14. TECHNICAL PROBLEMS IN MECHANIZATION OF SOIL PREPARATION

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Introduction

In the soil preparation of paddy field in Japan man and/or animal power is remarkably replaced by machine power at present, though it has not made a great progress in the upland fields distributed mainly in mountain districts.

Many technical problems have been raised in the course of the development, some of which have already been solved, but the others still remain to be solved and considerable efforts are now devoted to the research and improvement of the soil preparation.

Development

The development of the mechanization of soil preparation during the past quarter of a century can be divided into three periods.

(1) First period (1945–1954)

The drive type walking tractor called "power tiller", which has been used on a very small scale in the western districts of Japan, was introduced mainly into the farmers of a high economic level at the rice zone in northern districts at the end of this period.

The use of this conventional power tiller was limited only to the pulverization of soil, and then it was improved for puddling, which helped the diffusion of power tiller (Fig. 1). In addition the improvement of rotary tine from pointed to knife tine (so-called natazume) gradually unifies the three types of power tiller (crank, screw and rotary type) into the rotary type.

In the middle of this period, air-cooled engines and garden tractors similar to the Western ones were tentatively produced.

These improvements were partly due to the embarkment of big factories on the manufacturing of agricultural machinery after World War II.

(2) Second period (1955–1960)

The walking tractors which were restricted mainly in the rice field were introduced into the upland field in this period. From the beginning of this period so-called "tiller", pull type tractor mounted with small air-cooled engine of light weight, appeared on the field in addition to the conventional "power tiller".

This newly devised small pull type tractor costs only about half the price of power tiller. It can perform plowing similar to the conventional cattle one by pulling Japanese plow, while the power tiller does plowing and harrowing in one operation, and this brought several problems. Moreover, its implements can be changed to be used for harrowing, puddling, levelling, ridging, intercultivating, and especially transporting. That is why the small pull type tractors were utilized even by the small farmers, and they exceeded drive type tractors in number in 1960.

The improvement of walking tractors has been hastened by the national tests conducted since 1953.

(3) Third period (1960–)

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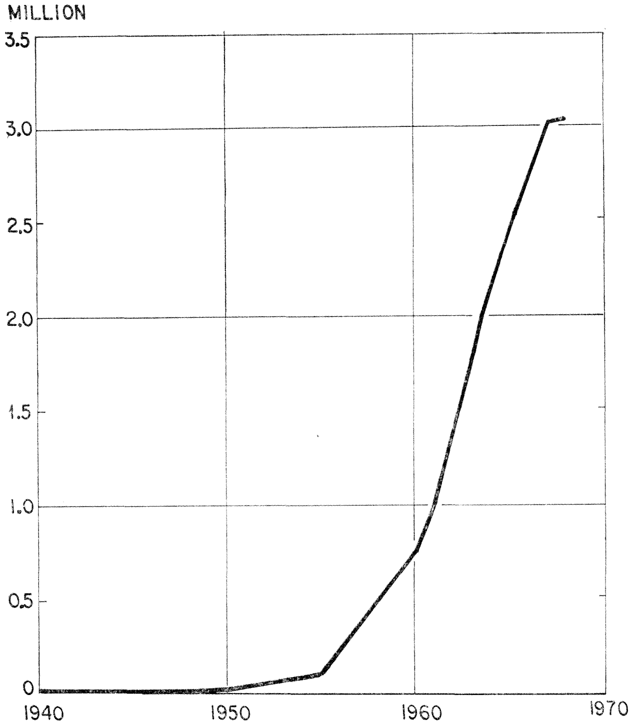

Fig. 1. Walking tractors on farms

The walking tractors of less than 10 hp mechanized the soil preparation before the second period.

In Hokkaido, the northern part of Japan, where the farm size is large and fields are mostly upland, the conditions are more favorable for mechanization than in the other districts, and the riding tractors of around 30 hp began to be used. In the prefectural districts, the riding tractors were introduced into the upland and the orchard districts and cooperatively used at the beginning of this period, and later they prevailed widely in the rice districts (Fig. 2).

