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Determination of Optimum Timing of Paddy Harvesting Based on Grain Loss and Milling Quality

姜 和 錫* · 李 鍾 瑚* · 鄭 昌 柱*

Kang, Whoa Seug Lee, Chong Ho Chung, Chang Joo

Summary

This experimental work was conducted in order to find out the optimum time of harvest of Japonica-type(Akibare) and Indica-type(Tong-il) rice variety for three harvesting systems by investigating the harvesting losses and milling quality. The study was also concerned about the nature and amount of grain losses incurred during the each sequence of post-harvest technologies, and based on these results, a modification of existing systems giving a minimum grain loss was attempted. Binder, combine, and traditional harvesting systems were tested in this study and five grain moisture levels were disposed according to the decrease of grain moisture.

The results are summarized as follows:

1. The total losses of Akibare variety were ranged from 1.1 to 1.5 per cent for the traditional harvesting system, 2.1 to 4.8 per cent for the harvesting system by use of binder, and 2.8 to 4.3 per cent for the harvesting system by use of combine as the grain moisture content was reduced from 24 to 15 per cent. Milling recovery of the harvesting system by use of binder, 74.8∼75.7 per cent, was a little higher as it was compared to that of traditional harvesting system, 74.3∼75.0 per cent, and that of the harvesting system by use of combine, 73.8∼75.0 per cent. Head rice recovery of mechanically dried paddy samples was higher than that of sun-dried paddy samples.

2. The total losses of Tong-il variety were ranged from 3.8 to 5.0 per cent for the traditional harvesting system, 5.2 to 10.0 per cent for the system by use of binder, and 3.0 to 5.0 per cent for the system by use of combine as the grain moisture was reduced from 28 to 16 per cent.

* 서울大 農大 農工學科

3. Milling recovery of Tong-il variety harvested by the traditional harvesting system was 72.3～73.6 per cent and it was lower when compared to that of 72.3～75.0 per cent harvested by binder, and 73.0～74.6 per cent harvested by combine.

4. Head rice recovery of Tong-il variety harvested by the traditional harvesting system (58.0～61.5 per cent) was lower when it was compared to that of 62.1～64.9 per cent harvested by binder, and 63.4～64.8 per cent harvested by combine.

5. About 70 per cent of total losses for the traditional harvesting system of Tong-il variety occurred during the handling operation. This amount of grain loss could be reduced by omitting the hauling and shocking processes and by threshing the stalk paddy soon after the cutting operation. The total losses at the optimum harvesting time would be reduced from 3.4～4.9 per cent to 0.9～1.5 per cent by appling such a modified system.

6. In the harvesting system of Tong-il variety by use of binder, the grain loss was mainly due to the handling (shocking) and throwing loss. It can be reduced by threshing the stalk paddy when it was wet, and the bundle-kicking mechanism of the binder should be improved for the harvesting operation of Tong-il variety to minimize the grain loss. It was found that the total losses of 6.0～7.3 per cent at the optimum harvesting time would be reduced to 2.1～3.6 per cent by applying the modified system in which handling operation would be omitted.

7. The moisture content of the optimum harvesting time was found to be 26 to 19 per cent for Tong-il variety and 20 to 16 per cent for Akibare variety, respectively. The optimum harvesting time was determined based on the maximum total milled rice recovery.

I. Introduction

A. Traditional paddy harvesting systems in Korea

In Korea, paddy harvesting begins from the end of September. There exist considerable differences in paddy harvesting processes and periods according to the machinery used, soil conditions, rice varieties, weather conditions, cropping systems, and regional customs.

When the paddy is harvested traditionally, it is generally laid down in the field after the cutting process and is spread on the field for sun-drying. Before making bundles, the stalks must be dry. This generally take several days to a week depending upon the weather and the availability of labor. But in some regions where the drainage may be poor during the harvesting season, all the paddy stalks cut for harvest are bound in proper size just after the cutting process and then are hauled out of the paddy field for shocking. This is done because the water in the paddy field could hinder the grains from natural drying.

The paddy stalks of high shattering Indica varieties are also bound into bundles soon after the cutting process. These bundles are hauled for shocking process to reduce a severe handling loss of the dried stalk grains caused

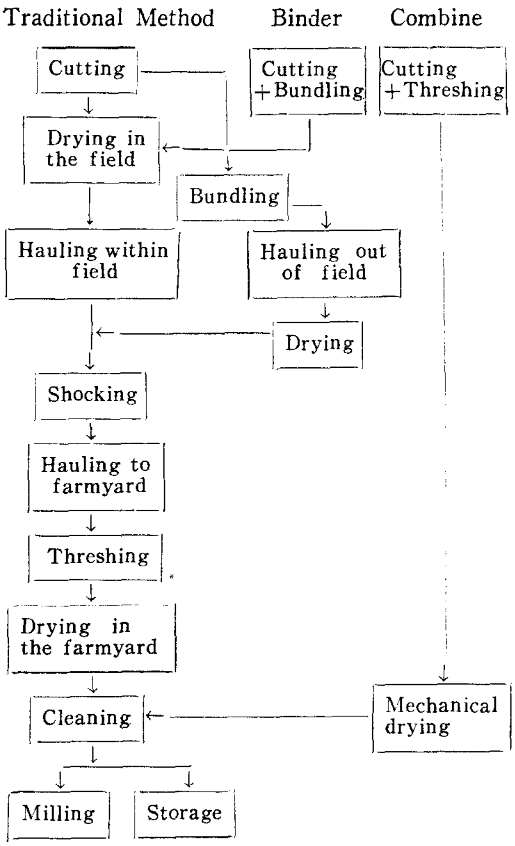

Fig. 1. Paddy harvesting systems in Korea.

by the bundling operation.

Sun-dried paddies are shocked within the field or on the bank of the field for further drying to reduce damage from bad weather, and to ease the hauling operation from field to farmyard.

The period of sun-drying of the stalk grains varies by regions. In most regions, the stalk paddy is sun-dried for about two weeks or more while shocking until the grain moisture be reduced down to 18 or 16 per cent before threshing. This moisture content is not dry enough for processing, marketing, or storing for a long period. The threshed paddy is therefore dried again to about 15 per cent by sun-drying. This is done by spreading it on a straw-mat at the farmyard. This enables the grain to be stored for a long period and to be milled with a high recovery.

In many occasions, the Indica-type of paddy is threshed soon after the cutting operation in the field in order to reduce the grain loss which occurs during the handling process. The Japonica-type is threshed either on the field or in the farmyard after hauling. The threshing operation is done by use of an auto-thresher or semi-auto-thresher. The main power source of the thresher is a power-tiller or small motor.

Usually, the hauling operation is done by use of a power tiller, tractor, or rear-car. Recently man-power is seldom used except for the hauling operation from the fields located in hills. Farmers generally do not have an additional cleaning operation for the grains threshed by the thresher because the thresher itself includes a cleaning unit.

Unfilled or greenish grains and dry grasses are separated from the grain by a fan when the farm-level milling is done.

B. Importance of the study

Many countries in the world have tried to increase their food productions to meet the domestic demands. Korea, whose major food resource is paddy rice, succeeded in increasing paddy production by improving the varieties and by adding the cash input such as fertilizers and pesticides. So far, the major efforts to increase grain yield have been focused on impoving varieties and increasing cash inputs.

Planting the high shattering Indica-type varieties, a great deal of grain is lost during the harvesting and processing operations. Grain loss of several per cent in a farmer's field may seem negligible, but the total loss of the whole nation has enough value to be considered.

The grain losses occur in various ways

and result from the cutting, handling, threshing, drying and milling operations. Unfortunately, there is not much information available on the nature and magnitude of grain losses incurring during the post-harvest operations for the new high yielding variety. In addition, the alternative post-harvest technology necessary to achieve the reduction of the grain losses has not been assessed. There has been increased interest in the potential increase of output available through the use of improved post-harvest systems.

Labor shortage on farms has become an important constraint in performing the timely operation of paddy harvesting. The use of modern machinery, such as combine and binder, may alleviate the labor constraint. However, the systems using the combine and binder have not been tested in reference to the nature and amount of grain losses for the Indica-type varieties. The information related to these modern machinery may be necessary to determine the solution for the problems of mechanized harvesting technology

C. Objectives of the study

The general purpose of this study was to determine the solution for post-production technology of the new Indica-type variety by assessing the quantitative losses and the milling quality. The nature and magnitude of grain losses incurred by the traditional system and alternative modern technologies were to be fully studied to investigate the modified system which may give minimum grain loss and maximum milling quality.

