Hyper Low-cost Ultimate Rice Mechanization System

Sistema de Mecanização do Arroz Hyper Low-cost Ultimate

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ABSTRACT
About 480 million tons of rice (milled rice base) are produced annually in the world. It is one of the cereals with a low trade rate for its production. In Asia, more than 90% of the world's production is produced. The top 10 countries in rice production are all Asian countries. The main operation of rice cultivation consists of planting, management while rice growing (weed & pest control, water management), harvesting, and post-harvest processing. In addition to infrastructure development such as irrigation and drainage system through field reclamation, the development of chemical fertilizers, herbicides, and pesticides contributed to labor saving. However, the introduction of the combine harvester, which can significantly save labor and simplify the harvesting operation, is one of the required parts of the technological innovation.
In this paper, one direction is shown to realize hyper-low cost of rice cultivation system through these technological innovations, demand and consumption increase of rice, and open up new markets as a response to the future food crisis.

Keywords: Rice mechanization system, Asian agriculture, Direct sowing of rice, Combine equipped with de-husking function, Seed coating, Brown rice dryer.

RESUMO
Cerca de 480 milhões de toneladas de arroz (base de arroz branqueado) são produzidas anualmente no mundo. É um dos cereais com uma baixa taxa de comércio para a sua produção. Na Ásia, mais de 90% da produção mundial é produzida. Os 10 principais países na produção de arroz são todos os países asiáticos. A principal operação de cultivo de arroz consiste na plantação, gestão enquanto o cultivo do arroz (controlo de ervas daninhas e pragas, gestão da água), colheita, e processamento pós-colheita. Para além do desenvolvimento de infra-estruturas, tais como sistemas de irrigação e drenagem através da recuperação do campo, o desenvolvimento de fertilizantes químicos, herbicidas, e pesticidas contribuiu para a poupança de mão-de-obra. No entanto, a introdução da ceifeira-debulhadora, que pode poupar significativamente mão-de-obra e simplificar a operação de colheita, é uma das partes necessárias da inovação tecnológica.
Neste documento, mostra-se uma direcção para realizar um custo hiperbaixo do sistema de cultivo de arroz através destas inovações tecnológicas, aumento da procura e do consumo de arroz, e abrir novos mercados como resposta à futura crise alimentar.

Palavras-chave: Sistema de mecanização do arroz, agricultura asiática, Sementeira directa de arroz, Combinação equipada com função de descasque, Revestimento de sementes, Secador de arroz castanho.

1 INTRODUCTION

1.1 ASIAN AGRICULTURE

Asia is one of the huge agricultural production regions in the world. The ASEAN Economic Community (AEC) consisting of 10 member countries of the Association of Southeast Asian Nations. On November 22, 2015, the Kuala Lumpur Declaration on its inauguration as of December 31, 2015 was signed by the leaders of ASEAN countries. It was expected that active economic exchanges would be achieved by achieving a high level of liberalization of goods, such as the fact that tariffs on goods in the region have already become zero for more than 90% of items.

Needless to say, the establishment of an economic community lies in the economic promotion of non-Asian regions, but economic promotion is not limited to that, and contributes to the stable maintenance of regional peace. Cooperation and competition for mutual coexistence and co-prosperity among member countries are extremely important and necessary for the growth of ASEAN.

One of the strengths of Asia is that it is one of the world's leading agricultural production areas, and the fact is that the 10 ASEAN member countries are more or less dependent on the agricultural economy. Figure 2 shows the top 10 countries in rice production and consumption. It can be found from this fact that the 1st to 8th and 9th place are occupied by Asian countries.

Furthermore, in order to promote the ASEAN Economic Community, it is necessary to actively cooperate not only with the scope of member countries but also with neighboring countries in Asia and Europe and the United States. Figure 1 shows the main cereal production and trade ratio in the world. Rice ranks third after corn and wheat. Rice is a cereal with a low trade rate for its production, but Asia produces more than 90% of the world's total rice production. This shows that rice is an important staple food in Asia. When the unexpected pandemic seen in COVID-19 occurs, problems such as food supply stop immediately occur. Rice does not require much difficult technique in cultivation and can be cultivated by anyone relatively easily.

In Asia, not only rice but also agricultural products such as fruit trees and vegetables, as well as natural energy resources are actively produced, and sugar cane and palm oil fall under these categories. The author has been proposing projects with the ASEAN community centered on agriculture for the last few years. The concept is as follows. In other words, although Asia produces a large amount of agricultural products, it is still not sufficient in terms of quality control. Therefore, Japan, which is a technology-oriented country, and Asia, which is a resource-oriented country, bring resources and complement each other's shortcomings. It is about creating and developing food products and continuing sustainable development and stable maintenance of regional peace.

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Figure 1 Main cereal production & trade

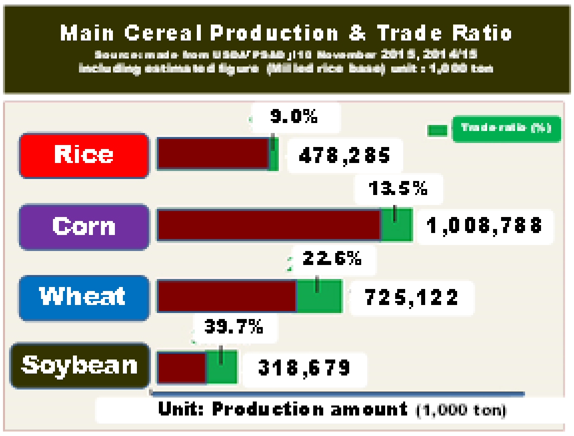
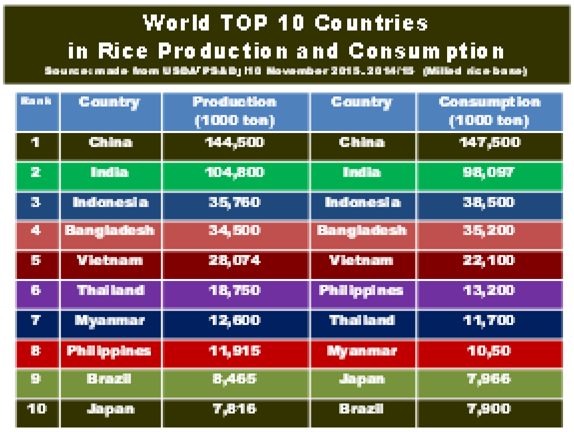