These riding tractors were imported from the United Kingdom, the United States, Germany, etc. in the early stage, and the domestic ones of 15 to 20 hp appeared since 1959 or thereabout. At present, most of the tractors of less than 40 hp are manufactured in Japan (Table 1).

The number of walking tractors exceed three millions in 1967, but their growth has slowed down in recent years. The present demand for walking tractors is filled in nearly all the farms, and in future the sales are expected to improve when tractors are renewed but to fall off along with their increase per farmer. After they reach the peak of about 3 millions, the walking tractors will decrease gradually as farms decrease and farmers come to use of higher powered tractors.

Technical problems

(1) Soil turning and pulverization

The rotary tilling is superior to the plowing in the rate of work, but inferior in soil turning (Table 2), which induces weed germination and too fine pulverization of

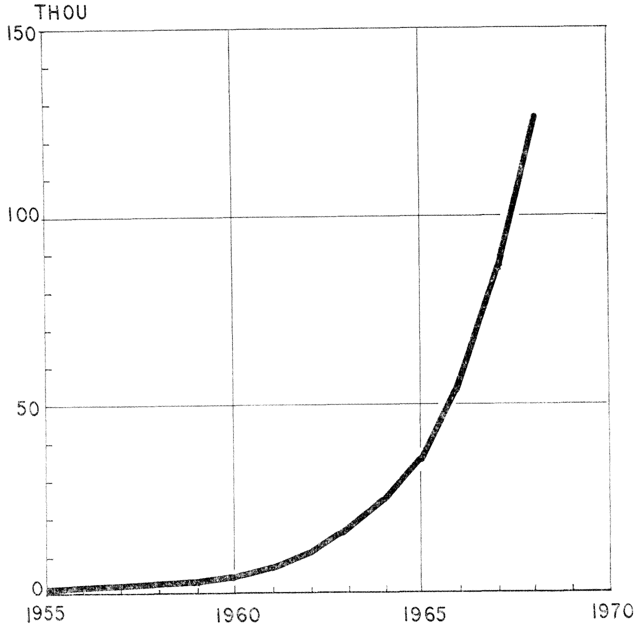

Fig. 2. Riding tractors on farms.

Table 1. Number of riding tractors introduced in 1969, by manufacturing countries and sizes

	Wheel type (hp)								Crawler type (ton)				Total
	-10	10-15	15-20	20-30	30-40	40-50	50-	Total	-5	5-10	10-	Total	
Japan	19 (2)	21, 862 (15)	8, 486 (11)	14, 742 (19)	1, 089 (15)	64 (1)	26 (3)	46, 288 (56)	153 (5)	519 (13)	1, 240 (14)	1, 912 (32)	48, 200 (88)
United Kingdom					340 (3)	2, 428 (6)	1, 443 (8)	4, 211 (17)					4, 211 (17)
Czechoslovakia					484 (1)	208 (1)	100 (1)	792 (3)					792 (3)
Italy					2 (1)	419 (3)	152 (4)	573 (8)	7 (3)			7 (3)	580 (11)
West Germany					43 (4)	212 (5)	103 (4)	358 (13)					358 (13)
United States						102 (1)	37 (1)	139 (2)			5 (1)	5 (1)	144 (3)
France					52 (1)			52 (1)					52 (1)
Total	19 (2)	21, 862 (15)	8, 486 (11)	14, 742 (19)	2, 010 (15)	3, 433 (17)	1, 861 (21)	52, 413 (100)	160 (8)	519 (13)	1, 245 (15)	1, 924 (36)	54, 337 (136)
Export		511 (3)	105 (3)	587 (3)	62 (3)	8 (2)		1, 273 (14)	8 (2)	5 (1)	49 (1)	62 (4)	1, 335 (18)

Remarks: Figures in the parentheses show the number of models
Source: Ministry of Agriculture and Forestry

soil. That is why it becomes necessary to introduce weedicide spraying operation or increase intercultivation and to simplify tilling and puddling operations in order to prevent too much pulverization of soil. The soil turning by rotary tiller was improved later as shown in Table 2, along with the improvement of shape and arrangement of tine, and of shape of shield, etc.