The specific objectives of the research work were as follows:

1) To assess a) the magnitude and cause of grain losses b) the milling quality occurring during the post-harvest processes by use of the combine, binder, and traditional paddy harvesting systems used for the Japonica and Indica-type varieties.

2) To determine the optimum timing of paddy harvest to obtain maximum grain yield using three harvesting systems and two varieties based on the grain losses and milling quality measured.

Ⅱ. Review of Literature

A. Measurement technology of grain loss

In order to determine the harvest-operation losses, various methods were used by many researchers.

To determine the cutting loss, Cristal and Eliodoro(19) counted the number of grains fallen within a quadrat measuring one square meter, and recorded before and after harvesting. And FAO(1968)(21) and Ruiz et al. (1965)(30) ascertained harvest(cutting) losses be taking a number of one square-meter samples directly after the cutting operation in other to collect loose grains, parts of panicles and whole panicles which had escaped harvesting. The average loss per square meter was converted into kilograms of loss per hectare by taking 1,000 grain weight. But Horiuchi et al. (1971)(15) used a large tin tray for collecting the fallen grains during the cutting operation. To catch the fallen grains the plants were bent slightly over the tray.

To determine the bundling(binding) losses, Cristal and Eliodoro(19), and Ruiz et al. (1965)(30) counted the number of grains within a quadrat measuring one square meter after bundling operation. Horiuch et al. (1971)(15) put the cut stalks on the stubles, which were transferred from the field and placed in a special set-up covered with polyethylen sheet.

FAO(1968)(21) measured the threshing

loss by assessing the amount of grains which were left in the straw sample after threshing. When the paddy was threshed in bundles, the threshing loss was measured by selecting 10 per cent of such threshed bundles. In the other areas where the paddy bundles are untied before threshing, the assessment of threshing loss was made on loose stray by collecting the 10 per cent in weight of threshed straw.

In this study, threshing loss was classified in detail.

McNeal Xzin(1950)(39) determined the cutter-bar loss of combine by counting the number of grains on the ground on several square-foot area after the combine had passed.

B. Grain Loss

The economic value of a 15 per cent loss may seem relatively unimportant when yields are only 2 tons per hectare, but a similar loss with a 5 ton yield is of considerably greater importance.

The level of loss is particularly sensitive to the date of harvest which is dependent upon the moisture content of the grain. Higher moisture contents resulting from early harvests generally mean lower grain losses (14)(15)(19)(30). According to Samson and Duff(1973)(28), handling and threshing losses can be reduced by performing thres-hing, in the field at the time paddy is harv-ested. Ruiz and Castelo(1965)(26) indicated that the grains (BPI-121, a medium shatter-ing variety) harvested 24 days after the flowering stage, which registered a moisture content of 23.9∼25.8 per cent, exhibited the least grain losses of 3.68 per cent from harvesting to shocking. However, the grain loss of moisture content 20.8∼22.8 per cent at harvest marked 7.22 per cent. But the grains(IR-8-288 rice selection)(19) harvested 116 days after seeding (four days before maturity) which registered a moisture content 31.40 to 34.80 per cent exhibited the lowest average grain loss of 11.92 per cent from harvesting to stacking.

During the sun-drying process, the over-mature paddy begins to shatter and is lost in the muddy soil. Some of the paddy in con-sumed by birds and rodents and some is lost in the cutting and transporting. Bhole et al. (1970)(18) indicated that these losses account for 21.6 per cent reduction in field yield during the field drying, harvesting and threshing process. For IR 24 variety(10) the grain loss was highest during the bundling process and lowest for the field drying process. Total losses were minimized at 113DS (days after seeding) and were at a maximum at 125DS.

When the head-feeding combine was used in the paddy harvesting operations(14), the minimum and maximum total losses for Tong-il variety were 1.55 per cent and 2.60 per cent when the paddy was harvested 35 and 49 days after heading, respectively.

3. Field yield and milling quality

Moisture content in the grains plays a very important role in determining the har-vesting time and the head recovery of the milled white rice.

Bhole et al. (1970)(18) and other resear-chers(10)(21)(22)(26) found that the moist-ure content of the paddy is a good criterion in determining the optimum time of harvest, irrespective of varieties and dates of heading. As a rule of thumb, the optimum moisture content corresponds to about 20 per cent at harvest. A close correlation was also found between harvest time and milling recovery. Both early and late harvests resulted in higher percentage of broken grains.

Morse, et al. (1967)(26) reported that total grain yield per acre increases as the grain moisture recedes to about 20 per cent at harvest. The increase in yield is slow after rice reaches 26 per cent moisture. The per cent head rice generally peaks as kernel moisture declines to between 30 and 26 per cent. Total milled rice per acre continues to increase as grain moisture decreases to 12 per cent, however not rapidly once the grain is down to 26 per cent moisture.

Smith and Jones (1937)(40) indicated that when a rice crop is harvested at the stage of maturity at which the rice contains from 23 to 28 per cent of moisture, good yields per acre of high milling quality will be produced.

The average field yield at the optimum harvest moisture level(between 21% and 24% for IR 8 variety) was 6740 kg/ha and was reduced to 5550 kg/ha when the crop was harvested at 15 per cent moisture level(18). Malabuyoc, et al (1966)(29) reported that the yield at 30 and 35 days from heading was higher than at 20 and 25 days. Milling recovery was stable within the periods of 25 to 35 days from heading. The percentage head rice, however, was high at 25 and 30 days only.

It was observed (1968)(22) that harvesting between 27th to 39th day after flowering at high moisture content (23 to 18%) gave maximum amount of head rice recovery. Harvesting before or after this period gave considerable amount of brokens. The reason for the high percentage of brokens observed in the samples harvested before 24th day was found to be due to the presence of a large number of green and ill-filled grains (10)(22).

In as much as the moisture content of the standing rice is the best index of the stage of maturity, it is essential that accurate moisture tests of the rice as it approaches maturity be obtained.

Ⅲ. Experimental Methodology

A. Experimental design

The experimental work was carried out in typical paddy fields located in Anwha-Ri, Osung-Myeon, Pyungtack-Gun, Gyonggi Province during the paddy harvesting season of 1976.

The test fields were rented for the harvest-operation that was undertaken fully under the controlled design.

The varieties planted in the test field were the Indica-type variety(Tong-il) and Japonica-type variety(Akibare), whose agronomic data are shown in Table 1.

Table 1. The agronomic data of the rice varieties used for experimental harvest-operatior

Variety		Tong-il	Akibare
Sowing		April 12, 1976	April 12, 1976
Transplanting		May 29, 1976	June 4, 1976
Harvesting	begin	Oct. 7, 1976	Oct. 7, 1976
	end	Oct. 26, 1976	Oct. 26, 1976

The total area of the test fields were about 3,000m² for the Indica-type(Tong-il) variety and 5,000m² for the Japonica-type(Akibare). The test fields were divided into equal blocks of 1.5m×25.5m and 1.7m×40.0m for the Tong-il and Akibare variety.

So as to carry out each experimental harvest-operation without hinderance and in order to give a free path for the binder and combine, two-meters were provided between the neighbouring blocks by cutting out the stalk paddy.

The harvesting technologies tested were the traditional system, the technology using the binder, and the technology using the auto-threshing-type combine. These technologies were examined to investigate the amount of losses for different levels of grain maturity and grain moisture at harvest.

The moisture content of grains of the uncut rice stalk was measured to determine its average rate of change during the harvest season and to decide the suitable date for the experimental harvest operation under the controlled experimental design.

The moisture content of the standing stalk-grains was measured using a Kett moiture-meter which possesses the accuracy of ±0,5%. The measurements of the grain moisture were taken between 1 and 2 P.M. every day for the samples obtained from various sections within the test block. The daily moiture variations within the period of experimental harvest-operations and the level of moisture content at which the test runs were taken are shown in Fig.2. The values of the grain moisture in Fig.2. are average of ten trials.

The average moisture contents at harvest were 27.0%, 23.4%, 20.5%, 18.7% and 16.2% (w.b.) for Tong-il variety, and 23.3%, 20.4%, 18.3%, 16.0%, and 15.7% (w.b.) for Akibare variety. Because of the frequent rainy days and of different environment conditions during the harvest season, the dates for harvest-operation were selected based on an appropriate moisture reduction which was about 2 to 3 per cent in general.

The average reducton per day in grain moisture was 0.57 per cent for Tong-il, and 0.39 per cent for Akibare variety.

