was used for the test on the prevention of the attenuation of the drying effect during the dry season by applying an improved plowing method. Field No.21 consisted of four plots. The surface water in two of the plots was drained and the plots were dried from the end of 1975, while the remaining two plots

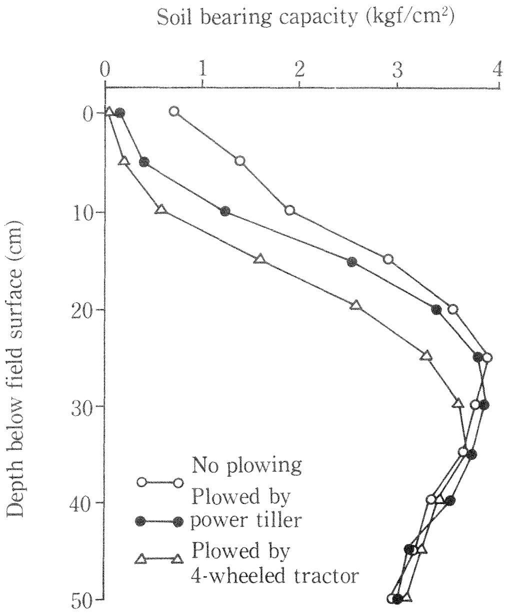

Fig. 5 Cross-section of soil hardness in field.

had been kept under water from the beginning of 1975. After these treatments, the plots were plowed, puddled, and kept under water; however, the plots were not planted.

The plowing machines used for the test were as follows: power tiller (P-T), 70 Hp 4-wheeled tractor + rotary tiller (4-W-R), 65 Hp half-track tractor + rotary tiller (H-T-R), 65 Hp half-track tractor + drum rotor tiller (plowing depth was approximately 4 cm) (H-T-N), including the control treatment, i.e. no-plowing and no-puddling (0). The combination of treatment and plowing machine in each plot is indicated in Table 3. Average soil bearing capacities from the ground surface to a depth of 25 cm in each combination are listed in Table 4. It is evident that the soil bearing capacity did not undergo any change.

Three factors affecting the soil hardness such as dry or wet treatment, plowing machine, and number of months after the plowing and puddling operations were used for the three-way analysis of variance. No significant difference was found in the number of months in the analysis where the data from the first to the fourth months after plowing and puddling in Plots I and II were used. A significant difference was found in the remaining two factors such as dry or wet treatment and type of plowing machine. For the same plowing machine, the average soil bearing capacity of the dry plot was higher than that of the wet plot, suggesting that the drying effect during the dry season remained unchanged even under inundated field conditions. The average soil bearing capacity during the first four months was high in the order of (0) > (P-T) > (4-W-R).

In the analysis where the data from the first to the fifth months in Plots III and IV were used, a significant difference was only found in the type of plowing machine used. Plot III was treated as a dry plot although it was only slightly dried due to the inadequate drainage of the surface water. The average soil bearing capacity from the ground surface to a depth of 25 cm during the first five months after plowing and puddling was high in the order of (0) > (H-T-N) > (H-T-R).

Table 3 Combination of treatment and machine

Plot No.	Field treatment in dry season	Machine used for plowing and puddling under water	Reference No.
I	Dry	P-T	1
		0	2
		4-W-R	3
II	Wet	P-T	4
		0	5
		4-W-R	6
III	Dry	H-T-N	7
		0	8
		H-T-R	9
IV	Wet	H-T-N	10
		0	11
		H-T-R	12

Remark: 0=No plowing and no puddling,
P-T=Power tiller,
4-W-R=70Hp 4-wheeled tractor+rotary tiller,
H-T-R=65Hp half-track tractor+rotary tiller, and
H-T-N=65Hp half-track tractor+drum rotor tiller.