Table 2. Soil turning performance*

Implement	Stubble exposing rate**	
	1955–56	1960–61
Rotary tiller	42.3%	16.6%
Plow (Western)	7.9***	—
Plow (Japanese)		
Single bottom	19.1***	—
Double bottom	5.6***	—

Note: * Calculated from National Test Report

** $\frac{\text{No. of stubbles exposed after operation}}{\text{No. of stubbles before operation}} \times 100$

*** The values were obtained after harrowing in the case of plow.

The change gear of forward speed of walking tractor increased in number from 2–3 in 1952 to 6 in 1968, and that of rotary shaft speed from 1–2 in 1952 to 2–3 in 1968. The change gear of PTO speed of riding tractor also increased to 2–4. These improvements made it possible to distribute soil in the size of clod easily.

(2) Working depth

The working depth of plowing or rotary tilling by walking tractor is 10 to 15 cm, which restricts the development of soil managements and fertilizing techniques. To overcome these problems and enlarge the tilled soil layer, it may be necessary to plow by riding tractor. However, plowing by riding tractor makes dead or back furrow in the center or sides of the field which causes weed germination or ill-growth of rice plants.

As the efficient method of levelling these furrows is not established, soil preparation system including plowing operation is not completed yet. Furthermore, to expect high yield by deep plowing, it is necessary to establish an appropriate soil management and fertilizing technique according to soil and climatic conditions.

(3) Rate of work

Formerly, in most cases the rotary tilling was smaller than the outside distance of tractor tires. The reduction of power requirements by the improvement of shape and arrangement of tine, and of shape of shield, etc. made the tilling width larger than the outside distance of tractor tires. The rate of work in relation to the engine horsepower of recent tratcors is shown in Fig. 3, which is expressed by the following equation.

$$t = \frac{9}{p} + 0.1$$

where,

t: time required for tilling 10a (hr)

p: engine horsepower (hp)

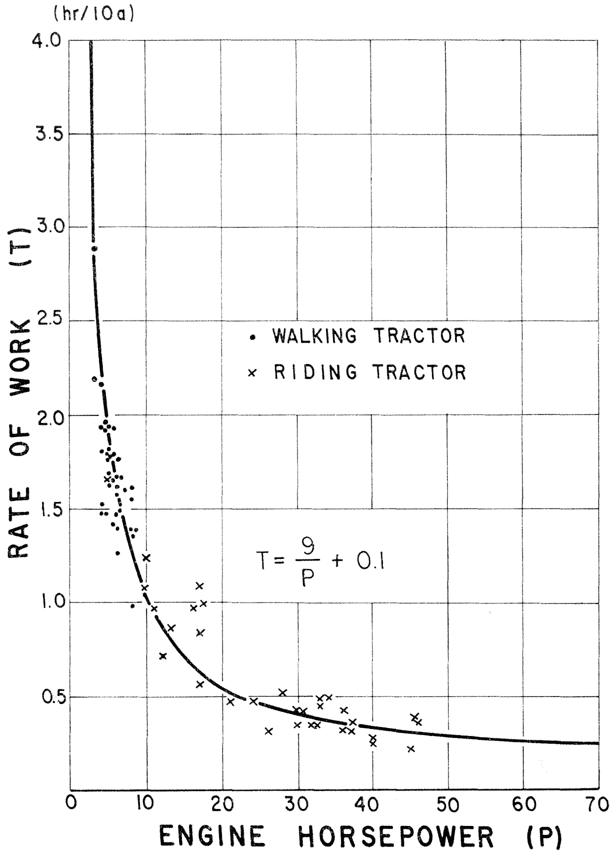

Fig. 3. Working rate of rotary tilling.

(4) Necessary condition for rice transplanting machine

The recently developed rice transplanting machines have raised several problems in soil preparation.

To utilize rice transplanting machine for unwashed seedlings it is necessary to control irrigation and drainage, that is, to make water level low in planting and then high at the erection of seedlings. For this purpose it is necessary that levelling be done carefully in puddling and that the field should be in the condition that irrigation and drainage can be done easily and rapidly.