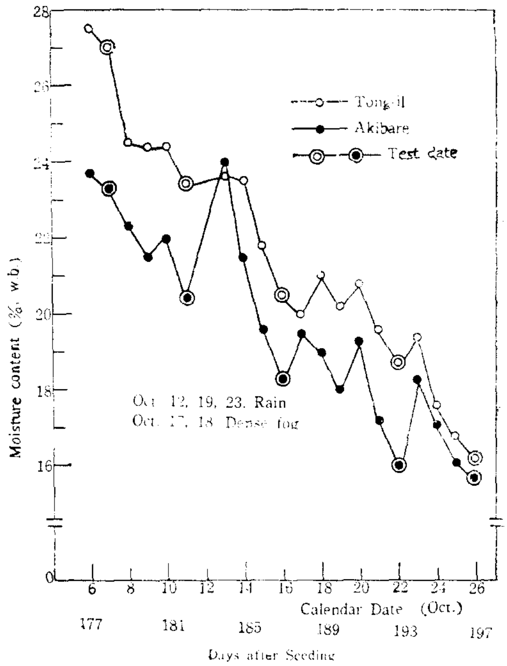

Fig. 2. Moisture variations of standing stalk-grains exposed to natural environment during the rice harvesting season of 1976.

B. Equipments and instruments

The equipments and measuring instruments used for the experiment are shown in Table2.

Table 2. Specifications of the equipments and measuring instruments.

Nomenclature	Type/Model	Capacity/Dimension	Remarks
Combine	Iseki, TARO 700	Cutting width 750mm, Drum dia. 444mm	Drum R.P. M:450-500 for Paddy 2 Row
Binder	Suzue, $B_2$60A	Cutting width 570mm	2 Row
Thresher	Hae-ryuk HN 67 Auto-thresher	Drum dia. 554mm	Drum R.P. M.:400-450 for Paddy
Dryer	Hyup-shin Batch-type	1.8m×1.8m	
Lab.Huller	Satake	Feed rate 140-150g/min.	Roller Clearance 0.03 in

Lab. Miller Sizing Divice	McGill No. 2 Burrows		Developed by U.S.D.A
Whiteness meter	Kett C-3	0-110	
Moisture meter	Kett SP-1	11-30% w.b.	Electrical Resistance Type
Tachometer	Smiths Industries Venture ATH. 6.	0-10,000 R.P.M.	

3. Measuring technology of grain lossse

The experimental harvesting operation was designed as close as the actual harvesting technologies on farms. Grain losses involved in each of the sequences of harvesting operation were defined and the technologies for measurement and evaluation of their losses were specified according to the post-harvest technologies interested in this study.

Traditional Harvesting System. The grain losses incurred during the traditional post-harvest technology were classified as shown in Fig. 3.

The cutting operation using a sickle was simulated by a well experienced local farmer on the test block specified.

The cut stalks were laid down on ground as the similar pattern as done by the traditional system. Within the test block, three small plots with one square meter in size were selected at random and the grains fallen within the plots were collected by use of pincettes. The grains collected were regarded as the cutting loss. The number of collected grains was converted into the weight in kilograms per hectare at 14 per cent moisture content in wet basis on the weight of 1,000 sound grains measured.

After the stalk paddy was sun-dried down to about 17 per cent grain moisture, bundling operation was performed. Some of the bundles were taken out from the test block to collect the grains fallen on the ground during the bundling operation. Within the test block

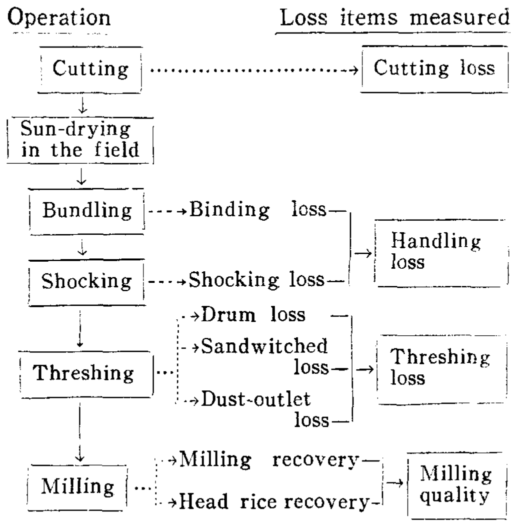

Fig. 3. The Classification and terminology of the grain losses occurring during the traditional post-harvest technology.

with some of the bundles taken out, three small plots, one square meter in size, were selected at random and the grains fallen within the plots were collected by use of pincettes. The grains collected were regarded as the binding loss. The number of collected grains could be easily converted into the weight in kilograms per hectare by comparing it with the weight of 1,000 sound grains measured at 14 per cent moisture content in wet basis.

Just after the bundling operation, the paddy bundles were hauled for shocking. This shocking operation was conducted in this experiment because it is common practice for the local farmers. As the farmers do, the shocked paddy bundles were left in the field for about two weeks and in case of rainning they were covered with vinyl sheets. After the shocked paddy bundles were hauled to the threshing site, grains fallen on the shocked ground were collected with pincettes to count the number of grains lost during the shocking process. The number of counted grains were converted into the weight in kilograms per hectare. This grain loss was regarded as the shocking loss. The sum of binding loss and shocking loss was defined as handling loss of traditional harvesting system.

An auto-thresher, which powered with a 8HP power-tiller, was used for threshing operation. During the threshing operation, the threshed bundles flowing out of the thresher were sampled at random for evaluation of grains lost in the bundles. The sampled bundles were completely shaken on the wide polyethylen sheet in order to collect the threshed grains remained between paddy straws but would be lost unless a speical treatment be undertaken to separate grains out from the straws. This grain loss was regarded as the straw-sandwitched grain loss. The threshed grains thus collected were counted and the number of counted grains was converted into the weight in kilograms per hectare. The grain loss in the kilograms per hectare was obtained by calculating the proportion of the sampled bundles total ones in the block tested.

After the straw-sandwitched grains were collected, the grains attached to the threshed paddy ears sampled were all plucked and the number of the plucked grains were counted. The number of counted grains was converted into the weight in kilograms per hectare as done for determining the straw-sandwitched grain loss. This grain loss was regarded as drum loss.

In order to collect blown-off materials from the out-let of the auto-thresher which may include sound grains while the threshing operation is being performed, a wide polyethylene sheet was within the range for the paddy grains to be blown. The dry leaves and cut paddy stalks or ears were removed by use of a hand-rake. The collected grains and draff of paddy stalks were treated once again in the auto-thresher as the farmers usually do. Then the paddy grains being blown off from the dust-outlet were collected by use of a net bag (Photo 2). Of the collected grains and draff of the paddy stalks, the grains were sorted out by winnowing. These sorted grains were counted and the number of the grains were converted into the weight in kilograms per hectare. This grain loss was regarded as the dust-outlet loss.

The sum of drum loss, straw-sandwitched loss and dust-outlet loss was defined as threshing loss of traditional harvesting system. The sum of cutting loss, handling loss and threshing loss was defined as total loss of traditional harvesting system.

To determine the proportion of grain loss to the yield, it may be necessary to determine the weight of threshed grains yielded from the block under testing. The total weight of the threshed grains from the test block was converted into the weight in kilograms per hectare at 14 per cent moisture content.

The grain yield thus obtained was defined as the field yield, and the sum of total loss and field yield was defined as total field yield.

Of the field yield, three samples, 5-kilograms each, were sealed in polyethylene bags and preserved in a cold storage room for milling tests.

Harvesting System by Use of Binder: The binder harvesting system is different from the traditional harvesting system only in the process of cutting and bundling. The binder system along with its source of grain losses is systematically shown in Fig. 4.

The average operating forward speed for binder was about 0.91 meter per sec. with 2nd gear, which may be considered as its general operating condition.

Before the operation of a binder, a polyethylene sheet, 5.4m×2.7m in size, was spread just beside and along the paddy row to be cut. During the binder operation, the paddy bundles which were kicked off from binder and laid down on the sheet, were removed from the sheet and the grains fallen on the sheet were collected(Photo 3). The number of collected grains was converted into the weight in kilograms per hectare. This grain loss was regarded as the throwing loss of binder.

After the polyethylene sheet removed from the test block, three small plots with one sequare meter in size were selected at random within the area that the binder was operated. The grains fallen within the plots, which were occurred during the cutting process, were collected by use of pincettes. The grains collected were regarded as the cutter-bar loss. Because of difficulty of measuring separately the grain losses that were caused by the pick-up divice and the binding mechanism, these losses were included in the cutter-bar loss. The number of grains collected was converted into the weight in kilograms per hectare.

