SYSTEMATIZED FARM OPERATIONS USING MACHINES FOR RICE DOUBLE CROPPING IN THE MUDA AREA, MALAYSIA

Koichi TANAKA*, Hiroyuki SHINOZAKI**
and Kiat Choon YEOW***

ABSTRACT

The purpose of this study is to establish a systematic mechanized farm operation program suitable for the Muda area in Malaysia based on the use of the drive harrow, transplanter, head-feeding combine and large combine harvester.

The method of raising mat seedlings using mountain soil had already been established. To further increase the adaptability of the method to the Muda area, efforts were made to use puddled paddy soil, simplify the working method and transportation of mat seedlings. As for the land preparation, two rounds of tilling with a wide and shallow tiller drive harrow were tested mainly, and the adaptability of this method to the field was examined at an early time after harvesting, when a large amount of fresh straws still remains in the field.

In the transplanting operation, four-row walking type transplanter was found to be a high performance machine in the on-farm test field. At the latest stage of this study, six-row riding type transplanter was tested also.

The studies on harvesting operation were started using the head-feeding combine "KANAN" mainly, and the performance of this machine was found to be lower than that of the large combine. Therefore, a new commercial type head-feeding combine was tested. Moreover, the performance of the large combine was reassessed due to the diffusion of this machine in the Muda area and, the differences in the performance between these two types of combine were clarified.

To analyze the characteristics of the mechanized working system, comparison was made between the mechanized working system and the present farmers' working systems.

Characteristics of individual operation methods in the working systems

1 Raising of seedlings

Raising good seedlings is one of the most important conditions for mechanical transplanting.

The characteristics of good seedlings must be as follows:

1) Sufficient strength and height.
2) Width of seedling mat must fit to the transplanter, otherwise shrinkage of the mats is likely to occurs.
3) Uniform establishment.
4) Sufficient hardness and strength of mat soil without obstacles like small stones.

The method for raising seedlings using mountain soil involves a large number of operations and is labor-intensive. Due to the difficulty of gathering mountain soil, the development of a method for raising seedlings using paddy field soil is necessary. To be adapted to the farmers' field conditions, seedlings 30 cm in height (25 days) are required which is more than the present 25 cm seedlings (20 days). To solve these problems, improved methods of raising seedlings have been tested and analyzed. Based on the results obtained, two methods are being proposed:

* Agricultural Engineer, Hokkaido National Agricultural Experiment Station, Sapporo, 004 Japan.
** Agricultural Engineer, Kyushu National Agricultural Experiment Station, Fukuoka, 833 Japan.
*** Agricultural Engineer, Muda Agricultural Development Authority, Alor Setar, Kedah, Malaysia.

Method	System 1		System 2
Kind of soil	Mountain soil		Paddy field soil
Soil preparation			
Gathering	(1)	(2)	
Crushing	by individual	by organization	
Sieving	Farmer	(F.A.)	
Mixing			
Transportation		Farmer	
Site	Indoors	In the nursery	
Soil packing	Under the roof		In the nursery
Sowing	Automatic sowing machine with watering device		In the nursery by seeder
Germination	In piled-up seedling trays		
Water control			1.0 cm (2 - 3 days)
Transportation	To nursery		Unnecessary

Mountain soil was used in system 1. And since in this system the method for raising seedlings has been established, seedlings of good quality can usually be obtained. However, this system is inferior to system 2 due to the high cost of the trays. For the farmer, it is easier to use mountain soil on a group basis than on an individual basis. Paddy field soil was used in system 2 and since in this system soil gathering is not required, the transportation of the seedling trays (they are empty) is easy and the cost is lower. But, it is not certain whether good seedlings can be obtained due to possible rainfall damage.

2 Land preparation

Suitable conditions for mechanical transplanting are as follows:

1) Flat soil surface and uniform level of the field.
2) Flat hard pan.