In the case of rice transplanting machine for washed seedlings the misplanting and damage of seedlings occur when the soil hardness is not proper or straw trashes are mixed in the soil.

(5) Necessary condition for rice direct sowing

In the case of rice direct sowing on dry paddy field, it is necessary that soil be dried up, soil particles be fine, field surface be level, and rice or weed stubbles be not mixed in the soil.

In direct sowing on wet paddy field, when the soil is too soft, germination is hampered as seeds are covered with mud. On the contrary, when the soil is too hard, not only the implement is difficult to operate as the soil sticks to its drive wheel, but also the seeds float when submerged. When the ground surface is not level or is corrugated, the seed depth and the water level after submerging are irregular and germination and weed control are impeded.

(6) Levee making

The working rate of tilling operation is high when a plot of field is large, but irrigation and drainage are efficient when it is small. Making levee is laborious and time consuming, and several kinds of machines such as plastic sheet layer, levee plaster, and temporary levee builder (Fig. 4) have been devised. However, their price and performance still prevent their diffusion at present. Concrete levees are also increasing gradually.

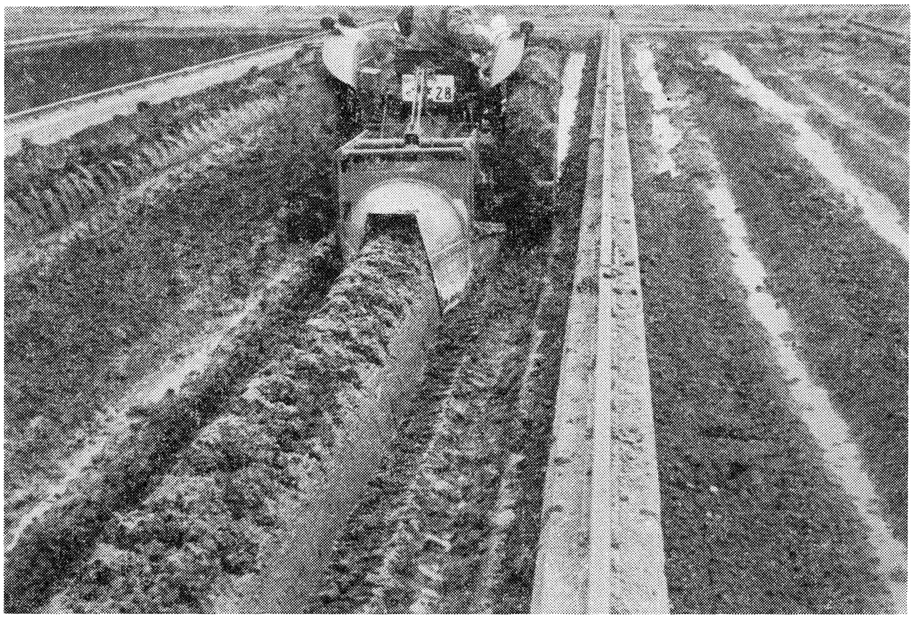

Fig. 4. Tmporaray levee builder (Test scene in seibens).

(7) Trafficability

Wet and semi-wet paddy fields occupy as much as 45% of total paddy field in Japan (Table 3). In these areas as well as in the newly reformed land the trafficability of tractor is a serious problem.

Many kinds of traction aids such as high lug tires steel wheels, cage wheels, girdles, strakes, half and full tracks were devised and evaluated on different soil conditions. By these efforts trafficability of tractor on soft soil has made long strides.