Figure 2 World top 10 countries in rice ratio production and consumption



World TOP 10 Countries in Rice Production and Consumption

Rank	Country	Production (1000 ton)	Country	Consumption (1000 ton)
1	China	144,500	China	147,500
2	India	104,800	India	98,097
3	Indonesia	35,760	Indonesia	38,500
4	Bangladesh	34,500	Bangladesh	35,200
5	Vietnam	28,074	Vietnam	22,100
6	Thailand	18,750	Philippines	13,200
7	Myanmar	12,600	Thailand	11,700
8	Philippines	11,915	Myanmar	10,50
9	Brazil	8,465	Japan	7,966
10	Japan	7,816	Brazil	7,900

1.2 EXISTING AND FUTURE RICE MECHANIZATION

Figure 3 shows the comparison between existing rice cultivation process and future one, which the author would like to change the existing way by combining and simplifying the operations in planting and harvesting for further improvement to achieve the ultimate rice mechanization system.

Basically the rice cultivation consists of the following seven processes. They are 1) Seed preparation, 2) Land preparation, 3) Planting, 4) Management while rice is growing, 5) Harvesting, 6) Post-harvest processing, 7) Packaging for sale & shipping. With new technology development and innovation, there can be seen more possibilities to combine the operations in series for simplifying and saving the time, energy and labor. When it comes to think about the rice cultivation, there can be seen more possibilities in planting and harvesting system,

Three operations consisting of seed sowing, nursery plant growing and transplanting of nursery plant of rice can be combined and simplified by replacing the direct sowing. Then time, labor and energy saving can be surely achieved drastically.

Figure 3 Rice cultivation process now and

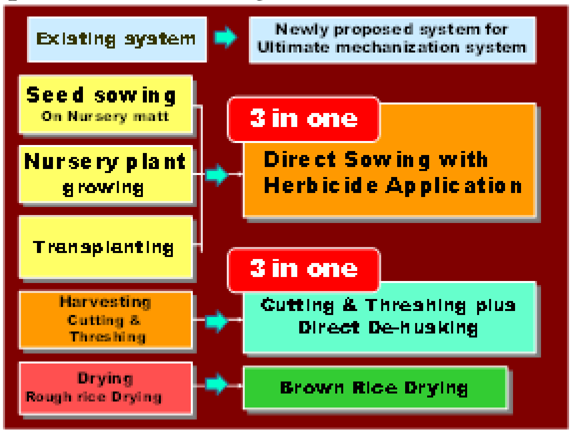
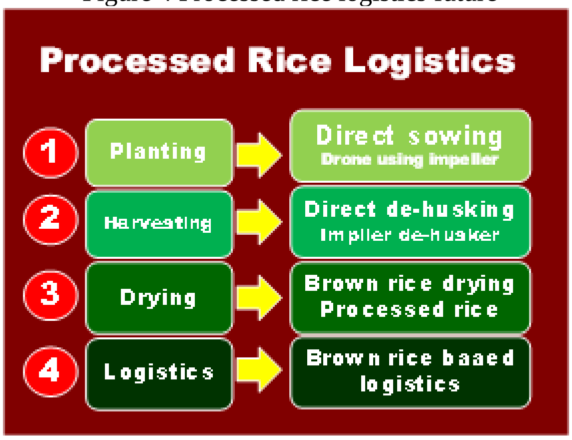


Figure 4 Processed rice logistics future



In addition, even in harvesting stage of rice, further change of the system can be possibly achieved. The existing rice harvesting operation is consisting of a combination of two operations: harvesting the rice itself and threshing the paddy from the rice. The author found, however, that the impeller type de-husker could de-husk even for high moisture rough rice even a small problem is still remained without being resolved due to high speed rotation of impeller. He tried to mount this de-husker directly on the commercial rice combine and investigated the possibility of application. As the result of investigation, it could be found that the de-husking could be possibly functioned even for high moisture rough rice. For further more details about the results were shown later. Figure 4 focuses on processed rice and shows how logistics such as supply & value chain could / should be changed by the cultivation system change. By the introduction and impeller de-husker application to the actual rice agriculture, more merits can be found, however on the other hand some demerits can be found in case too. If the idea can't be put to commercialization for practical use in a short period of time, many possibilities should be explored. If there is still a problem in terms of quality for example, it should also be significant to focus on the use of processed rice and explore its potential.

1.3 RESEARCH OBJECTIVE

Based on the above mentioned description, the following shows the research objectives

1) To propose New Rice production system by applying two methods of operations in Planting & Harvesting stage

2) To clarify and show the obstacles to negotiate for solving the problem

3) To show the effect how the Rice production system can be simplified essentially

4) To discuss how the Rice supply chain can be changed to provide further possibility and cultivation system improvement by the newly proposed system

2 RICE PLANTING

2.1 TRANSPLANTING IN JAPAN

There were three hard operations in rice cultivation. They were 1) Transplanting, but it was solved by the development of transplanter and nursery plant growing technique, 2) Weed control. This issue was solved by chemical herbicide development. It was being done by man-powered and animal powered, however, finally it became mechanical powered one, but nowadays the weeds are being popularly controlled by use of chemical herbicide and, 3) Harvesting, but even for this, rice combine harvester was developed and accepted. The reason why most of the farmers prefer transplanting to direct sowing depends on the condition as shown below. The initial stage of rice nursery plant has leaves and roots enough to absorb the nutrition required for growth, therefore, rice is very much competitive with weed in early stage of growing just after transplanted. In addition chemical herbicide can control the weed perfectly. The area of direct sowing rice is due to the outflow of agricultural labor due to high growth. In 1974, it spread to 55,000 ha, mainly for direct sowing of upland paddy rice fields. It occupied 2% of the planted area, but since then, it has been used for rice transplanters and seedling raising equipment. It decreased due to the above etc., and in 1993, it was mainly sown directly from upland paddy fields in Okayama prefecture, however, it decreased to 7,200 ha (this is equal 0.3% of the rice cultivated area) in Japan. Most of the farmers like to accept more stable and reliable ways, especially in Japan the ratio of professional farmers to part-time farmers is 15% to 85%, therefore, part-time farmers don't like to be involved in any problems even for a small problem. Normally they must go to work during week days. They must complete the operation timely. Due to small scale rice farming, they have any interests in production increase. They want to finish the season quickly as the result of long time rice production control policy done by the government. They are totally discouraged and no more successors could be grown up. The young generation's image of agriculture has declined dramatically.