During the binder operation, there were some occasions that uncut paddy stalks rem-

Photo 1. The photo shows the experimental threshing operation by use auto-thresher. Women are plucking the grains from stalks sampled.

Photo 2. The photo shows the collection of the materials emitting from the dust-outlet of auto-thresher

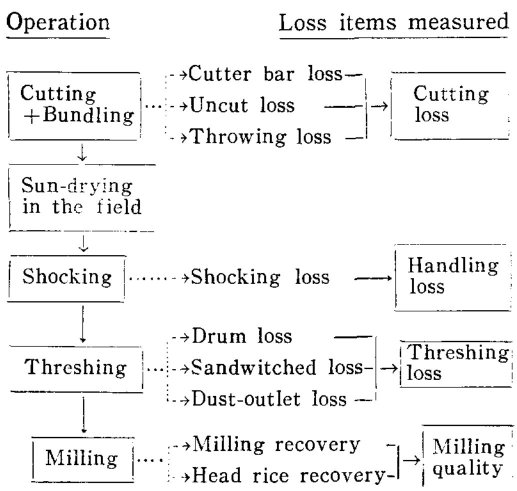

Fig. 4. The classification and terminology of the grain losses occurring during the post-harvest technology by use of binder.

ained in the field as the paddy stalks were planted extremely out of row-line or the binder was not properly operated. These stalks should be treated as grain loss because they would be cut if they were cut manually. The loss was measured and converted into the weight in kilograms per hectare, which was regarded as the uncut loss.

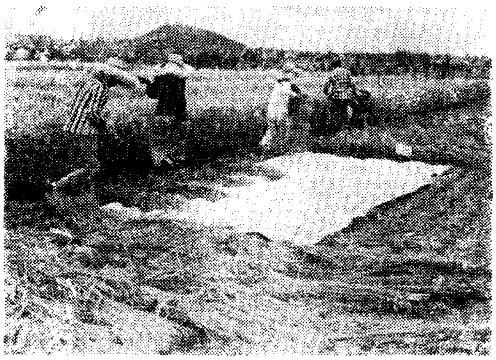

Photo 3. The photo shows the experimental binder operation. The polyethylene sheet was spread over ground to collect grain loss during binder operation.

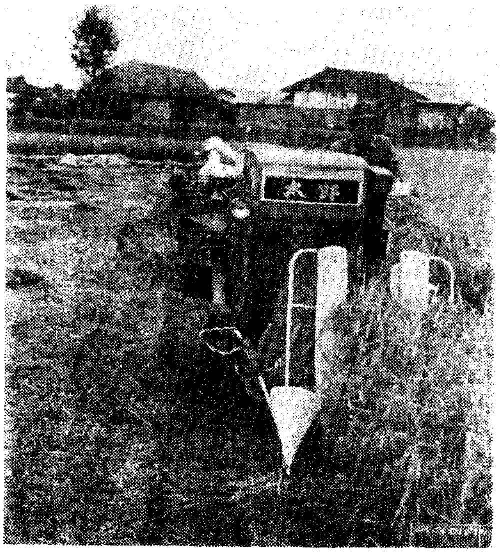

Photo 4. The photo shows the experimental combine operation. The net bag was attached to the dust-outlet to collect the grains emitting from the dust-outlet of combine.

The sum of throwing loss, cutter-bar loss and uncut loss was defined as the cutting loss of binder. The other losses such as the handling and threshing losses followed by binder operation were measured in the same way as specified for traditional harvesting system.

Harvesting System by Use of Combine: The sources of grain loss that can occur during the combine operation and subsequent processes of rice post-harvest technology are classified as shown in Fig. 5.

The combine operation in the experimental blocks was performed in the average forward speed of 0.46 meters per second. The other operational conditions of combine were set as recommended by its manufacturer.

Major grain loss occurring during the combining may come from the loss of sound grains blowing out of the dust-outlet. To measure this loss, a net bag was attached to the dust-outlet during the combining of the specified area so as to catch the materials other than the dust (Refer to Photo 4). The net bag was made possible to catch the emitting materials without setting up any back pressure on the blower unit. The sound grains were sorted out from the caught

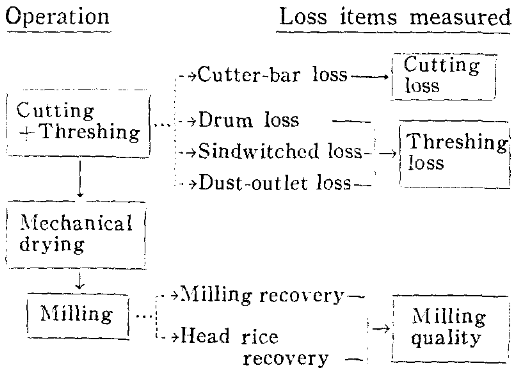

Fig. 5. The classification and terminology of the grain losses occurring during the post-harvest technology by use of combine.

material, and counted to convert them into the weight in kilograms per hectare.

The grains that were sandwitched between straws and that remained as paddy ears may be the other sources of grain loss during combining. To measure these losses, almost the same method was used as did for the measurement of the corresponding threshing losses of the auto-feeding thresher. After a steady-rate of combining operation was reached, an armful of straws flowing out from the combine was collected on polyethylene sheet and the corresponding distance of combine travel was measured. The sampled straws were fully shaken to remove the sandwitched grains within the straws. The amount of the collected grains was converted into kilograms per hectare, which was regarded as the straw-sandwitched loss by combine.

After the sandwitched grains were collected, all the grains attached to the sampled paddy ears were plucked and counted. The number of plucked grains was converted into the weight in kilograms per hectare. This grain loss was regarded as the drum loss of combine. The sum of dust-outlet loss, sandwitched loss and drum loss was defined as the threshing loss of combine.

When the combine operation was over, three small plot with one square meter in size were selected at random within the test plot to measure the amount of grain losses which were caused by the cutter-bar and pick-up units. The loss was referred to as the cutting loss by combine. The number of collected grains was converted into the weight in kilograms per hectare. The sum of threshing loss and cutting loss was defined as the total loss of combine.

After the combining test was finished, total amount of threshed grains for the combined block was weighed and converted into the weight in kilograms per hectare at 14 per cent moisture content. This amount of grains was defined as the field yield of combine, and the sum of total loss and field yield was defined as the total field yield of combine.

A batch-type grain dryer of 1.8m×1.8m in size was used for mechanical drying of grains harvested by combine.

The operating temperature of the heated air was controlled at 37°C±2°C during the drying operation. The thickness of the paddy in the batch-type dryer was kept at about 40cm throughout the tests. To make an even drying between the upper and bottom layers, the turning operation of grains was performed in the interval of about 3 hours. As the moisture content was reached at about 15.0 per cent in wet basis, the paddy was cooled and unloaded from the dryer. Three grain samples, 5-kilograms each, were taken as the samples for milling test and sealed in a polyethylene bags.

Milling Test: Two 125-grams paddy samples per block were taken for laboratory milling test to evaluate the head rice recovery and milling recovery for three different harvesting systems. The amount of sample of 125-grams was determined based on the official method of the United States Department of Agriculture(31).

The samples of paddy that were harvested by traditional system and binder were re-dried in order to reduce the grain moisture to about 14 per cent.

The milled kernels were sealed in paper bags to prevent unneccessary breakage due to rapid cooling.

The bran was screened through a 20×20 mesh wire screen to recover the small, broken kernels that passed through the miller screen(31). The finely broken kernels thus recovered were aspirated and added to the milled kernels to obtain the milling recovery.

To evaluate the head-rice recovery, the whole kernels were separated from the total milled rice by use of the Burrows' sizing device(31). Two passes were needed to select the whole kernels through the sizing device.

IV. Results and Discussion

A. Grain loss

Grain loss could be presented either in the absolute amount as the weight of grain loss per unit area, or in the relative amount as the percentage of grain loss for a given area to the total yield for the same area. The former may be very desirable in comparing the grain losses between varieties which may have a considerable difference in total yield. A good example of this matter is found in comparing the grain losses between the Japonica-and Indica-type varieties, in which, Japonica varieties showed a much greater percentage loss when compared with the Indica varieties. Thus, two indexes were equally used in this study in discussing the total loss according to the convenience of comparisions.

Akibare Variety : Grain losses incurred during the traditional harvesting operations are shown in Fig. 6.