Furthermore, to improve the trafficability on soft soil, the recent domestic tractors have lower weight per horsepower as expressed in equation (a) than that of imported or old domestic ones as in equation (b).

$$w=65-0.7P \quad \ldots\ldots\ldots\ldots \quad (a)$$
$$w=75-0.7P \quad \ldots\ldots\ldots\ldots \quad (b)$$

where,

w: weight per horsepower (kg/hp)
P: maximum PTO horsepower (hp)

Table 3. Paddy field area, by ground water level

(Unit: Thousand ha)

Field	Area	Percentage
Wet paddy field	489.9	15.3
Semi-wet paddy field	879.7	27.6
Dry paddy field	1823.6	57.1
Total	3193.2	100.0

Remarks: 1) 1960, excluding Hokkaido
2) Ground water level
Wet paddy field.........Higher than 40cm
Semi-wet paddy field 40 to 70cm
Dry paddy field.........Lower than 70cm
3) Source: Ministry of Agriculture and Forestry

Great efforts have been made to establish the prediction method of trafficability. By using cone penetration, plate sinkage, or consistency index, the trafficability can be predicted fairly well (Fig. 5 and Table 4).

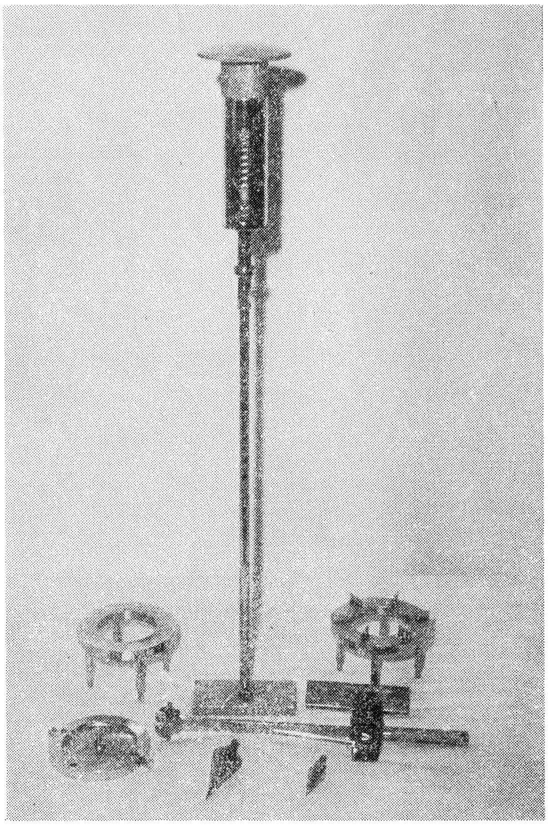

Fig. 5. SR-2 soil resistance tester.

Table 4. Prediction of trafficability

	Impossible						Passable						Fair					
	Wheel					Crawler	Wheel					Crawler	Wheel					Crawler
	Pneumatic tire			Girdle	Half track		Pneumatic tire			Girdle	Half track		Pneumatic tire			Girdle	Half track	
	Self propel	Rotary tilling	Plowing	Self propel			Self propel	Rotary tilling	Plowing	Self propel			Self propel	Rotary tilling	Plowing	Self propel		
Working condition																		
Depth (cm)	—	—	—	—	—	—	—	10	12	—	—	—	—	10	12	—	—	—
Speed (m/s)	—	—	—	—	—	—	—	0.4	1.0	—	—	—	—	0.4	1.0	—	—	—
Travel red. (%)	20<	20<	40<	20<	5<	5<	20~10	20~10	40~20	—	—	—	10>	10>	20>	10>	3>	3>
Sinkage (cm)	12<	12<	10<	12<	12<	12<	12~3	15~3	10~3	—	—	—	3>	3>	3>	3>	3>	3>
Criterion																		
Cone index (kg/cm²)	2.5	2.5	4.0	2.0	2.0	1.5	2.5~5.0	2.5~5.0	4.0~6.5	2.0~3.5	2.0~2.5	1.5~3.0	5.0	5.0	6.5	3.5	2.5	3.0
Plate sinkage (cm)	9.5	10.5	3.0	11.0	10.0	15.0	9.5~4.5	10.5~6.0	3.0~0	11.0~3.5	10.0~8.0	15.0~5.0	4.5	6.0	0	3.5	8.0	5.0
Consistency index	0.2	0.2	0.4	—	—	—	0.2~0.5	0.2~0.5	0.4~0.6	—	—	—	0.5	0.5	0.6	—	—	—

Remarks: (1) Cone: top angle 30°, base area 2cm², mean value in the range of 0 to 15cm depth.
(2) Plate: rectangular plate 10×2.5cm, pressure 1.6kg/cm².
(3) Consistency index: (liquid limit—water ratio)/plasticity index.

