Agricultural mechanization system of rice production of Japan and proposal for China

Yang Mingjin[1], Yang Ling[1], Li Qingdong[2], Chen Jian[1]
(1. *Engineering Technology College, Southwest Agricultural University, Chongqing* 400716, *China*;
2. *Teaching Affairs Department, Southwest Agricultural University, Chongqing* 400716, *China*)

Abstract: This paper analyzed agricultural mechanization system of rice production using full mechanization (riding type) series and semi-mechanization (walking type) series. Effective field capacity, coverage area, operational cost, cost index, etc. were analyzed, including the land tilling, seedling transplanting, crop protection, chemical application and harvesting operation. Total machinery utilization cost per hectare for each farm work was also presented. On the basis of analysis of agricultural mechanization system of rice production of Japan, a rational proposal to the development of agricultural mechanization of China was made. Financial analysis results show that agricultural mechanization development of China can not directly copy the way of Japan, and agricultural mechanization of China can only be realized step by step.

Key words: agricultural mechanization system; rice production; cost index; Japan; China
CLC number: S23 **Document code**: A **Article ID**: 1002-6819(2003)05-0077-06

1 Introduction

Rice is one of the most important crops in the world. It is used as staple food in many countries especially in Asian countries such as China and Japan. In China, 60% of its population feeds rice as staple food, total cultivated area is 3.13×10^7 hm^2, accounting for 34% of total cereal cultivated area and 21% of total rice cultivated area in the world, and total output is 19.85×10^{10} kg, accounting for 43% of total cereal output and 36% of total rice output in the world[1,2]. It can be also used as biomass fuel through fermentation. It has high potentiality for ethanol in which the production efficiency is 0.43 m^3/t, the highest among the agricultural crops[1~3]. Increase of rice production is the major part of the increase of crop production in China. Leveling up the agricultural mechanization status of rice production can benefit to achieve the object. Especially in south China, main areas of rice production, to develop the mechanization of rice production is imperative[1,4]. The development of agriculture and the renewal of agricultural machinery rely heavily on innovation of science and technology, and there is a need of new decision-making methods[5,6].

The level of agricultural mechanization of China is somewhat low. There is a large gap of agricultural mechanization between China and developed countries. The development of agricultural mechanization is in disproportion in China. The main obstacle to the development is that the small farm scale of each farmhouse is unsuitable to the large scale of agricultural machinery production and the high investment for agricultural machinery[7,8]. A suitable agricultural mechanization system of a country should be established through the development of machines adjusted to her traditional farming methods, and economy, energy and environment should also be taken into consideration[9]. The economic analysis of agricultural mechanization of rice production and a proposal to the development of agricultural mechanization of China are reported as follows.

2 Methods and materials

2.1 Experiment arrangement

Rice production system includes many types of farm work, namely land preparation, seedling preparation, transplanting, crop protection, chemical application and harvesting operation and so on. For the purpose of better understanding and easy analysis of Japanese agricultural mechanization (AM) system of rice production, we separated the agricultural mechanization system into two series, namely full mechanization (riding type) series and semi-mechanization (walking type) series. The terms of riding and walking took the names after riding type tractor and walking type tractor.

Experiments related to riding type series include riding type puddling, riding type transplanting, power weeding, power spraying and combine harvesting.

Received date: 2003-06-03
Biography: Yang Mingjin (1973-), born in Dazhu, Sichuan province, lecturer of Engineering Technology College, Southwest Agricultural University, Chongqing 400716, China. Majored in Agricultural Engineering; trainee in Tsukuba International Center, CA, Japan (2002.2~2002.11). Email: yangmingjin6709@sohu.com

Experiments related to walking type series include walking type puddling, walking type transplanting, manual weeding, mist spraying, and reaping and power threshing. Power weeding and manual weeding are for crop caring, and power spraying and mist spraying are for chemical application. All experiments were done on the attached farm in the block A3, 0.2 hm^2, of Tsukuba International Center, Ibaraki-ken, Japan. Tests were oriented to items of cost analysis such as effective field capacity, annual fixed cost, variable cost, etc. Items concerning with field conditions and machinery performance were also performed. All test procedures were based on National Test Code of Agricultural Machinery of Japan or Asia and the Pacific Regional Network for Agricultural Machinery (RNAM) test codes.

2.2 Methods of analysis

Effective field capacity is the actual rate of land or crop processed in given time. Work capacity is reciprocal to effective field capacity. The following formula applies

$$EFC = A / T \quad (1)$$

where, EFC is effective field capacity, hm^2/h; A is field area, hm^2; T is total time required in a farm work, h.