Cutting loss, which was less than 10kg/ha for all moisture levels, has the least proportion of the losses. The amount of grain loss may be negligible in the practical sense. Threshing loss amounted to more than 50 per cent of total loss. The threshing and handling losses did not show notable differences as the grain moisture was reduced. These results apparently seem to mean that the grain moisture content at harvest had no

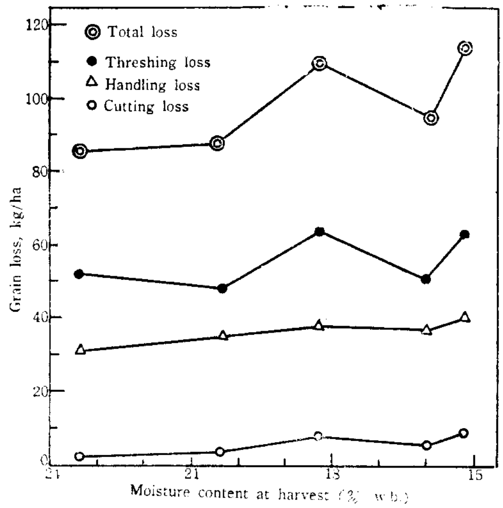

Fig. 6. Grain losses vs. grain maturity for the Akibare variety incurred by traditional paddy harvesting system.

affect on the harvesting losses of Akibare variety. The total grain loss of traditional harvesting system was hardly affected by the grain moisture variation at harvest. This loss ranged from 1.1 to 1.5 per cent of total field yield and from 78.3 to 104.0kg/ha in the absolute amount.

As in the traditional harvesting system, cutting loss of binder was the least, and it suddenly increased at 16.0 per cent of grain moisture at harvest (Fig. 7). Handling loss was much greater than threshing loss. The relatively high handling loss may haveresulted from the fact that small bundles bound in a wet state loosened during sun-drying, and could be susceptible to handling loss, and the paddy bundles thrown from the binder. Straw in these paddy bundles was easily broken, with a resultant loss of grain during handling process.

Threshing loss increased from 65.8 to 149.2 kg/ha as the grain moisture was reduced and it suddenly increased at the 16.0 per cent grain moisture at harvest.

The total loss of binder continually incr-

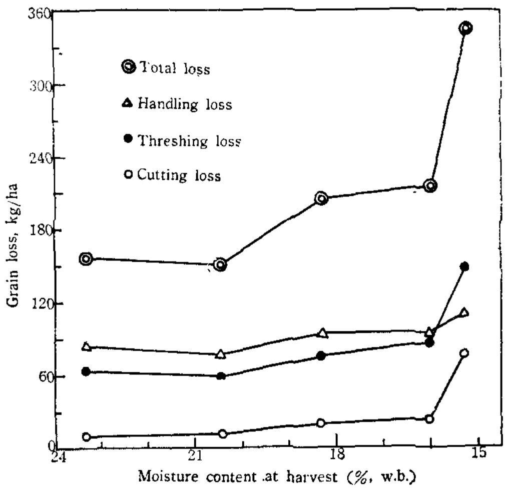

Fig. 7. Grain losses vs. grain maturity for the Akibare variety incurred by the paddy harvesting system by use of binder.

eased from the early stage of harvest. The range of total loss was 2.1 to 4.8 per cent of total field yield.

About 88 per cent of the grain loss resulted from the threshing operation when the Akibare variety was harvested by combine (Fig. 8). Low shattering tendency of the

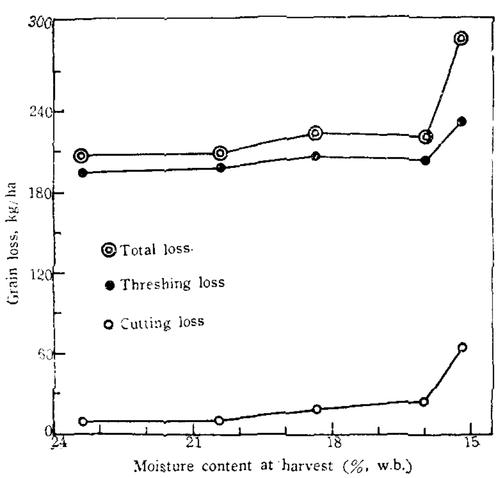

Fig. 8. Grain losses vs. grain maturity for the Akibare variety incurred by the paddy harvesting system by use of combine.

wet Akibare variety might result in increasing the threshing loss. The remainder of the combining loss was incurred during cutting and feeding procedures. However, the cutting loss became greater when the paddy was harvested at the moisture content of about 16.0 per cent or less.

The total loss of combine, about 2.8 per cent (194.1 kg/ha) of total field yield, was almost constant until the grain moisture reached about 18 per cent. After this stage, the total loss gradually increased to about 4.0 per cent(277.3 kg/ha) of total field *yield.*

Analysis of variance for total loss of Akibare variety showed that the differences among harvesting systems and moisture levels were highly significant.

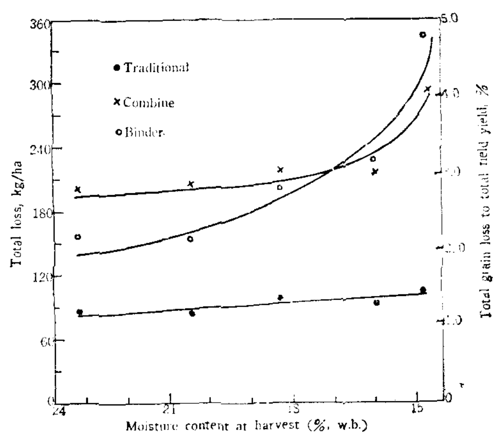

Fig. 9. Total grain losses of Akibare variety vs. grain moisture at harvest for three harvesting systems.

The difference of total loss between combine and traditional harvesting system was highly significant, and that between binder and traditional harvesting system was significant at the 1 per cent level (Table 3). But the differences are not so important in practical sense.

Table 3. Differences (1) in means for total loss between harvesting systems (2) of Akibare variety.

	T98.4	B217.9	C228.7
T98.4	—		
B217.9	119.5*	—	
C228.7	130.3**	10.8ⁿ·ˢ	—

(1) LSD for the difference between two harvesting systems of Akibare variety:
5% : 75.7
1% : 125.5

(2) Note : T: Traditional harvesting system
B: Harvesting system by use of binder
C: Harvesting system by use of combine

Tong-il Variety : Fig. 10 shows the grain losses occurred during the traditional harvesting operations of Tong-il variety.

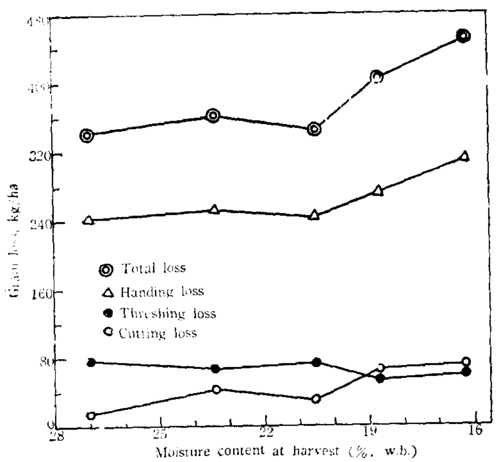

Fig. 10. Grain losses vs. grain maturity for the Tong-il variety incurred by traditional paddy harvesting system.

Cutting loss was increased from 18.8kg/ha (0.2 per cent of total field yield) to 71.7kg/ha (0.8 per cent of total field yield) as the grain moisture at harvest was reduced.

The threshing loss of Tong-il variety was slightly decreased from 78.6kg/ha(0.9 per cent of total field yield) to 68.4 kg/ha (0.8 per cent of total field yield) as the grain moisture at harvest was reduced. This result showed a different tendency from the result of Horiuchi (1971)(15), that ranged from 0.70 to 1.50 per cent of total grain yield as the days after heading were delayed. And this percentage of 0.9 to 0.8 to total field yield was much less than that of 1.0 to 3.0 per cent of total grain yield obtained by Samson and Duff (1973)(10)

Handling loss, which was the largest part of total loss, was ranged from 242.7kg/ha (2.7 per cent of total field yield) which may be remarkably greater than that of Akibare variety.

The total loss of traditional system was slowly increased as the grain moisture at harvest was reduced. The range was from 3.8 to 5.0 per cent of total field yield and from 341 to 449 kg/ha in absolute amount. This amount of total loss is much more than that of Suweon 215 (sister line of Tong-il variety) which ranges from 1.7 to 2.3 per cent of total field yield as the days after heading were varied from 35 to 49(Han, et al. 1971)(14). According to Horiuchi (1971) (15), the total loss of Padi Bahagia ranged from 1.57 to 3.14 per cent of total grain yield at between 27th and 41th day after heading.