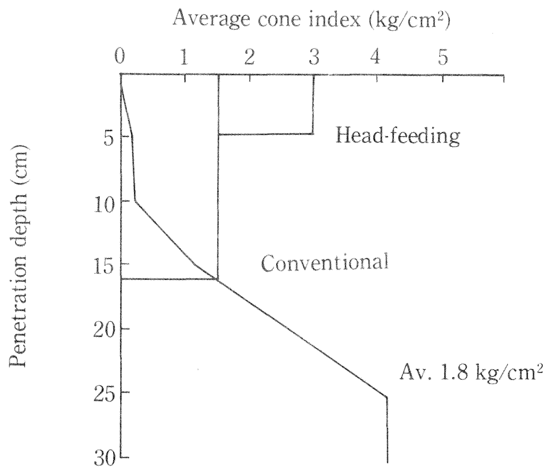

Fig. 1 Soil bearing capacity and depth of rut by combine.

3) Moderate hardness of top soil.
4) Sufficient bearing capacity of hard pan.
5) Depth of top soil should not be excessive.
6) Few floating straws on the field.

As a suitable method of land preparation, two rounds of tilling with a wide, shallow drive harrow under submerged field conditions is proposed, as it affords a high performance and enables to obtain a shallow hard pan.

Since the drive harrow is a shallow tilling implement, refilling of the depth of rut is limited to around 20 cm. For the same reason, straws can not be buried sufficiently into the soil when a large amount of fresh straws is present on the soil surface.

The damage to the hard pan can be chiefly attributed to the ruts of the large combine especially at the headlands and in the area where paddy is unloaded. It is considered that the shallow tilling drive harrow is effective in forming and maintaining the hard pan especially when it is tied up to the head-feeding combine (Fig. 1, Fig. 2).

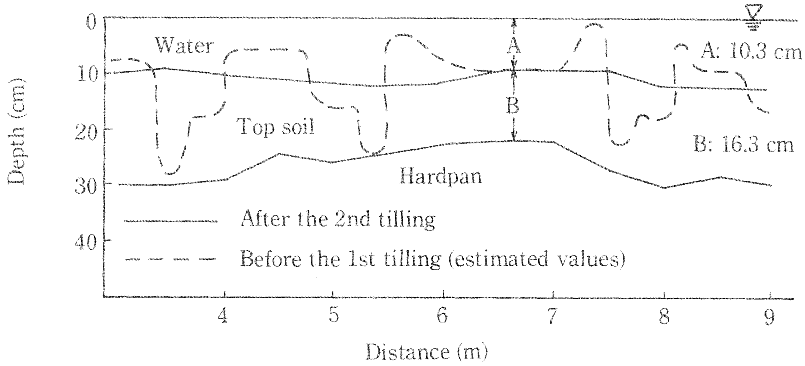

Fig. 2 Levelling conditions after the 2nd tilling operation in farmers' fields.

3 Transplanting

Labor-saving and increased yield can be expected when the transplanter is being used.

Under the on-farm testing field conditions, the performance of the transplanter was approximately 5-6 hr/ha. This value is equivalent to approximately 1/8–1/10 of that by manual transplanting. Consequently, hired labor can be reduced or avoided, and it is also possible to transplant at the optimum time, which contributes to the stabilization of rice double cropping. Moreover mechanical transplanting affords a proper density of hills and a more shallow planting depth than manual planting which in turn results in the increase of the yield of rice.

Based on the data obtained in this study, the difference in the performance of the six-row riding type and four-row walking type transplanter was not appreciable, but the riding type transplanter was superior to the walking type transplanter in terms of reduced fatigue of the operator and higher adaptability to deeper and softer soil conditions.

Cost is a problem for the adoption of mechanical transplanting. Whether the cost of mechanical transplanting can be offset by the reduced wages and the increased yield depends on economic conditions such as cost of the machine, labor wages and price of paddy. Moreover, with the use of younger seedlings for mechanical transplanting, research on the new cultural practices, as compared to the traditional ones will be needed.