Daily capacity is expressed the value on a farm work by several sets of machines with operators in several field blocks within a day. In manual farm work, the value of daily capacity is expressed by a group of workers

$$DC = EFC \times D_n \quad (2)$$

Where, DC is daily capacity, hm^2/d; D_n is net work hours per day, h/d.

Coverage area is used for determining farm work ability of a certain period, normally a seasonal period for a crop, and it is simply obtained by the following process

$$CA = DC \times AWD \times M / N \quad (3)$$

Where, CA is coverage area, hm^2; AWD is available work days in a certain period, d; M is number of machine sets; N is number of operation sets, normally $N = 1$.

Break even point of custom charge and machinery cost is an important datum to define actual service charge. Machinery cost per hectare decreases when annual operation area of machine increases normally, and breaking even point of area is calculated as follow

$$BEP = AFC / (CC - VCa) \quad (4)$$

Where, BEP is breaking even point, hm^2; AFC is annual fixed cost, dollar; CC is custom charge, dollar/hm^2; VCa is variable cost per hectare, dollar/hm^2.

Cost index (CI) is an important datum for a farm work or a farm work system, and it is expressed by

$$CI = (\text{Cost per hectare} / \text{Cash income per hectare}) \times 100\% \quad (5)$$

Analysis and evaluation of a whole work system can be carried out when we compare cost with cash income per hectare. If cost equals cash income per hectare at a certain farm scale, this farm scale is breaking even point of the system[10].

2.3 Materials and equipment

Japonica variety was cultivated and experimentally processed on the attached farm in Tsukuba International Center from March to September 2002. Machines used related materials are sighting poles, markers, cone plumb, soil hardness tester, measuring tapes, stopwatches, anemometers, etc.

3 Analysis of agricultural mechanization system of rice production of Japan

3.1 Analysis of riding type series

After experiments were done, by means of methods mentioned above, effective field capacity, daily capacity and breaking even point, etc. were calculated and shown in table 1. There are blank cells in the table because data of custom charge (CC) of farm work of weeding and spraying were not available. System analysis of riding type series was done as shown in table 2. In order to analyze cost index of the whole system, some farm work data, such as land tillage, nursery, drying and so on which are not from experiments but from reference book[11], are also presented in table 2, where, type of work: M means machinery; C means contract; L means manual work; total coverage area of the system, namely 6.5 hm^2 is the minimum coverage of individual farm work. Considering cash income per hectare of rice 12 015 dollars, breaking even point of the riding type series could be calculated. It is 1.7 hm^2. Furthermore, from the data of annual fixed cost (AFC), variable cost per hectare (VCa) and cash income of rice per hectare, cost per hectare at certain cultivated area of rice could be calculated as follows

$$\text{Cost per hectare} = (AFC + VCa \times A) / A \quad (6)$$

Where, A is cultivated area of rice, hm^2. Then, figure of cost or cash income per hectare vs. cultivated area of rice could be drawn as shown in Fig. 1. Figure 1 shows that while increasing cultivated area of rice, farmers can get more profit per hectare.

Table 1 Effective field capacity, daily capacity, and breaking even point of riding type series of Japan

Farm work	EFC/$hm^2 \cdot h^{-1}$	DC/$hm^2 \cdot d^{-1}$	CA/hm^2	AFC/dollar	VCa/dollar $\cdot$ hm^{-2}	CC/dollar $\cdot$ hm^{-2}	BEP/hm^2
Puddling	0.110	0.703	15.4	3 102	119	731	5.1
Transplanting	0.134	0.860	18.8	3 820	155	538	10.0
Power weeding	0.072	0.396	11.9	270	171	—	—
Boom spraying	0.529	2.923	35.1	542	118	—	—
Combine harvesting	0.060	0.332	6.5	4 973	202	1 385	4.2

Table 2 Summary of riding type series of Japan

Work	Machinery	Type of work	WC /$h \cdot hm^{-2}$	AFC /dollar	VC /dollar $\cdot$ hm^{-2}	CA /hm^2	Annual cost at farm scale of CA /dollar $\cdot$ hm^{-2}	CI at farm scale of CA /%
Tillage	Tractor with rotary	M	3.5	1 907	48	69.4	343	2.9
Puddling	Tractor+ puddler	M	9.1	3 102	119	15.4	599	5.0
Nursery	Nursery (buying)	C	0	0	1 231	1 000	1 231	10.2
Transplanting	Transplanter	M	7.4	3 820	155	18.8	746	6.2
Power weeding	Power weeder	M	14.0	270	171	11.9	212	1.8
Power spraying	Power sprayer	M	1.9	542	118	35.1	202	1.7
Combine harvesting	Combine harvester	M	16.7	4 973	202	6.5	1 099	9.1
Drying	Dryer (contract)	C	0	0	865	1 000	865	7.2
Husking	Husker (contract)	C	0	0	288	1 000	288	2.4
Water management	Water facilities	L	0	0	269	1 000	269	2.2
Total			52.6	14 613	3 594	6.5	5 854	48.7