Grain losses incurred during the harvesting operations by binder were shown in Fig. 11. In contrast to traditional harvesting operations, cutting loss of binder was much more than threshing loss. The most part of cutting loss of binder was the throwing loss. When the paddy bundles were thrown from binder to field, many grains of high shattering Tong-il variety were dropped on the field by the impact. Cutting loss was continually increased from 142.8kg/ha to 383.5kg/ha as the grain moisture at harvest was decreased.

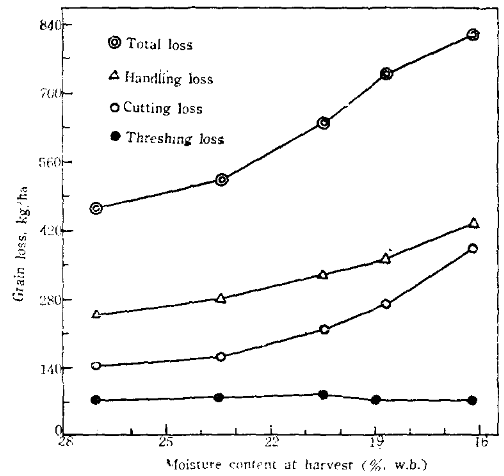

Fig. 11. Grain losses vs. grain maturity for the Tong-il variety incurred by the paddy harvesting system by use of binder.

The threshing loss, throughout the moisture levels tested, was almost constant as 81.3kg/ha in average. Handling loss, which was more than a half of the portion of total loss throughout the moisture levels, was gradually increased from about 253kg/ha to 440kg/ha as the grain moisture was decreased. As in the Akibare variety, small size of bundles and ears broken might be the main causes of increasing the handling loss of the harvesting system by use of binder.

The total loss was rapidly increased from 5.2 to 10.0 per cent of total field yield as the grain moisture at harvest decreased. This rate of grain loss was about 467 to 898 kg/ha in practical amount. With this great amount of grain losses incurred, the binder harvesting of Tong-il variety should not be in practical use. A considerable reduction of grain losses could be achieved if the sun-drying and shocking processes may be omitted and if the threshing operation in the condition of wet paddy may be carried out soon after the cutting. Another possbility to decrease grain losses incurred by binder may be an attempt to modify bundle kicking mechanism of binder such that it should not exert a high impact force on bundles.

Fig. 12 shows the variations of grain losses incurred during the harvesting operations by use of combine. Threshing loss of combine was slightly increased from 111kg/ha to 135 kg/ha as the grain maturity progressed. A larger part of threshing loss was due to drum loss(average 43.9kg/ha). This result is well coincided with that of McNeal Xzin (1950)(39).

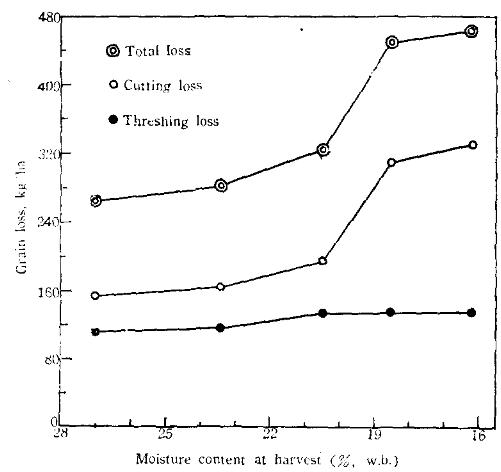

Fig. 12. Grain losses vs. grain maturity for the Tong-il variety incurred by the paddy harvesting system by use of combine.

Cutting loss of combine gradually increased from 156 to 328kg/ha as the grain moisture at harvest was decreased. The average grain loss as 231.2 kg/ha is very different from the result of McNeal Xzin(39), in that the average of 22.43kg/ha of Zenith grains were lost during cutting operation. It seems that the differences of varieties, machine used, weather conditions may bring about entirely different results.

Total loss of Tong-il for combine harvesting system was slowly increased until the grain moisture at harvest was reduced to around 20 per cent. After this stage of grain maturity, the total loss increased rapidly. The range of total loss was from 2.7 to 5.0 per cent of total field yield and from 230 to 425 kg/ha in absolute amount. This range of grain loss is higher than the range Han (1971)(14) measured.

In order to reduce the total loss of Tong-il variety for harvesting operation by use of combine, it would be desirable to finish the harvesting operation before the grain moisture is reached about 20 per cent.

The total losses among harvesting system of Tong-il variety were of significant difference.

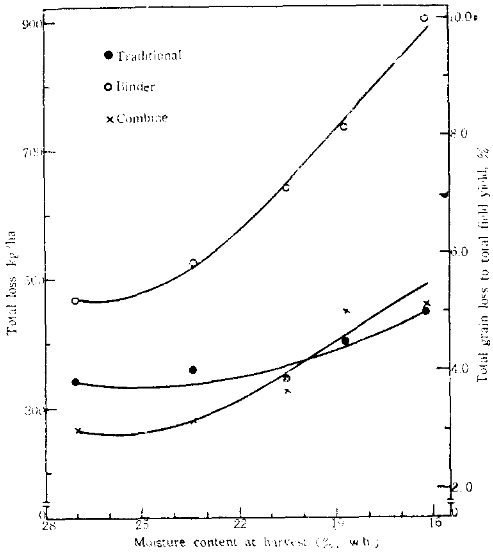

Fig. 13. Total grain losses of Tong-il variety vs. grain moisture at harvest for three haresting systems.

Total loss incurred by use of binder, 655.6 kg/ha in average, was the highest among harvesting systems of Tong-il variety, and it showed great differences when it was compared with 380.7 kg/ha (4.5per cent of total field yield) and 357.0 kg/ha(4.2 per cent of total field yield) by traditional and combine harvesting systems(Table4).

Table 4. Differences (1) in means for total loss between harvesting systems (2) of Tong-il variety.

	C357.0	T380.7	B655.6
C357.0	—		
T380.7	23.7$^{n.s.}$	—	
B655.6	298.6**	274.9**	—

(1) LSD for the difference between two harvesting systems of Tong-il variety:
5% : 74.8
1% : 124.2

(2) Note: C: Harvesting system by use of combine
T: Traditional harvesting system
B: Harvesting system by use of binder

B. Milling recovery

Milling Recovery for Akibare Variety : The milling recoveries of Akibare variety harvested by three harvesting systems tested are shown in Fig. 14. Milling recoveries of sun dried Akibare paddy samples taken from binder and traditional harvesting systems were 75.7 and 75.0 per cent, which were a little higher than the milling recovery of mechanically dried paddy samples until the grain moisture at harvest was reduced to

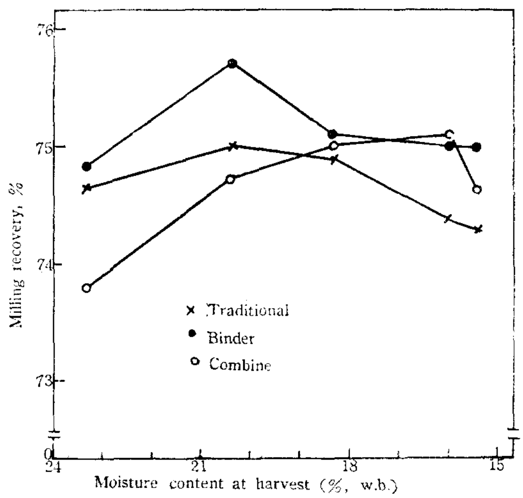

Fig. 14. Milling recovery vs. moisture content at harvest of Akibare variety for different harvesting systems

about 20 per cent.

The milling recovery of mechanically dried paddy samples, which, harvested by use of combine, was gradually increased to 75.0 per cent until the grain moisture reached at 16.0 per cent, but it suddenly dropped after this stage of maturity. In contrast, the maximum milling recoveries for the traditional system and system by use of binder were seen at a little higher grain moisture level at harvest.

It is difficult to justify why the milling recovery of sun-dried paddy samples harvested by binder was higher than that of sun-dried paddy samples harvested by traditional harvesting system. There is no enough evidence available to support the result. However, a study conducted by Samson and Duff(1973) (10) showed that sun-dried IR-20 rice variety produced a little higher total rice recovery than when the variety was mechanically dried. A further study is needed to clear up this result.