2.2 DIRECT SOWING IN JAPAN

As already mentioned above, transplanting is mostly and popularly accepted by the rice farmers. Japanese rice agriculture can be normally characterized by the following features.

1) Small scale farming

2) Professional farmer needs more farmlands for scale up to increase the income from agriculture.

Many farmers are aged and can't work anymore, therefore, professional farmer wants to rent the farmlands from them for farming scale up, however, the paddy fields are not in one place, and difficult to put a big machine in. Especially for a small scale rice farming, the income is less and hard to introduce the machines. Farming operation must be done precisely controlling the total loss. The unique ways of direct sowing was developed considering the obstacles to negotiate. They are 1) Bird attack, 2) Lodging, and Weed control. Considering these three problems, the finally derived conclusion was to sow the seed beneath the paddy field ground surface. If the seed is sowed beneath the paddy field soil surface, the bird can't see and find the seed due to the coverage by soil. The recommendable seeding depth was found around 10 mm, almost equal to the three times thickness of the rough rice seed. The seed sowed beneath the ground surface needs oxygen to be germinated with higher percentage more than 85~95%. For the purpose of achieving this condition, some of the chemical coating aids were developed and widely accepted such as calcium per-oxide, in which the registered commercial product name is simply called "Calper". Ferrite-coating aid, Fe2O3 can be used for adding the seed weight to make it easier to penetrate into the soil. In addition it can be used for magnetic seed metering device for precision sowing because the number of seeds passing through the seeing pipe can be counted and monitored for the driver to know how many seeds are being sowed from time to time. Further description about this is shown in the separate section later.

2.3 DIRECT SOWING IN THAILAND

As always generally said that the farm mechanization is not only the technology development and application but also it includes social issue, because the farmer makes decision which way should be taken, to hire the worker or to buy the machine. Needless to say, the decision can be made based on the labor fee payment comparison how much should be paid even the direct seeder was already developed and commercialized. Thai farmers are also following the same way as mentioned above.

Figure 5 Change of direct sowing ratio from 1990 to 1997

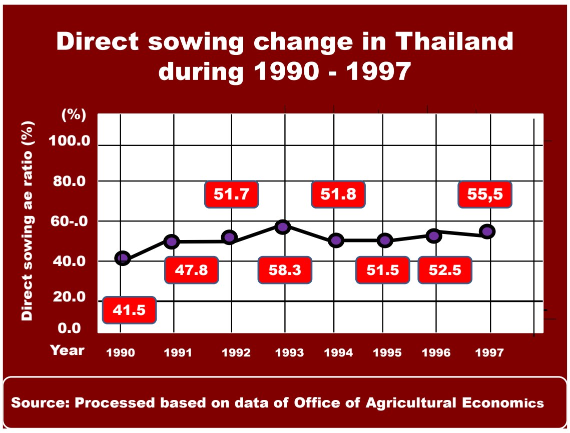


Figure 6 Change of direct sowing ratio from 2010 to 2018

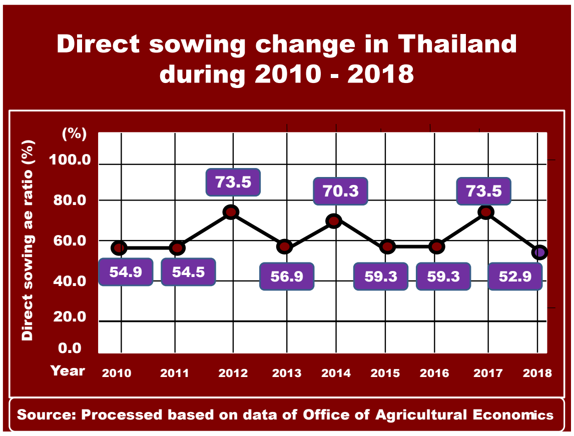


Figure 5 and Figure 6 show the change of direct sowing ratio (%) from 1990 to 1997 and 2000 to 2018 in Thailand respectively. Figure 6 and 7 show the direct sowing acceptance in four regions in Thailand and its expanding rate in recent 28 years from 1990 to 2018 respectively.

It can be found and summarized from those four figures that

1) Direct sowing of rice has been accepted on average almost more than 50% in Thailand even though the rate is different depending on the regions.

2) Acceptance higher ranking is Central region, Northern region, Southern region and North Eastern in order.

3) Direct sowing acceptance has been increased 12% in the past 28 years from 1990 to 2018.

Figure 7 Direct sowing acceptance in four regions in Thailand

Direct sowing acceptance in four regions in Thailand (%)

Region	1990	1991	1992	1993	1994	1995	1996	1997
NE	7	12	26	54	26	25	24	27
N	39	57	57	51	52	52	56	65
C	76	83	83	83	82	87	91	90
S	44	39	41	45	45	42	39	40

Figure 8 Expanding rate of direct sowing (%)

Expanding Rate of Direct Sowing (%)
(How it was accepted in the past 3 decades)

Year	Ratio of Direct sowing
1990	41 (%)
1997	55 (%)
2010	55 (%)
2018	53 (%) 12 %

Processed by Author from the combination data 1990-1997 & 2010-2018, Source: Office of Agricultural Economics

Reasons why direct sowing had a rapid transition can be listed as shown below.

1) Labor force shortage in rural areas

2) Labor hiring wages was going up for transplanting operation

3) Even with direct sowing, the yield was almost equal to/or higher than transplanting in some areas

2.4 FARMERS SCOPE HOW THEY ARE THINKING ABOUT DIRECT SOWING

The following shows the responses from farmers for questions about the scope of direct sowing of rice.

1) Farmers answered as shown below

70 % like to introduce Direct sowing

23.6 % expect Farmland lending and consignment

2) Rain fed area farmers

66.7% Direct sowing introduction

5.0% Farmland lending and consignment

3) Irrigated area farmers

80.0% Direct sowing introduction

20.0% Farmland lending and consignment

It can be concluded from the above mentioned that farmers are willing to introduce direct sowing toward the future.