Source: The Agriculture, Forestry and Fisherise Council, Ministry of Agriculture & Forestry.

The predictions of drawbar pull of tractor, draft of plow, and power requirement of rotary tiller by measuring dynamic properties of soil are under test, which is getting a considerable success.

(8) Water proof performance

The tractors in our country are often used on submerged or ill-drained fields, and it is serious both for driver and machine if the water proof performance of brake system is not sufficient.

The brakes of most of the domestic tractors are situated on the shafts in front of rear axles and are sealed. However, close attention should be paid, lest water should enter from any openings when the drive wheels splash water on the tractor body.

The water proofing of front axle and rotary shaft bearings should also be taken notice of. According to the results of the two hours' test in the testing pool by the IAM (Fig. 6), water comes into the front axle bearings of 22% tractors, and into the brake systems of 7%.

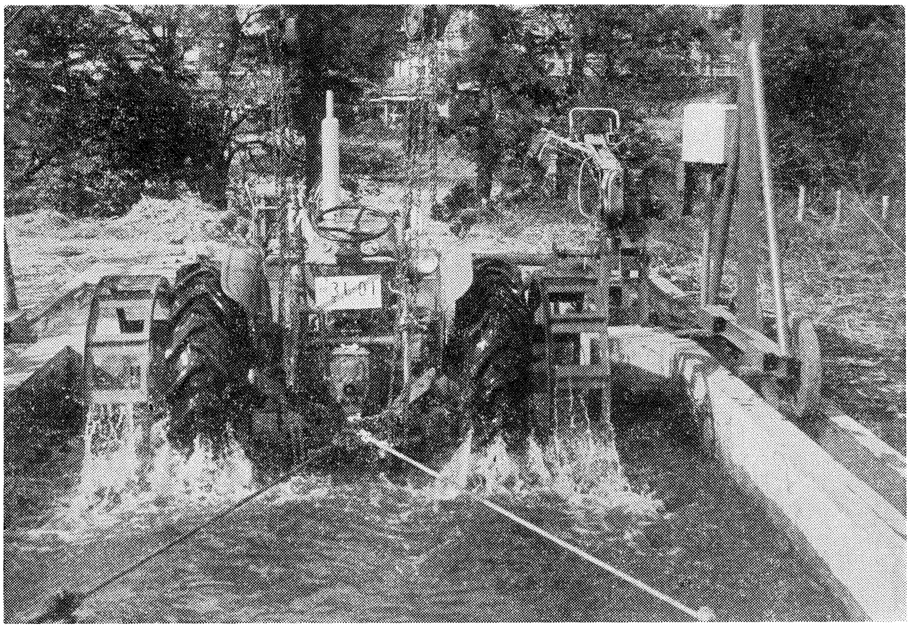

Fig. 6. Water proof test.

The muddy water comes into engine cylinder through air cleaner which is situated at a comparatively low position, and wears the bearings and cylinder. It also comes into the clutch from holes on the clutch housing, and when it dries up the clutch facings stick each other and are not disengaged.

These problems have been almost eliminated in the modern domestic tractors.

(9) Easiness of operation, ridability and safety

In the early stage of introduction of tractor, its capacity, durability and economy were the matters of concern. With the increased use of tractor, the easiness of operation, ridability and safety are requested.

The recoil or electric starter and the reduction of vibration of the engine, the automatic stopper of rotary shaft revolution when it is reversed, the power shifting of wheel tread, and the power offsetting of rotary part are the improvements of walking tractor.

The use of tractor for sloping grassland, which has become important under the recent agricultural circumstances, hastens the establishment of the safety devices for overturning of riding tractor. These problems have been studied in several research stations, and the standardized testing rigs for safety frame were constructed in IAM this year.

In the near future, hydrostatic transmission, new types of engine such as fuel cells, and even the driverless field operation are expected to be adopted.