As mechanical transplanting requires the development of new methods for raising the seedlings and new cultivation methods to reduce the cost it will be necessary to carry out research on the new technology.

It is considered that mechanization of transplanting will enable to increase rice production in the Muda area. But, many problems must be solved before this system can be adopted.

4 Harvesting

Shallow ruts of the head-feeding combine do not damage the hard pan. In the Muda area, there are large areas where the water depth in the fields is too high. In such fields, land preparation, transplanting and field maintenance operations are more difficult to perform. In these fields, the combined use of a head-feeding combine and shallow tilling drive harrow is favorable for the formation of a shallow hard pan. On the other hand, the large combine leaves deep ruts in the field whereas the head-feeding combine leaves only shallow ruts. This factor makes it difficult to prepare the field and also damages the hard pan at headlands or corners of the field. If the cone index of the machine is less than 1.0 kg/cm^2 at the depth of 0–30 cm, the hard pan will be damaged.

The performance of the large combine is clearly higher than that of the head-feeding combine. The performance of the head-feeding combine "KANAN" is around 1/3–1/4 of that of the large combine. However, the commercial type of head-feeding combine is being improved year by year, and the performance of the head-feeding combine "Y" which is being marketed is about 1/2–1/3 of that of the large combine.

The complexity of the mechanical construction and low durability of the head-feeding combine in Japan require improvement.

Grain losses associated with the use of the large combine are lower than when the head-feeding combine is used, although the separating accuracy of the large combine is inferior to that of the head-feeding combine, but still acceptable. One of the shortcomings of the large combine is the destruction of the farm road facilities and difficulty in transportation. The cutting height of the large combine is generally too large and high stubbles are left behind which makes land preparation and rice cultivation slightly difficult.

Working systems

Outline of the proposed working systems is shown in Table 1. These must be selected to

Table 1 Working systems

Raising of seedlings				
	Soil	Sowing place		Characteristics
1	Mountain	Under the roof		Stable good seedlings
2	Nursery	In the nursery		Labor-saving. Slightly unstable
Field works				
	Land preparation	Transplanting	Harvesting	Characteristics
1	Drive harrow 2 rounds	Riding type 6-row	Head-feeding combine	Permanence of the system. High performance.
2	Drive harrow 2 rounds	Working type 4-row	Head-feeding combine	Low cost of transplanter.
3	Drive harrow 2 rounds	Riding type 6-row	Big combine	High performance. Damage to farm facilities.
4	Drive harrow 3 times	Riding type 6-row	Head-feeding combine	When there is a large amount fresh straws.

suit the farming conditions in the Muda area. Detail of system 1 and comparison of system 1 with the traditional farmers' system are shown in Table 2.

Individual operations in the proposed systems carried out under the on-farm testing field conditions are as follows:

1) Land preparation

Cone index (at 20-30 cm depth): 3.5-5.2 kg/cm^2

Depth of ruts: 4-15 cm (maximum 28 cm)

2) Transplanting

Depth of top soil: 5.5-28 cm

Table 2 Comparison of main operations between the two working systems

Operation	Mechanical system: Machine	Mechanical system: Man-work (hr/ha)	Farmer's system: Machine	Farmer's system: Man-work (hr/ha)
Raising of seedlings	(System 1)			
Soil preparation	Lorry, Crusher Sieve, Mixer	3.0		
Seed preparation		0.4		0.4-0.8
Sowing	Seeder	3.8		1.0-1.6
Tray transportation	Trailer	1.6		
Nursery preparation		2.6-8.0	Power tiller	2.6-8.0
Nursery control		3.6-13.2	Pump	3.6-13.2
Sub-total		15-30		7.6-23.6
Raising of seedlings	(System 2)			
Seed preparation		0.4		
Nursery preparation		2.6-8.0		
Soil packing		3.2		
Sowing		2.8		
Nursery control		3.6-13.2		
Sub-total		12.6-27.6		
Field preparation				
Irrigation		little		
1st tilling	Drive harrow	2.14	Power tiller	5.4-7.0
2nd tilling	Drive harrow	1.96	Power tiller	5.4-7.0
Levelling			Power tiller	5.6-11.0
Sub-total		4.1		16.4-25.0
Transplanting				
Taking out and transportation of seedlings	Trailer	1.9		22-42 3-22
Transplanting	Transplanter	10-12		60-112
Sub-total		12-14		85-159
Harvesting				
Harvesting	Head-feeding combine	7.5	Large combine	1.8
Bagging		10		10
Sub-total		17.5		11.8
Estimated total of only main operations	System 1 System 2	48.6-65.6 46.2-63.2		120.8 219.4