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2.5 SHIFT AND PROBLEMS FROM TRANSPLANTING TO DIRECT SOWING

1) Drastic Energy & labor saving can be done by material handling and massive nursery plants transportation in addition to management for nursery plant growing preparation
2) No need to grow nursery plant, just needed seed only
3) In case of using drone, the planting can be completed quickly in a short time

On the other hand, the obstacles to negotiate are shown below.

1) Low germination and sprouting rate. This means the ratio how many number of rice plants could come out of the covered soil successfully even if they are germinated in the soil.
2) Low liability for rice plant sprouting
3) Low stable growing, especially in the early stage of planting due to the following problems as already mentioned previously: 1) Bird attack, 2) Lodging, and 3) Weed control

Figure 9 Average production cost comparison

The average production cost of rice planting / rai compared among manual direct sowing (DS), mechanical direct sowing (MDS) and mechanical transplanting (MT)

	DS	MDS	MT
2 times of land preparation	3 400	1 400	2 400
Seeds	160	240	600
Planting	1,140	150	40
Weeds controlling	-	160	160
1st chemical fertilizing	425	300	425
2nd chemical fertilizing	375	300	375
3rd chemical fertilizing	170	-	170
Insects controlling	600	500	600
Harvesting	450	450	450
Transporting to mill houses	140	140	140
Total cost	3,970	2,800	3,520

Small portable type to Drone or Sharing ?

Unit: baht Source: Pirote (2013)

Figure 10 Yield per unit area (ha) comparison

YIELD PER UNIT AREA (ha)

Planting method	Average yield (ton / ha)
Direct sowing	2.499
Transplanting	2.718

Source: Tsuyoshi Sumita, Masuo Ando (2002) Economy of Direct Seeding of Rice in Northeast Thailand and its Future Direction, Japanese Journal of Rural Economics, Vol. 40, No.1 (No. 112)

Figure 9 shows the average production cost for three kinds of direct sowing method, DS, manual direct sowing, MDS, mechanical direct sowing, and MT, mechanical transplanting. For the production cost comparison, the cheapest ranking is shown as MDS (mechanical direct sowing) > MT (mechanical transplanting > DS (manual direct sowing) in order. Further mechanical direct sowing may be expanded by the development of drone with low price and precise control function because of compactness and ease in handling. Figure 10 shows the comparison of rice yield per unit area (ha). It shows almost 200 kg difference between them. How this difference could be evaluated depends on the farmers individually. The rice yield per unit area (ha) looks almost half of the case of Japan and USA (6 tons/(ha). The reason why such a difference cold be seen is not clear yet, however, rice can be cultivated two to three times a year in Thailand and other some countries in Asia.

2.6 SEED COATING

In conventional direct sowing cultivation, seeds were sown on the surface of the field, but under flooded conditions, the seeds may float in water, be damaged by birds, or fall down because the seeds are sowed on the surface of the field. There was a problem. It was found that these problems can be solved by sowing seeds in the soil, but new problems have emerged, such as a decrease in germination rate due to lack of oxygen in the soil. Therefore, coating with lime peroxide was proposed as oxygen supplement, and it seemed that direct sowing would replace rice planting, but due to the instability of initial growth after sowing, it now accounts for 1.4% of the total rice cultivation. It is decreasing (Fig. 11). However, since direct cultivation is ultra-labor-saving and low-cost cultivation compared to rice planting, rice cultivation is expected to replace direct sowing cultivation in the future. However, since the way to farm mechanization is decided by the farmers involved in many cases by comparison with the costs of employed workers, it is difficult to disseminate it unless conditions such as the need for large-scale production and high yields are met. Figure 12 shows the seed coating operation with calcium peroxide and ferrite coating aids. The amount of coating agent required for coating is the same as the amount of seeds. Direct sowing in Thailand does not use a coating agent. Since the temperature is high throughout the year, it is presumed that germination by direct sowing is relatively early.

Figure 11 Difference in direct sowing

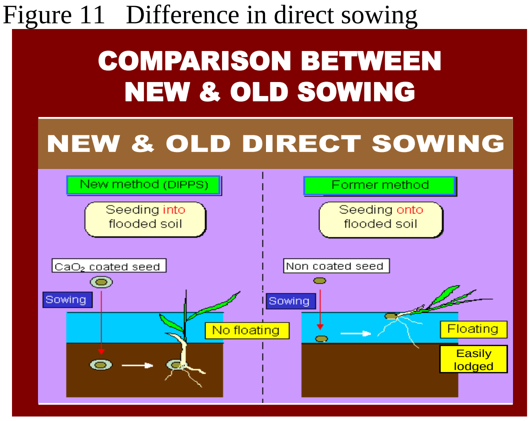


Figure 12 Seed coating aids

Figure 13 shows the diagram for precision sowing system. The meaning of the precision sowing system is a function that can continue the sowing work while always maintaining the sowing density uniformly even if the travelling speed of the seeding machine changes. The seeding density is based on the seeding amount per unit area, generally the seeding amount per hectare. Even if the traveling speed of the seeding machine changes during the sowing operation, the sowing amount is fed out accordingly and the sowing density is maintained at a constant target value. The seeding density can be obtained from the seeding amount and seeding area per unit time using the measurement, measurement and running speed of the seeding amount, and the driver can always monitor the value converted to the seeding amount per hectare. At the end of the sowing work, it is necessary to establish a state in which the prepared seed amount is accurately sowed. This type of control can be also applied to the similar machines for applying compost, pesticides, chemical fertilizers, etc. The amount of rice seed per unit area (ha) is different depending on the country. In Japan, it is 30kg/(ha), however, in USA they use almost 3 to 4 times more than Japanese case. This comes from the difference of farming scale between Japan and USA. In the United States, seeds are sown three to four times as much as in Japan. The background to this is to prevent damage due to bird attack by sowing it in the soil, but in the United States, if a bird comes to eat, it should be sown in anticipation of the damage. Also, regarding weeding, instead of completely managing the field so that there are no weeds, farmer apply a minimum amount of herbicide, but they don't care even if weeds grow, and they harvest rice at about half of the rice plant height. In case of large scale farmers they do without worrying about the details.