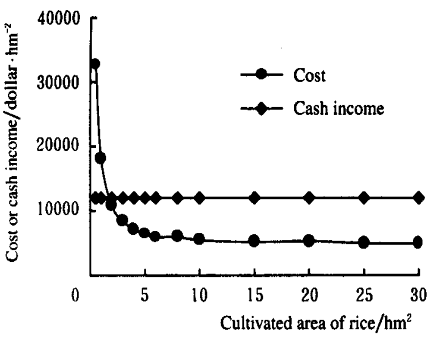

Fig. 1 Cost or cash income per hectare vs cultivated area of rice (riding type)

3.2 Analysis of walking type series

Following the same analysis process as riding type series, effective field capacity, daily capacity and breaking even point, etc. of each farm work of walking type series could be calculated and shown in table 3, system analysis of walking type series was done as shown in table 4, and breaking even point of the walking type series could be calculated. It is 0.7 hm^2. Figure of cost or cash income per hectare vs cultivated area of rice is shown in Fig. 2.

Table 3 Effective field capacity, daily capacity, and breaking even point of walking type series of Japan

Farm work	EFC/$hm^2 \cdot h^{-1}$	DC/$hm^2 \cdot d^{-1}$	CA/hm^2	AFC/dollar	VCa/dollar $\cdot$ hm^{-2}	CC/dollar $\cdot$ hm^{-2}	BEP/hm^2
Puddling	0.053	0.342	7.5	706	221	731	1.4
Transplanting	0.090	0.575	12.6	771	146	538	2.0
Manual weeding	0.047	0.258	7.7	44	247		
Mist spraying	0.447	2.470	29.6	291	96		
Reaping	0.250	1.381	26.9	923	51	654	1.5
Threshing	0.027	0.147	2.9	2 045	1 049	1 385	6.1

Table 4 Summary of walking type series of Japan

Work	Machinery used	Type of work	WC /$h \cdot hm^{-2}$	AFC /dollar	VC /dollar $\cdot$ hm^{-2}	CA /hm^2	Annual cost at farm scale of CA /dollar $\cdot$ hm^{-2}	CI at farm scale of CA /%
Tillage	Tractor with rotary	M	18.0	583	223	13.5	426	3.5
Puddling	Tractor+ puddler	M	18.7	706	221	7.5	467	3.9
Nursery	Nursery (buying)	C	0	0	1 231	1 000	1 231	10.2
Transplanting	Transplanter	M	11.1	771	146	12.6	415	3.5
Manual weeding	Manual weeder	M	21.4	44	247	7.7	263	2.2
Mist spraying	Mist sprayer	M	2.2	291	96	29.6	198	1.6
Reaping	Reaper	M	4.0	923	51	26.9	374	3.1
Threshing	Thresher	M	37.6	2 045	1 049	2.9	1 763	14.7
Drying	Dryer (contract)	C	0	0	865	1 000	865	7.2
Husking	Husker (contract)	C	0	0	288	1 000	288	2.4
Water management	Water facilities	L	0	0	269	1 000	269	2.2
Total			113.1	5 362	4 687	2.9	6 558	54.6

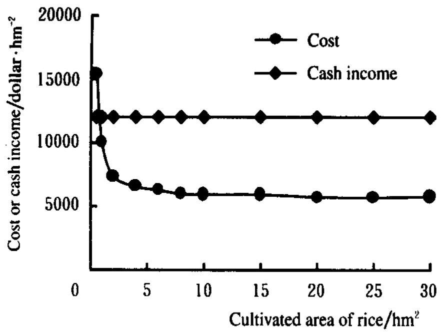

Fig. 2 Cost or cash income per hectare vs cultivated area of rice (walking type)