It was shown from the statistical analysis (Table 5) that the average milling recovery of sun-dried paddy samples harvested by binder was higher than that of mechanically dried paddy samples.

Table 5. Differences(1) in means for milling recovery between harvesting systems (2) of Akibare variety.

	T74.6	C74.6	B75.1
T74.6	—		
C74.6	—	—	
B75.1	0.5*	0.5*	—

(1) LSD for difference between two harvesting systems of Akibare variety:
5% : 0.5
1% : 0.8

(2) Note: T: Traditional harvesting system
C: Harvesting system by use of combine
B: Harvesting system by use of binder

The milling recovery among harvesting systems and grain moisture levels of Akibare variety were all highly significant. The interaction between harvesting systems and grain moisture levels was not significant.

Milling Recovery for Tong-il Variety: As shown in Fig. 15, the milling recovery of mechanically dried paddy samples of Tong-il variety was continually increased from 73.0 to 74.6 per cent according to the reduction of grain moisture at harvest.

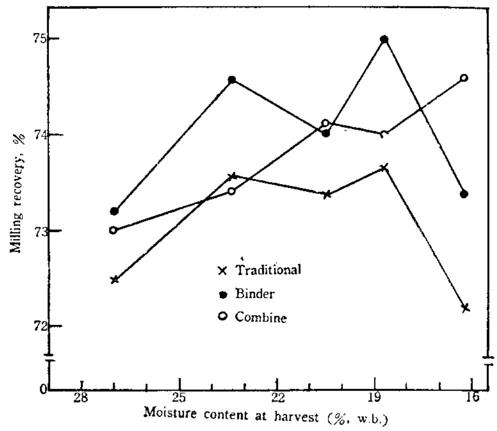

Fig. 15. Milling recovery vs. moisture content at harvest of Tong-il variety for different harvesting systems.

The paddy samples harvested by binder and traditional harvesting system at the grain moisture of 20.5 per cent showed relatively lower milling recovery than expected. The result may be due to two times of rainfall that occurred during the sun-drying experiment, by which rewetting of dried or partially dried grains increased checking of the kernels, thereby decreasing milling recovery rates.

Sun-dried paddy samples harvested at early and late stage of maturity produced lower milling recovery than at the other stage. It seems that the effect of early and late harvesting is reflected by way of the reduction in the total recovery of the milled rice (10)(22)(29)(40).

The whiteness of final products measured by the kett whiteness meter ranged from 42.7 to 46.0.

Statistical analysis showed that the milling recovery of Tong-il variety harvested by different systems was significant at the 5 per cent level.

As analyzed in Table 6, the sun-dried paddy samples harvested by binder produced higher milling recovery than that harvested by traditional harvesting system.

Table 6. Differences(1) in means for milling recovery between harvesting systems (2) of Tong-il variety.

	T73.1	C73.8	B74.0
T73.1	—		
C73.8	0.7**		
B74.0	0.9**	0.2$^{n.s.}$	—

(1) LSD for difference between two harvesting systems of Tong-il variety:
5% : 0.4
1% : 0.7

(2) Note: T: Traditional harvesting system
C: Harvesting system by use of combine
B: Harvesting system by use of binder

C. Head rice recovery

As shown in Fig. 16, the head rice recovery of Akibare variety was higher than that of Tong-il variety.

The milling recovery of mechanically dried Akibare and Tong-il paddy samples were higher than sun-dried paddy samples. From this result, it can be stated that mechanical drying is advantageous over sun-drying to obtain higher head rice recovery.

A relatively high head rice recovery for two varieties could be obtained at the grain moisture at harvest of about 18.0 to 19.0 per cent. Too early or too late harvest might reduce the head rice recovery, which was coincided with the past works (22)(29)(39).

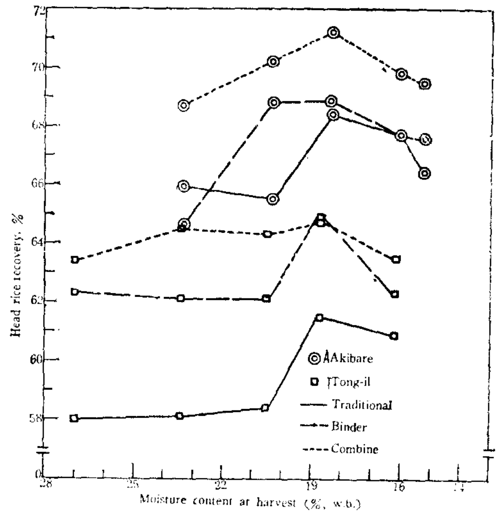

Fig. 16. Head rice recovery vs. moisture content at harvest for two varieties and different harvesting systems.

The paddy samples of Tong-il variety harvested at 20.5 per cent grain moisture produced an extremely lower head-rice recovery than expected. This result was considered to be due to the two times that rain occurred during the sun-drying process, which caused the grains to crack and thus breaking them during hulling and whitening processes.

Analysis of variance showed that the differences in head rice recovery of Akibare variety among harvesting systems and moisture levels were significant at the 1 per cent level.

The head rice recovery among harvesting systems of Tong-il variety was also of statistically significant difference at the 5 per cent level.

D. Field yield

The analysis of field yield for Akibare and Tong-il variety are shown in Fig. 17.

The field yield of Akibare variety, harvested by binder and combine, gradually increased until the grain moisture reached

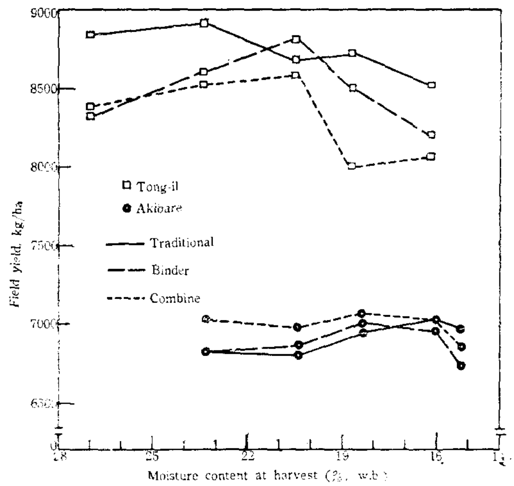

Fig. 17. Field yields of Akibare and Tong-il variety for three harvesting systems at different grain moisture levels at harvest.

to about 18 per cent, and the field yield harvested by traditional system increased to about 16 per cent at harvest.

Statistical analysis showed that the differences in field yield of Akibare variety, due to harvesting system and moisture levels were not significant at all, and the relationship between harvesting systems and grain moisture levels was also not significant.

The field yield of Tong-il variety showed a similar pattern to Akibare. The field yield of Tong-il variety harvested by binder and combine was increased until the grain moisture at harvest reached to about 19 per cent, and that harvested by traditional harvesting system to about 23 per cent. After these stages of maturity, the field yields began to decrease. The result of this work may be comparative with the experimental work by Morse, et al. (1967)(26), which indicated that the total grain yield per acre increased as the grain moisture reduced to about 20 per cent at harvest.

It is interesting to note that the Tong-il variety should be cut at earlier stage of maturity than Akibare to produce higher field yield and that the effect of total loss on the field yield of Tong-il variety, especially for the harvesting systems by use of binder and combine, was greater than Akibare variety.

Statistical analysis showed that the field yield of Tong-il variety among harvesting systems was of significant difference at the 5 per cent level.

E. Determining the optimum time of paddy harvesting

There are many factors involved in determining the optimum time of the paddy harvesting operation. One of the most important factors may be the condition for maximum output of the final product for human consumption.

Accordingly, total milled rice that is defined in this study as the quantity of milling recovery times the field yield was used as an index for determining the optimum time of paddy harvesting. Figs. 18 through 23 show the total milled rice for different varieties and harvesting systems analyzed as the function of the grain moisture at harvest.

It can be seen from the figures that regardless of varieties and harvesting systems

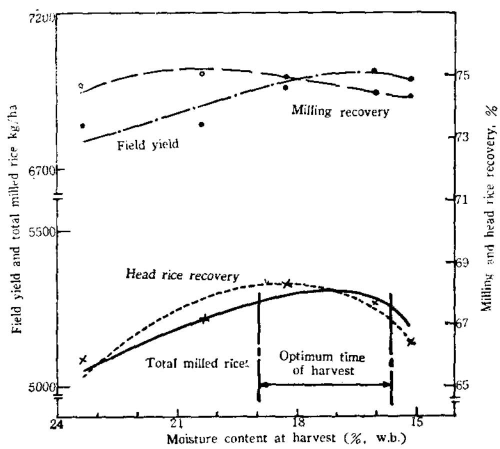

Fig. 18. Total yield, total milled rice, milling recovery, and head rice recovery of Akibare variety for different moisture levels at harvest operated by traditional harvesting system.