Figure 14 shows magnetic seeder using ferrite coated rice seed. Seed metering can be controlled by adjusting the electric voltage or current. Magnetic force can capture the corresponding amount of ferrite coated seed, proportional to input electric current or voltage. Figure 15 & Figure 16 show the principle of coil gun and experimental setup. It is necessary to calibrate in advance the relationship between how much magnetic force is generated by the input current or voltage and how much ferrite coated seeds are absorbed by the magnetic force to understand the relationship between the two. This relationship should be known in advance from the calibration test. In actual seed sowing operation, the number of coated seed passing through the seeding pipes can be counted by the sensor attached at the exit of seeding pipe. The sowing density is expressed by the amount of sowing per unit area. Since the width of seeding machine is known and the moving distance of the sowing machine per unit time is $x = vt$, the sowing area per unit time is the product of the working width of the seeding machine and the moving distance. The seeding amount is calculated by considering the seed amount counted by the sensor attached at the outlet of the seed pipe for the number of seed pipe in Figure 17. This information finally displayed in kg/ha for the driver to monitor time to time. Figure18 shows the recommendable herbicide "Top gun" (registered trade name) application in early stage of growing after planting from author's long term experience.[1]

Figure 13 Precision sowing system

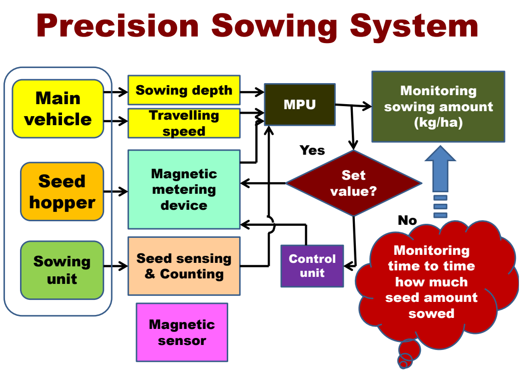


Figure 14 Magnetic seed metering system

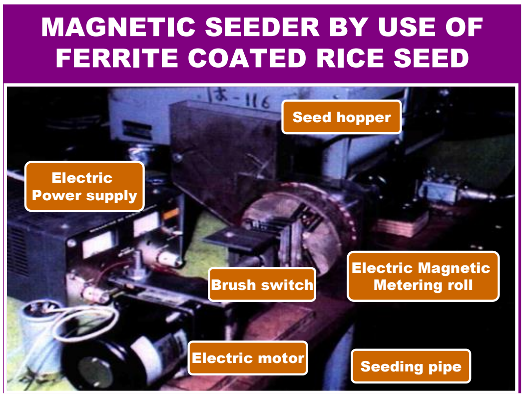


Figure 15 Principle of coil gun

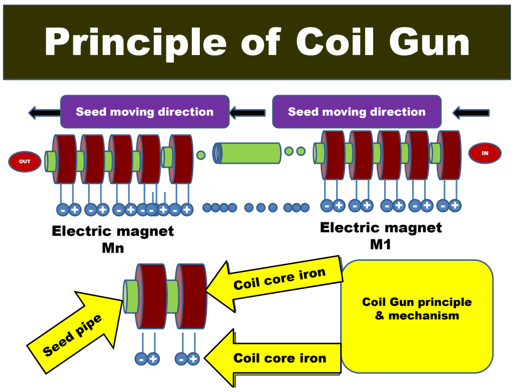


Figure 16 Coated seed sowing by coil gun

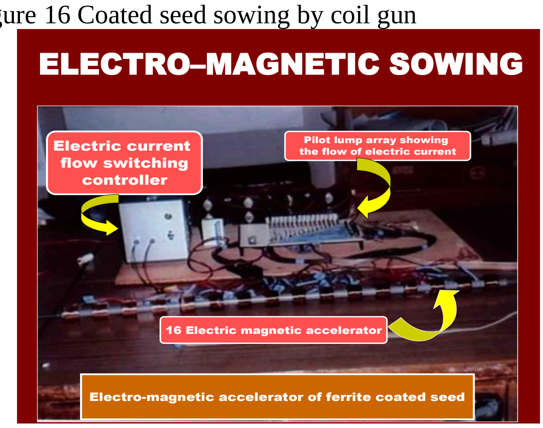


Figure 17 Seed density for precision seed sowing

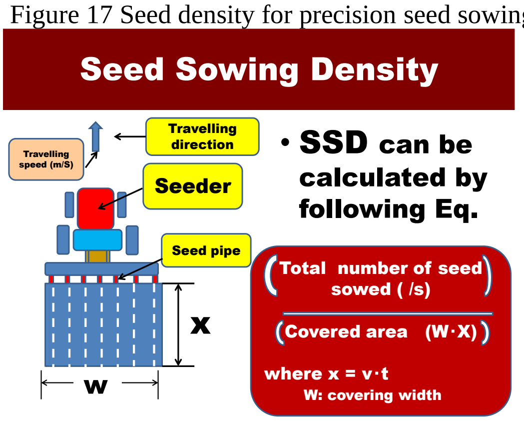
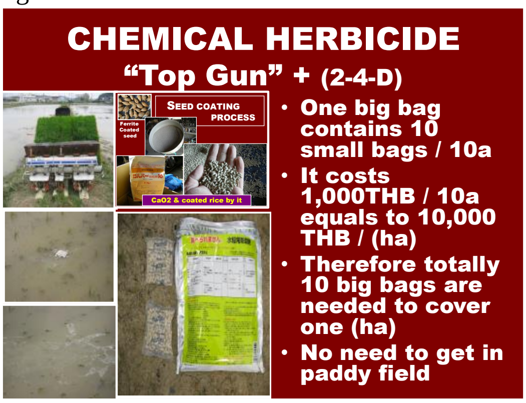