3.3 Discussion on agricultural mechanization system of Japan

From the analysis of the two types of farm work series, some major data can be derived as shown in table 5. In Japan, breaking even point of riding type series is 1.7 hm^2 and coverage area of one set is 6.5 hm^2. If cultivated area of rice of a farmer is 6.5 hm^2, equalling to coverage area of the system, the farmer can gain total profit 39 825 dollars from the system with profit per hectare 6 127 dollars. Breaking even point of the walking type series is 0.7 hm^2 and coverage area of one set is 2.9 hm^2. If cultivated area of rice of a farmer is 2.9 hm^2, equalling to coverage area of system, the farmer can gain total profit 15 636 dollars from the system with profit per hectare 5 392 dollars. Because most of Japanese farmers whose cultivated rice area is less than 3 hm^2 per farmhouse (average cultivated scale in Japan is about 1.0 hm^2 per farmer, namely 2~3 hm^2 per farmhouse), walking type series is more profitable than riding type series. For example, when cultivated area of rice is 2 hm^2, profit per hectare is 1 228 dollars for riding type series, and 4 647 dollars for walking type series; when cultivated area of rice is 3 hm^2, profit per hectare is 3 663 dollars for riding type series, and 4 859 dollars for walking type series. When cultivated area is around 5 hm^2, profit per hectare of riding type and walking type is nearly same. When cultivated area is more than 6 hm^2, riding type series is more profitable than walking type series. Data in table 5 shows that profit at farm scale of 3 hm^2 of walking type series is lower than that at farm scale of CA. Because 3 hm^2 is more than CA, two threshers are required in this system (table 3), which results in lower profit at farm scale of 3 hm^2 than that at farm scale of CA. Cost indexes of the two series at farm scale of coverage of their corresponding series are 48.7% and 54.6%, respectively.

Nevertheless, from history of Japanese agricultural mechanization development, farmers adopt riding type farm work series step by step other than walking type series, because adoption of riding type series can save a lot of time for their part jobs, and most of their families' main income is not from farm work but from part time jobs.

Table 5 Data of farm work series of Japan

Series	CA /hm^2	BEP /hm^2	Profit at farm scale of CA /dollar·hm^{-2}	Profit at farm scale of 2 hm^2 /dollar·hm^{-2}	Profit at farm scale of 3 hm^2 /dollar·hm^{-2}	Profit at farm scale of 5 hm^2 /dollar·hm^{-2}	Profit at farm scale of 6 hm^2 /dollar·hm^{-2}	CI at farm scale of CA /%
Riding type	6.5	1.7	6 127	1 228	3 663	5 611	6 099	48.7
Walking type	2.9	0.7	5 392	4 647	4 859	5 615	5 753	54.6

4 Proposal to development of agricultural mechanization of China

4.1 Conventional farm work system of China

In China, most farm work of rice production is finished by manual or animal energy. Power tiller and pedal thresher or power thresher are gradually adopted by more and more farmers for their land preparation and harvesting work. Combine harvesting, especially cross-district operation, is on the stage of popularization, and becomes more and more popular in relative rich or labor shorthanded areas[7,8]. On the basis of calculation of China Agricultural Machinery Yearbook 2000, yield of rice production in China was 6 300 kg/hm^2, cash income per hectare of rice production is 1 131 dollars. Cost per hectare, including annual fixed cost and variable cost, is 708 dollars. Then cost index of the traditional farm work system of rice production in China is 63.0%, which shows a higher cost index than farm work series of Japan (riding type 48.7%, walking type 54.6%)[2].

The conventional farm work system of rice production in China is not profitable because of small farm scale, about 0.1 hm^2 per farmer. It is quite difficult to increase the level of agricultural mechanization due to quite low income from farm work. However, in recent years, with more and more labor forces transferred to other industries and number of animals decreasing, there are potential demands and trend of mechanized farm work.

4.2 Proposal to development of agricultural mechanization of China

The level of agricultural mechanization in China is somewhat low. From the analysis and discussion on conventional farm work system of rice production in China and comparing it with that of Japanese conditions, we know that farm work in China is not profitable. Agricultural mechanization system of China cannot be directly transplanted from Japan, and the way of the development of agricultural mechanization of China can only realized sequentially and step by step. At the same time, Chinese government should produce more part time job opportunities for farmers in order to increase farmers' income from part time jobs. And new technology such as post harvesting process should be developed to increase additional value of rice products, then to increase farmers' income. Thus, farmers will have more impetus to improve their farm work conditions and have more impetus to save time from farm work. Consequently, some farmers will increase their cash income by means of enlarging their farm scale through hiring farm land from other farmers. Furthermore, government ought to make some policy and carry out some projects for infrastructure construction in order to improve farm land conditions, especially the farm road condition, to improve irrigation and drainage system and so on. Also promotion of farmers' knowledge and technology is an important factor to the development of agricultural mechanization in China. Following such measures, mechanized agriculture and modern agriculture can be realized gradually.