Depth of water: 0–12 cm
Depth of plumb penetration: 5.5–17 cm
Cone index (at 20–30 cm depth): 3.5–5.2 kg/cm^2
3) Harvesting
Cone index (at 10 cm depth): 0.2–1.0 kg/cm^2
Cone index (at 20–30 cm depth): 3.5–5.2 kg/cm^2

Suitable size of the fields for the operation of each machine is roughly estimated as follows:

	Suitable size	Problems when the field is too large
Drive harrow	50–100 a	Levelling
Transplanter	50–130 a	Seedling supply
Head-feeding combine	30–100 a	Paddy transportation
Large combine	70–150 a	
Average suitable size	50–100 a	

The duration of the period between transplanting and harvesting by the mechanical transplanting method tends to be longer.

Research has been initiated to verify this phenomenon.

Adaptability

For mechanized farm operations, the soil hardness of the tilled soil and the hardpan until a depth of 30 cm from the surface is very important.

When the soil is too hard, it is difficult to perform the tilling operation and also the hardness or softness of the surface soil affects the accuracy of the transplanting operation.

Under submerged field conditions as the soil conditions tend to change depending on the machine, it is difficult to indicate the limit of farm operation by the determination of the soil bearing capacity.

On the basis of the data obtained during the experimental period it appears that the soil bearing capacity for depths between 20 to 30 cm should exceed 2.5–3.5 kg/cm^2 at least, that is above 5 cm of the foot mark depth for the use of the mechanized system (Table 3).

Table 3 Soil classes for trafficability

Class	Cone index		Foot mark	Soil class	Hardness or ease of trafficability (Wheel type)						Comments
	Large 6 cm^2	Small 2 cm^2	depth (ankle bone)		No load traffic or driven tilling	Float strake Drive harrow	P. Trans-planter	R. Trans-planter	Head-feeding combine	Conven-tional combine	
	Av. 0-15 cm										
A	0-5.36	over 8	0-0.3	Extremely good	Extremely easy	○	○	○	○	○	
B	5.36-4.02	8-6	0.3-0.7	Good	Easy	○	○	○	○	○	Working limit (Rubber type)
C	4.02-3.02	6-4.5	0.7-2.0	Very bad	Very difficult	○	○	○	○	○	Need for the paddy wheel
D	3.02-2.01	4.5-3	2.0-5.0	Bad	Difficult	○	○	○	○	○	Difficulty in turning
E	2.01-1.34	3-2	5.0-9.0	Extremely bad	Extremely difficult	○	△	○	△	○	Impossible to turn
F	1.34-0	2-0	over 9.0	Dangerous	Impossible	×	×	×	×	×	Impossible to extricate oneself from bog

Symbol : ○ Good, △ Bad, × Worst

Relationship between large and small cones PL = 0.67 PS

Economic evaluation

The economic evaluation was performed by drawing the utility cost curve shown in Fig. 3 in assuming the following:

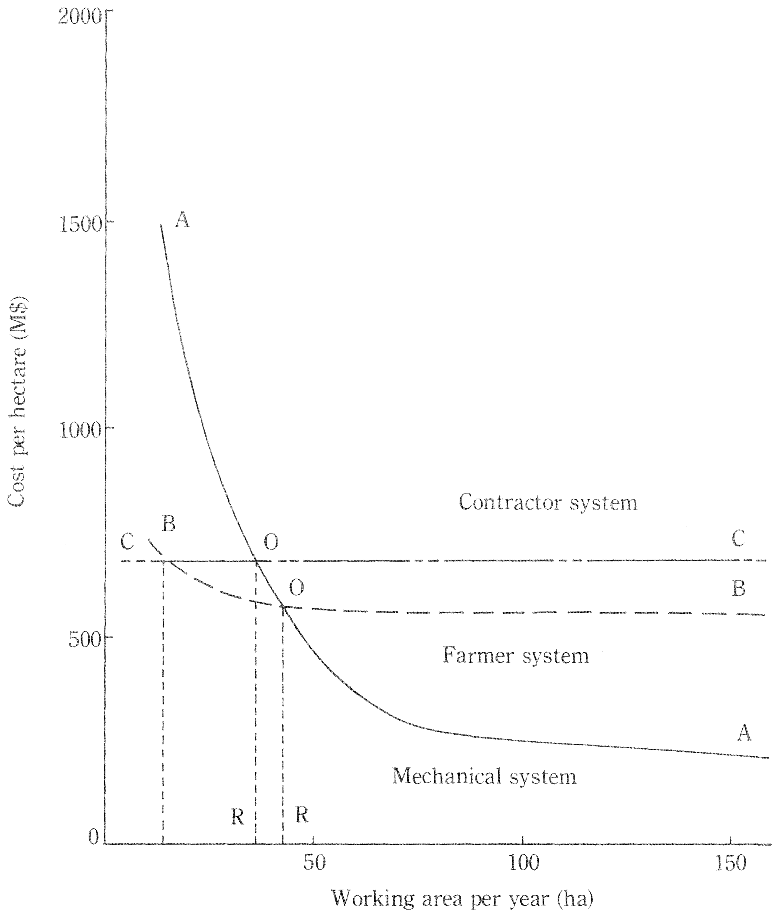

Fig. 3 Utility cost of the machines per hectare.

The machines used in the mechanized system consisted of a tractor, a rotary harrow, a trailer, a transplanter, a sieve crusher, a mixer, a sower, a sprayer, a water pump and a head-feeding combine.

The machines used in the farmer system included a power tiller with a rotary tiller, a sprayer and a water pump.

The contract charge for the transplanting and harvesting operations was M$227.50/ha (M$65/relong) for transplanting and M$245.00/ha (M$70/relong) for harvesting.

In the case of the contractor system, the calculation was based on M$210.00/ha for the tilling operation charge, M$27.50/ha for the transplanting operation charge and M$245.00/ha for the harvesting operation charge.

The line A-A′ shows the utility cost of the machine per hectare for the mechanized system.

The line B-B′ showes the utility cost of the machine per hectare for the farmer system.

The line C-C′ shows the utility cost of the machine per hectare for the contractor system.

Based on the graphs, it appears that the utility cost of the machine per hectare decreases with increasing working area. This utility cost curve varies with the size of the machines.

The utility cost of the machines tends to be higher for larger machines than for smaller ones. The reason is that though the large machines have a high efficiency, the price of the machines is high.

The point of intersection between the curve A-A′ and the curve B-B′ can be obtained in Fig. 3.

If the working area exceeds 42 ha/year, the mechanized system is preferable to the farmer system, but if it is less than 42 ha the farmer system is superior, i.e. the break-even point is 42 ha/year.

As for the relation between the mechanized system and the contractor system, the point of intersection, can also be obtained, i.e. R (36 ha) which is the break-even point.

Conclusion

In order to introduce mechanized transplanting methods to the Muda area, some problems should be solved. Some of them are comparatively easy to solve such as the gathering of mountain soil and farmers' training. It is considered that mechanized transplanting is useful for the farmer. Cost of and labor requirement for the mat seedling system must be improved. Therefore, the following aspects must be considered:

1 Further improvement of the methods for raising the seedlings, supply of mountain soil on a group basis and local production of seedling trays.