Figure 18 Chemical herbicide for rice cultivation



2.7 CO2 MITIGATION

Figure 19 shows the total amount of carbon dioxide emissions for each agricultural operation in rice cultivation. Totally 830.8 kilograms of carbon dioxide is emitted per hectare. Looking at the breakdown of agricultural operation, 18% of carbon dioxide is emitted in planting including preparation, 19% in harvesting operation, and 41% in post-harvest processing operation such as drying. 11% of carbon dioxide is also emitted from the materials used in cultivation, but it can be roughly divided into the operations of planting, harvesting, and post-harvest, which can be regarded as the main parts of carbon dioxide emission. On the other hand, the amount of carbon dioxide absorbed during the growth of rice is about 5 tons per hectare, and when subtracted, about 4 tons of carbon dioxide is absorbed in rice cultivation. From this point of view, rice cultivation contributes to the issues of global environment, food production and energy saving. It is a valuable key resource that is friendly to energy and the environment, but it also produces methane gas. The breakdown of greenhouse gases is that most of them are carbon dioxide, but the proportion of methane is 15.8%. The main source of carbon dioxide emissions in rice cultivation is the drying process in post-harvest process. In Japan, 85% of farmers are part-time farmers, and they have to work on weekends and holidays. They need to carry out the work timely as much as possible. A batch-type dryer was developed first, then a circulating type dryer came out next and became popular. However, farmers' work is shortened up to the harvested by the combine. Harvested rice is carried to the agricultural cooperatives, and the total amount rough rice weight and water content are measured to determine the purchase price, and money is paid into the farmers' bank accounts. At this time, an impeller de-husker is used for a sample hulling test for high-moisture paddy. Therefore, if petroleum is not used for drying rice, it is possible to suppress the emission of a large amount of carbon dioxide gas. As an alternative to this drying method, the author proposed harvesting with brown rice using a combine equipped with an impeller-type depilation function. The merit is no need to bother to transport rice husks which doesn't need to dry, and brown rice drying can effectively utilize 40% of the storage space of the facility. Since rice can be harvested as brown rice, it does not necessarily have to be hot air. It is a suggestion that if possible, a mere wind may be used. The prototype dryer consists of a double cylinder, and brown rice is put in between the inner cylinder and the outer cylinder, and the rotation of the cylinder inside causes the brown rice to slowly slide down along the slope of the space, causing friction between the brown rice. Make sure that the surface of the brown rice is not much damaged. Deterioration of appearance quality also affects the product price.

Figure 19 CO2 reduction due to rice direct sowing

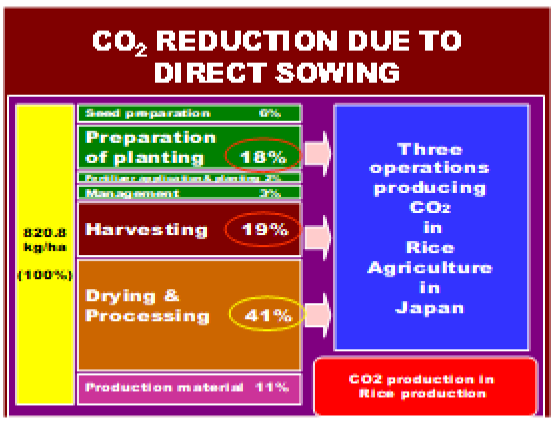
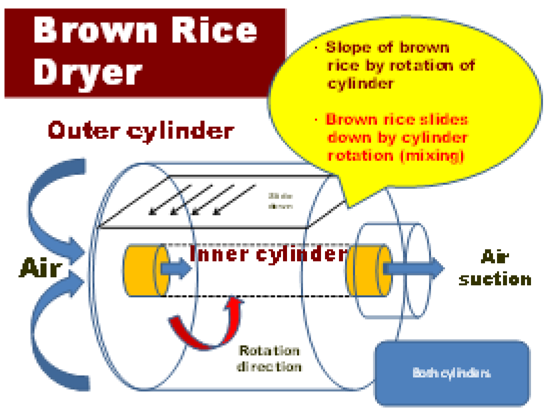


Figure 20 Proposed brown rice dryer



2.8 BROWN RICE DRYER

The two cylinders that make up the dryer are brown rice and small

A net-like iron plate with a hole is pasted. This is so that air can be sucked into the inside from anywhere outside the dryer. The reason why the outside air is sucked is that the facility where the dryer is installed is filled with dust in the air blowing method.

3 RICE HARVEST

Proposal of the ultimate rice mechanization system requires further system improvement. It's a harvesting operation. As already mentioned above, rice can be mostly harvested by the combine equipped with two functions of rice plant cutting and threshing, however, the combine newly proposed here has three functions of existing two plus de-husking function. In the existing rice cultivation system, de-husking operation is involved in the post-harvest operation, because the rough rice harvested by use of existing combine has higher moisture content, therefore, conventional rubber roll type de-husker can't complete the high moisture rough rice de-husking.

3.1 IMPELLER TYPE DE-HUSKER

There are two types of de-husker popularly used. They are rubber roll type and impeller type, however, the former is widespread and the latter is rarely used except for limited purposes and conditions. Since it is possible however to de-husk high-moisture rice at the same time as harvesting the rough rice, and to harvest the rough rice directly as the brown rice. However, although the main structure consists of an impeller that rotates at high speed and has the advantage of being extremely simple and requires almost maintenance free, the impact force of the impeller that rotates at high speed damages brown rice, which has hindered its widespread use. The peripheral velocity of impeller normally applied for de-husking rice with 13~14 % moisture content is 30 m/s. This peripheral velocity should be increased. This peripheral speed needs to increase as the moisture content increases. However, if the peripheral speed is increased, it is possible to remove the rice even with high moisture content, but the increase in impact force will increase the damage to the brown rice. It is necessary to find and determine the range and limit that enables the de-husking of high-moisture rice without increasing damage.

Rice is one of the main staple food resources for humans, however, it can be used for many other purposes such as:

1) Foods: Processed cooked rice, Retort cooked rice, Sterile packaged cooked rice, Chilled cooked rice, Dried cooked rice, Canned cooked rice, Rice flour bread, Rice flour noodles

2) Animal feeds: Straws, Bran

3) Additives: Beer brewery

4) Processed material: Plastic using rice, (Bio-plastics, CNF etc.)

5) Energy resources: Bio-fuel (Bio-ethanol)

6) Eco-products production: Compost, Organic fertilizer, Straw matt, Straw rope, Straw sandal,

Crafts

7) Daily life necessities: Cosmetics, Bath salts, Glue for building materials, Rice bran soap,

On the other hand, some problems will come out newly by changing the system. Not only the damage and injury including the internal crack of brown rice, but also the logistics issue may be reconsidered. It is necessary to always be prepared to deal with unexpected disasters such as theCOVID-19. In such cases, quality is not always a top priority as long as safety and security (reliability) are guaranteed, but rather it can be eaten today. Basically, the real preparation is not to pay attention to the price collapse due to overproduction or the decrease in the income of the farmer, but to secure a sufficient amount and always maintain the situation to take action for supply to respond quickly to demand.