Table 4 Average soil bearing capacity from the ground surface to a depth of 25 cm (kgf/cm^2)

	Date	12.23	'76.2.8	4.1	4.12	4.21	5.11	6.12	7.11	8.11	9.16	10.9
Plot No.	Reference No.				After plowing and puddling 1 day	10 days	1 month	2	3	4 months	5	6
I	1	2.0	5.8	2.5	1.7	1.7	2.0	1.9	1.8	2.0	1.7	1.6
	2	2.0	5.8	2.5	2.5	2.5	2.4	2.4	2.3	2.4	2.2	2.3
	3	2.0	5.8	2.5	1.3	1.1	1.4	1.4	1.5	1.4	1.3	1.2
II	4	2.1	1.7	1.9	1.4	1.1	1.5	1.5	1.4	1.4	1.2	1.2
	5	2.1	1.7	1.9	1.9	1.7	2.0	2.0	2.0	2.0	1.9	1.9
	6	2.1	1.7	1.9	1.1	0.8	1.1	1.3	1.1	1.1	1.1	1.1
III	7	1.8	2.8	2.2	1.8	1.8	2.0	1.9	2.0	2.0	1.7	1.6
	8	1.8	2.8	2.2	2.0	2.1	1.8	2.1	2.1	2.1	2.0	1.9
	9	1.8	2.8	2.2	1.3	1.3	1.7	1.5	1.6	1.6	1.6	1.3
IV	10	2.0	1.9	1.9	1.8	1.9	2.1	1.8	1.7	1.8	1.8	1.6
	11	2.0	1.9	1.9	1.9	1.9	2.1	2.1	1.9	1.9	2.0	2.0
	12	2.0	1.9	1.9	1.4	1.6	1.8	1.7	1.5	1.5	1.4	1.4

The condition of Plots II and IV did not change appreciably. No significant difference was found between the no plowing and no puddling treatments in the two plots. Then, the data from the first to the fourth months in Plots II and IV were used in order to analyze the effect of the type of plowing machine on the stabilization of the soil bearing capacity. The average soil bearing capacity from the ground surface to a depth of 25 cm during the first four months after plowing and puddling was high in the order of (0) > (H-T-N) > (H-T-R) > (P-T) > (4-W-R), as shown in Table 5.

Table 5 Difference between the average soil bearing capacity associated with the use of two plowing machines in Plots II and IV (kgf/cm^2)

Difference between the two machines	95% confidence interval
(0, IV)-(0, II)=0.04	No significant difference
(H-T-N)-(P-T)=0.43**	0.31~0.54
(H-T-R)-(P-T)=0.18**	0.06~0.29
(H-T-N)-(4-W-R)=0.70**	0.59~0.82
(H-T-R)-(4-W-R)=0.45**	0.33~0.57

A ** mark indicates the 99% level of significance.

The pronounced drying effect during the dry season along with the use of a low-ground-contact-pressure tractor equipped with a shallow-plowing tiller resulted in the maintenance of a relatively high soil bearing capacity even after the completion of the irrigation and plowing operations. The application of no plowing and no puddling treatments also enabled to maintain a high soil bearing capacity.

Fields No.23 and No.25 were plowed and harrowed under dry field conditions before presaturation. This method which is referred to as "dry cultivation" is a new attempt to maintain a high soil bearing capacity. After presaturation, Field No.23 was puddled but Field No.25 was planted without previous puddling. The average soil bearing capacity from the ground surface to a depth of 25 cm in Fields No.23 and No.25 was higher than the target value of 2.0 kgf/cm^2 under inundated field conditions. It is concluded that dry cultivation is one of the practical methods to preserve and enhance the soil bearing capacity even under inundated conditions.

Conclusion

The selection of a proper combine harvester is the first step for the mechanization of a paddy field with a weak soil foundation. It was, therefore, considered that the use of a medium-sized combine harvester would be more appropriate than that of a large-sized combine harvester. The value of the soil bearing capacity for the operation of the selected medium-sized combine harvester was set at 2.0 kgf/cm^2 as an average value from the ground surface to a depth of 25 cm.

It is extremely difficult to drain the surface water from the paddy fields in the Muda area, especially in the rainy season. Even if the surface water were to be drained completely from the paddy field, drying of the field in the rainy season would not be possible due to the limited number of continuous fine days.

The value of 2.0 kgf/cm^2 for the average soil bearing capacity can be maintained even under inundated field conditions by hardening the field soil through a prolonged dry season fallow combined with the use of a low-ground-contact-pressure tractor equipped with a shallow-plowing tiller for plowing and puddling. The dry cultivation is also useful for preserving the soil hardness of the paddy field even under inundated conditions.

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