2 The transplanter can be used in the field if the top soil depth is around 20 cm. But since the height of the mat seedling is limited, the paddy field has to be more shallow and level. Combination of the use of a drive harrow and head-feeding combine is effective in improving the field conditions. Moreover the performance of the drive harrow is also high. The performance of the head-feeding combine is lower than that of the large combine, but it can be improved.

3 In the farmer's working system, a large combine is helpful. On the other hand, the proposed mechanized working system should enable to develop a sequence of operations including the raising of seedlings, land preparation, transplanting and harvesting.

4 Based on the utility cost curve, when the working area exceeds 42 ha/year, the mechanized system is superior to the farmer system.

Summary

The purpose of this study is to establish a systematic mechanized farm operation program suitable for the Muda area in Malaysia based on the use of the drive harrow, the transplanter, the head-feeding combine and large combine harvester. In this paper, several problems are discussed.

The effect of the deep ruts from the large combine harvester on the tilling operation using the short blade type of drive harrow was investigated in farmers' fields. In fields harvested with the large combine, in spite of deep ruts ranging from 9.6 to 17.4 cm, a fairly good tilling operation could be performed. According to the results obtained, the surface of the top soil and hardpan after the 2nd tilling operation was comparatively more level than expected. Therefore, it was possible for the transplanter to travel easily.

When fresh wet straws were present in the fields, for instance during the rainy season, two rounds of tilling operations were needed in order to obtain a sufficient puddling accuracy in the fields harvested with the large combine. In fields harvested with the head-feeding combine,

however, tilling operations had to be performed three times.

Under the on-farm testing field conditions, the performance of the transplanter was about 5-6 hr/ha. This value is equivalent to approximately 1/8-1/10 of that obtained by manual transplanting.

The performance of the large combine was definitely better than that of the head-feeding combine. The performance of the head-feeding combine was about 1/2-1/3 that of the large combine.

Based on the utility cost curve, in the case of a working area exceeding 42 ha/year, the mechanized system was found to be superior to the farmer system.

References

1) Japanese Society of Agricultural Machinery (1984): Agricultural Machinery Handbook.
2) ANYOJI, H. (1978): Improvement of soil hardness in paddy field for the mechanization of harvesting-Study in the Muda Irrigation Project Area, Malaysia. *Bult. Natl. Res. Inst. Agr. Eng.*, **17,** 1-24.
3) MADA (1983): MUDA II Evaluation Survey-An impact evaluation study of the MUDA II Irrigation Project.
4) NOZAKI, M. (1984): Rice production system in the tropical monsoon lowlands-Rice double cropping in the Muda Irrigation Area, Malaysia. *Japan. J. of Trop. Agr.*, **28,** 67-71.
5) NISHIO, T. (1974): On rice cultivation practices in West Malaysia-Comparison of rice cultivation practices between the irrigated field area and the rainfed field area. *Japan. J. of Trop. Agr.*, **18,** 183-187.
6) The development of rice transplanter and combine harvester suitable for the Muda Irrigation Scheme, Malaysia (1974-1975). Institute of Agriculture Machinery, No.2-1, No.2-2, No.2-3, No.3-1.
7) YASHIMA, S. (1979): Development of field infrastructure for double cropping of paddy in the Muda Area. *Bult. Natl. Res. Inst. Agr. Eng.*, **18,** 63-73.

Discussion

Kikuchi, M. (Japan): Based on your economic analysis of machinery it appears that if the operational area exceeds 40 hectares, the mechanized system is profitable. It may not be advisable for the farmers to own machines particularly since the size of the holding in the Muda area averages 2 to 10 hectares. It may be preferable to promote the market for custom work to reduce the investment in machines.

Answer: I believe that for large machines, the best solution would be the purchase of machines such as combines by a group of 10 farmers who would operate jointly 100 hectares.