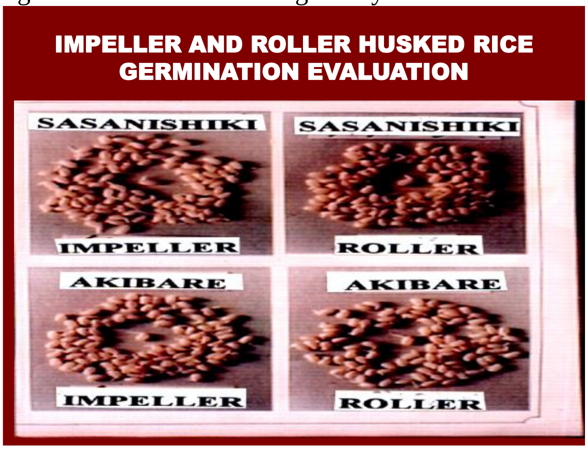
3.2 COMBINE DE-HUSKER

"Combine de-husker" named by the author, Ito is a unique combine that has the function of harvesting rice plant, threshing and de-husking In this section, the possibility of saving energy, labor, and time is discussed how rice cultivation system can be improved. Figure 21 shows the combine harvester mounted with impeller de-husker. The following is the explanation of each photo in one by one.

Top (left) Commercial de-husker equipped with milling function
Top (center) Combine mounted with impeller de-husker under harvesting operation
Top (right) The other side view of the same combine as shown above under harvesting operation
Bottom (left) Same type of impeller de-husker as Top (left), but by different manufacture
Bottom (center) De-husked brown rice coming after 3 operations of rice plant cutting, threshing and de-husking irrespective to the moisture content
Bottom (right) Rice husk (Chaff) blowing out after de-husking rough rice

Figure 21 Combine de-husker

Figure 22 Brown rice damage analysis



This section shows the background of the original idea of combine de-husker how it was born. Since the impeller de-husker can also de-husk high-moisture rough rice, if the de-husking operation can be completed at the same time as the harvesting operation, it can lead to significant saving of energy and time. For example, rice husks were originally discarded unless there was a particular purpose for use, but rice husks could not be rubbed until they were harvested and dried. There is no need to transport unused rice husks, and the volume occupied by the rice before drying is 40%, which can save a lot of space in the storage facility and increase the storage amount of rough rice instead accordingly. That is, the energy and statue space for transporting the harvested rice to the drying processing facility can be saved. Needless to say, new problems arise when the harvesting process and elated process are changed. This problem depends on how rice is ultimately used, but in preparation for the upcoming food crisis, we will never take measures to adjust production even if it is overproduced, but rather to expand demand and consumption and new markets. Efforts should be done actively for further development of new products by use of overproduced additional extra products. [2]

3.3 DAMAGE ANALYSIS ON BROWN RICE

Figure 22 shows the brown rice material species de-husked by impeller de-husker for two Japanese typical rice varieties of Sasa-nishiki and Akibare, As far as concerned with food, products should be fully guaranteed in liability and safety. The author has been proposing to consider four items consisting of four capital characters expressed by 2QSL, the abbreviated expression of Quantity, Quality, Safety and Liability, however, the apparent appearance damage and injury is considered comparatively less serious than chemical and biological ones. For further inspection of the damage on prepared species, some special idea should be applied such as image processing unit and related software because the damaged area is extremely fine and difficult to measure. How it can be negotiated depends on the idea of researcher. In this case, Diluted iodine liquid solution was prepared. Prior to take image of brown rice damaged area, material species were put in the iodine solution for one second and taken out. Then iodine solution tarts to gradually penetrate into the cracked or damaged part. Iodine solution plays therefore an important role to clarify the damaged area. Then the damaged area could be clearly limited and the number of damaged area was counted for each rice grain. Damaged / Injured area of one rice grain was processed one by one for two types of de-husker, rubber roll and impeller. Image photo of damaged was used for measuring a whole projected area of one rice grain and the total number of damaged area was counted automatically by the pre-installed software.

Fig. 23 Damage analysis on brown rice

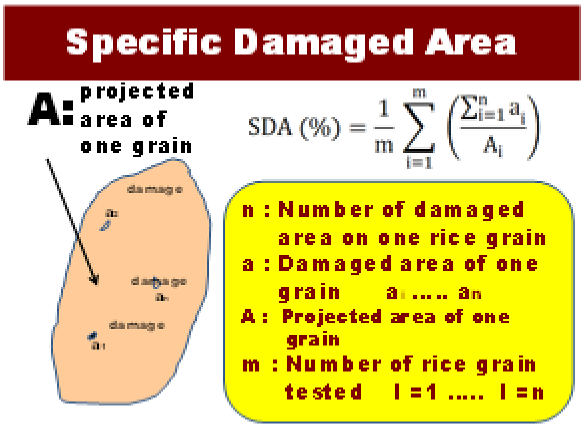


Fig. 24 Damage characteristics comparison between two kinds of de-husking methods

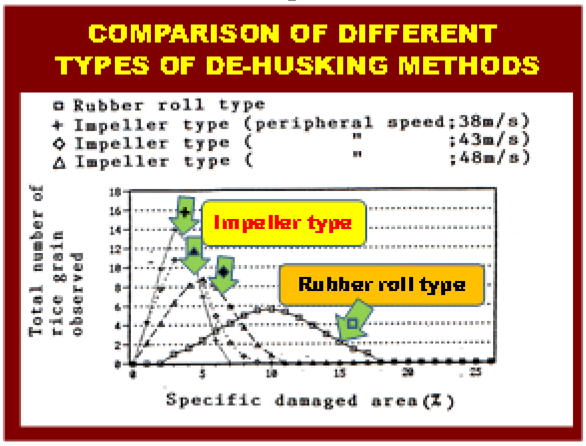


Figure 22 shows the procedure to compare and characterize the damage. The terminology "Specific Damaged Area" can be defined as the ratio of total damaged area to the projected area of one rice grain. The following data should be prepared for calculating "SDA". They must be therefore, prepared. Then

$$SDA\ (\%) = \frac{1}{m}\sum_{i=1}^{m}\left(\frac{\sum_{i=1}^{n} a_i}{A_i}\right)$$

where SDA: Specific Damaged Area (%)

n : Number of damaged area on one rice grain
a : Damaged area of one grain ai ….. a
A : Projected area of one grain
m : Number of rice grain tested I =1 ….. I =n