Moreover, full-mechanized farm work system in China cannot be gained at the same time for all the farm work from land preparation to harvesting. From development experience of agricultural mechanization of Japan and considering conditions of China, agricultural mechanization could only be achieved sequentially. First, mechanized harvesting (both combine harvesting and sectional harvesting, namely reaping and threshing) is superior. Because harvesting is timely and laborious, farmers vitally demand mechanized harvesting. Second, land preparation should be mechanized. It is not hard work powered by animals, but structures of power tillers are not complex, and they are easy to be designed and manufactured. They are multipurpose machines. Engines or tractors of the power tillers can do many kinds of farm work, so power tillers are quite profitable. After that, transplanting work should be mechanized. Mechanized transplanting can release farmers from bitter farm work and can set free a great number of labor forces. At last, crop caring, pest control, fertilizer application, etc. should be mechanized gradually.

5 Conclusions

Cost analysis of farm work system of Japan showed that farmers can gain different profit per hectare at a certain farm scale by adopting different series, namely riding type series and walking type series. Walking type series is profitable at a small farm scale. Neither riding type series nor walking type series of Japan is suitable or profitable on Chinese conditions. Cost index of the traditional farm work system of rice production in China is higher than that of farm work series in Japan. In China, appropriate farm work system is very important to agricultural development, and it ought to be different from Japanese conditions. Mechanized farm work system cannot be achieved at the same time for all the farm work. Therefore, agricultural mechanization of China can only be realized sequentially and gradually.

Acknowledgments: Heartfelt thanks are given to staff of Farm Mechanization Section in Tsukuba International Center (TBIC) and all participants of Agricultural Mechanization for Sustainable Farming System course, 2002.

[**References**]

[1] Song Jiannong, Zhuang Naisheng, Wang Lichen. The development tendency of Chinese rice planting mechanization in the 21th century [J]. Journal of China Agricultural University, 2000, 5(2): 30~33 (in Chinese).

[2] Editorial Committee of China Agricultural Machinery Yearbook. China agricultural machinery yearbook 2000 [M]. Beijing: Editorial Committee of China Agricultural Machinery Yearbook, 2000, 206~214 (in Chinese).

[3] Osamu Kitani. CIGR handbook of agricultural engineering V (energy & biomass engineering) [M]. Michigan: American Society of Agricultural Engineers, 1999, 139~163.

[4] Wang Liming, Qian Shengyue, Yang Jianping, et al. Discussion about coordinate development of agricultural mechanization with modernization [J]. Chinese Agricultural Mechanization, 2003, (3): 9~11 (in Chinese).

[5] Ding Yi, Yang Yuanliang, Xu Jinqiang. Decision making on agricultural equipment replacement [J]. Transactions of the CSAE, 2002, 18(4): 82~85 (in Chinese).

[6] Chen Zhi. Unique approach to develop farm machinery industry by innovation of science and technology [J].

Transactions of the CSAM, 2003, 34(3): 131～134(in Chinese).
[7] Liu Min. The development tactics and countermeasures of agricultural mechanization in the 21 century in China[J]. Chinese Agricultural Mechanization, 2002, (6): 3～5(in Chinese).
[8] Yu Shizhu. Stride forward the mechanization of paddy production whole course[J]. Chinese Agricultural Mechanization, 2003, (1): 4～6(in Chinese).
[9] Song Weidong. Several opinions to the development of agricultural mechanization in China after entey WTO[J]. Chinese Agricultural Mechanization, 2003, (3): 55～56(in Chinese).
[10] Douglas J, McConnell, John L Dillon. Farm Management for Asia: A Systems approach[M]. Rome: Food and Agriculture Organization of the United Nations, 1997, 89～134.
[11] Statistics Bureau. Statistical handbook of Japan 2001[M]. Tokyo: Japan Statistical Association, 2001, 51～63.

日本水稻生产机械化系统分析及对中国农业机械化发展的建议

杨明金[1], 杨　玲[1], 李庆东[2], 陈　建[1]
(1. 西南农业大学工程技术学院, 重庆 400716;　2. 西南农业大学教务处, 重庆 400716)

摘　要: 该文对日本水稻生产机械化系统的试验进行了分析。该水稻生产机械化系统分为两个系列: 全程机械化系列(乘式系列)和半机械化系列(走式系列)。详细分析了水稻生产机械化系列的各个作业项目的田间作业量、负担面积、作业费用及成本指数等, 这些作业项目的内容包括耕地、插秧、除草、植保和收获作业等。同时也分析了每个系列的每公顷机器使用总费用。在分析日本水稻生产机械化系统的基础上, 提出中国农业机械化发展的合理化建议。作业成本分析表明, 中国的农业生产机械化系统不能完全照搬日本模式, 中国的农业生产机械化的发展道路只能有序列的逐步实现。
关键词: 农业机械化; 水稻生产; 成本指数; 日本; 中国