Figure 24 shows the results of experiments to find out the relationship between total number of rice grain and specific damaged area (%). It can be found from this experimental result that

1) Number of damaged areas for the rubber roll type de-husker is almost only one, however it was two to three for impeller type de-husker. The reason why this result could be obtained depends on the de-husking mechanism as follows. The damage is caused by the friction between two rubber rolls rotating at the different rotating speed, however, the damage can be made by the impact force applied from impeller rotating at high speed for impeller type de-husker. The rough rice grain may be hit two to three times during one rotation of impeller, therefore, the number of damaged area was more than the rubber roll type one.[3]
2) In the impeller type de-husking, the number of damaged area of one grain of brown rice is larger than that of the roll type, but the damaged area of each grain is extremely small. It can be concluded that there are almost two to three pinpoint injuries in impeller type de-husker, and it is reasonable to think this way.
3) Increasing the rotating speed of impeller increases the total number of damage, however, the one damaged area is very small something like pinpoint.

3.4 DAMAGE LOSS COMPARISON IN IMPELLER DE-HUSKER MATERIALS

Commercially available impellers are made of plastic resin material. However, while plastic materials are readily available in developed countries, developing countries can't quickly supply parts in the event of damage. It is necessary to be prepared to avoid these inconveniences with alternative materials to plastics. Here, considering the further development of the impeller type de-husker and its widespread use in developing countries, the author made a prototype of a thin metal impeller such as wood and tin that can be replaced with our own materials even in developing countries, and the damage caused is commercially available. The purpose of the experiment was to find out how different it was from the plastic ones.

It can be easily guessed that the impeller type de-husker may be widely accepted because of simple mechanism and structure, ease in handling and operation, maintenance free, compact and portable etc. Figure 25 shows Specific Damaged area of brown rice (average value, %) and Figure 16 shows Brown Rice Damage Comparison de-husked by 3 types of impellers made of different three kinds of impeller respectively.

Figure 25 Specific damaged area comparison

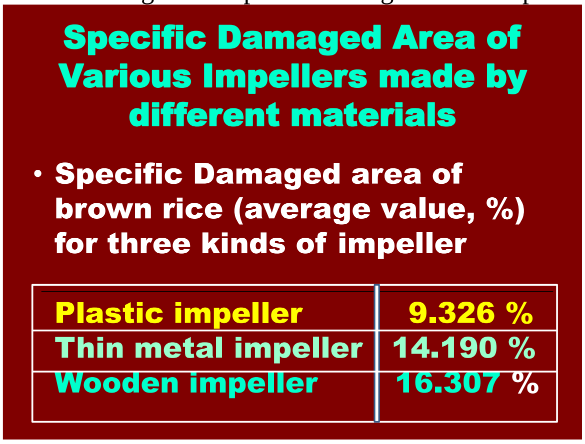
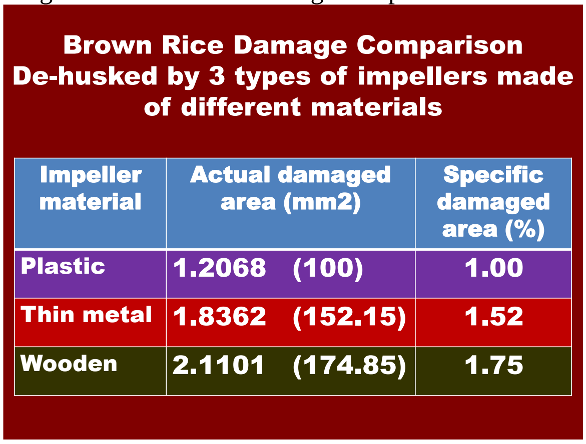


Figure 26 Brown rice damage comparison



Impeller material	Actual damaged area (mm2)	Specific damaged area (%)
Plastic	1.2068 (100)	1.00
Thin metal	1.8362 (152.15)	1.52
Wooden	2.1101 (174.85)	1.75

It can be concluded from the results shown in Figure 15 and Figure 16 that damage caused by de-husking made by wood and thin metal impellers is not as high as that of commercially available plastic impellers, but the damage rate of wood is about 14% and that of thin metal impellers is 16% in developing countries. It depends on how to evaluate it in use for damage. That is, whether these damage rates are evaluated as large, acceptable, or completely unspeakable. Some standard code for evaluating the damage level should be made, otherwise no judgment could be done. Figure 26 shows 1.52 times more damage in thin metal and 1.75 times more damage in wood than commercially available plastic products. In developing countries, this value is considered to be large or small. It has already been mentioned that the damage is pinpoint in the impeller de-husking.

4 CONCLUSION

The following shows the conclusions derived from this study.

1) Direct sowing cultivation of Thai rice has an average acceptance rate of 50%, although it varies depending on the region. Acceptance rate is Central (90%), Northern (65%), Southern (40), and North Eastern (27%) in descending order. It is natural that it varies depending on the regional conditions mainly based on the labor fee of workers in that year.
2) It was found that Thai farmers are positively willing to accept direct sowing toward the future, however the technology acceptance depends on the cost/performance.
3) It looks interesting to keep watching how drone innovation affects direct sowing
4) Challenges of direct sowing and direct de-husking in rice agriculture are yield increase and quality control although many merits could be already found after successful achievement
5) The direct seeding operation at planting and the de-husking mechanism for high-moisture paddy at harvesting are the tasks left to construct a hyper low-cost and simpler rice mechanization system.

Many hints for problem solving have been elucidated, but no concrete solutions have been presented yet. It is often talked about as a problem raised as if it were remembered, but a decisive solution has not yet been found. As for direct sowing, it is necessary to stabilize the germination and initial growth after sowing, and to reduce the degree of damage on the surface of unpolished rice as much as possible in dehulling high-moisture paddy. I am sure that in the near future, a simple and ultra-low-cost rice farming machine or system that incorporates these two tasks will be completed. In preparation for the food crisis, it is necessary to maintain research on the production of processed rice for the time being.

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