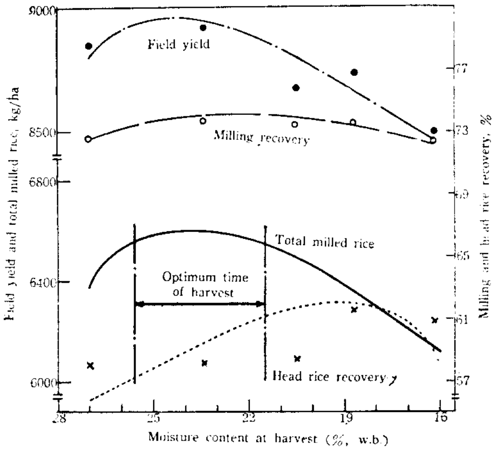

Fig.. 19. Total yield, total milled rice, milling recovery, and head rice recovery of Tong-il variety for different moisture levels at harvest operated by traditional harvesting system.

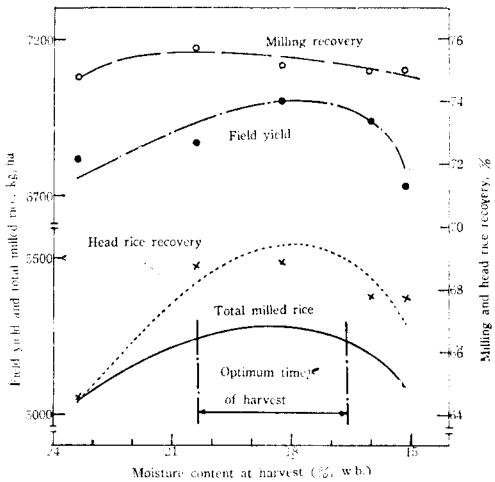

Fig. 20. Total yield, total milled rice, milling recovery, and head rice recovery of Akibare variety for different moisture levels at harvest operated by the harvesting system by use of binder.

tested, there exists a grain moisture at harvest that makes the total milled rice a maximum, which will be regarded as the optimum time for paddy harvesting.

In reviewing the optimum time for paddy harvest for different varieties and harvesting systems, two points may be noticed: Firstly,

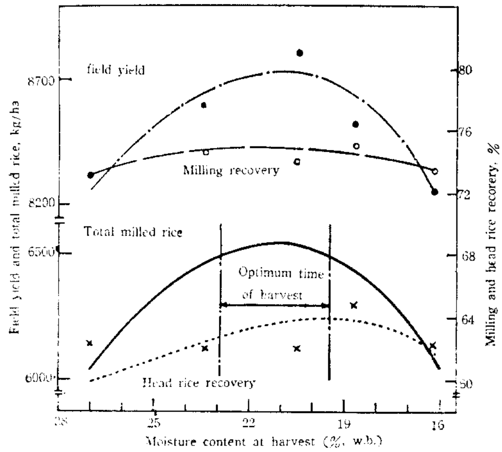

Fig. 21. Total yield, total milled rice, milling recovery, and head rice recovery of Tong-il variety operated by the harvesting system by use of binder.

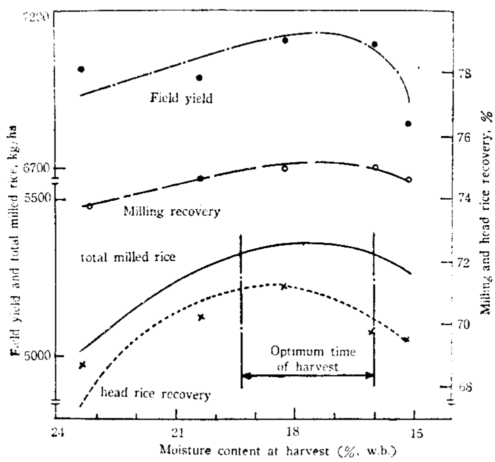

Fig. 22. Total yield, total milled rice, milling recovery, and head rice recovery of Akibare variety for different moisture levels at harvest operated by the harvesting system by use of combine.

the optimum harvesting time of Akibare variety for all harvesting systems tested is observed to occur in a relatively low grain moisture at harvest compared to that of the Tong-il variety; Secondly, regardless of varieties, the total milled rice around the optimum harvesting time for the system by use of binder is very sensitive in the variation of

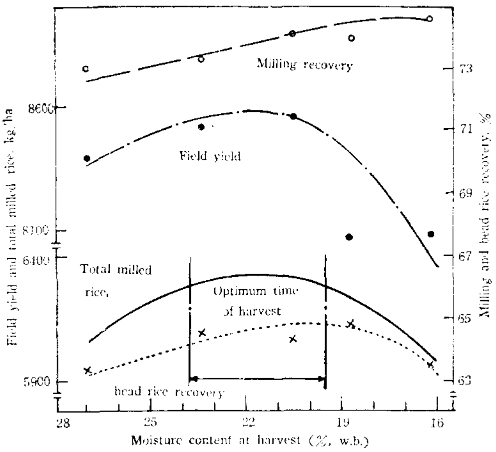

Fig. 23. Total yield, total milled rice, milling recovery, and head rice recovery of Tong-il variety operated by the harvesting system by use of combine.

grain moisture at harvest than those for the other harvesting systems tested. A reason for the result may be explained by the fact that grain loss incurred during binder operation are greatly affected by moisture variation.

The problem of establishing the optimum period of harvesting operation is a very complex one because of many factors which affect the actual operation. Theoritically speaking, the best time for paddy harvesting may be the optimum time specified above. However, in the view of practical application, it would be much desirable to give the best range of grain moisture at harvest or the period of optimum time within which the harvesting operation is accomplished. In this study, it was attempted to establish a reference for an optimum range of grain moisture at harvest based on the total milled rice which gave about 99 per cent of its maximum point.

The results of analysis are summarized in Table 7.

The average days required to accomplish

Table 7. The optimum range of grain moisture at harvest within which the harvesting operation is accomplished.

Variety	Traditional harvesting system	Binder	Combine
Akibare	19.0−15.7%	20.3 −16.7%	19.3 −16.0%
Tong-il	25.6−21.5%	23.0 −19.4%	23.8 −19.6%

the harvesting operation within the range of grain moisture specified in Table 7 can be obtained on the average rate of moisture reduction of stalk-grains which was indicated in Fig. 2. For instance, the period required for optimum harvesting of Tong-il variety by traditional systems may be about seven days.

F. Suggestions for modified harvesting system to reduce grain losses.

In the previous sections, the nature and magnitude of grain losses incurred by various harvesting operations of systems intersted in this study was fully discussed. As far as the grain losses are concerned, some sub-systems may be much more critical than the others and the losses of Japonica variety, if harvested on time, may be almost negligible compared to Indica variety.

One may ask whether it is possible to modify the existing harvesting operation of Tong-il variety so as to reduce the grain loss. the solution for this question may be a complex one. In this study, an attempt was made to suggesst a modified harvesting system for Tong-il variety by making use of the results of tests measured in this study and past experimental data available.

It was learned from the grain loss analysis that the handling losses of each harvesting system took a large part of total loss. By omitting the handling processes of each systems and by threshing the paddy soon after the cutting operation, some of the total losses could be reduced.

Two modified systems are established based on this fact and comparative grain losses which is expected from the modified systems are shown in Fig. 24.

Grain losses given in the Fig. 24 are the average values expected under the assumption that the harvesting operation may be accomplished within the optimum. time. However, grain loss incurred during the threshing and handling operations of the wet paddy was not tested in this study and thus information available from past work[1] has been used.

As shown in Fig. 24, the total loss of traditional harvesting system would be reduced from 3.6~4.9 per cent to 0.9~1.5 per cent of total field yield if the modified systems are applied. The total loss of the harvesting system by use of binder would be expected to be reduced from 6.0~7.3 per cent to 2.1~3.6 per cent of total field yield.

In implementing the modified systems, it is clear that subtantial adjustments in current post-harvest technology will be required. One of the most difficult adjustments may be the substitution of mechanical dryer to dry the high moisture grains at harvest instead of the traditional method of sun drying. Another problem to be faced with the modified systems could be the difficulty of obtaining mobility of present auto-thresher within fields. A further study on the technical and economic feasibility of the modified systems strongly recommended.

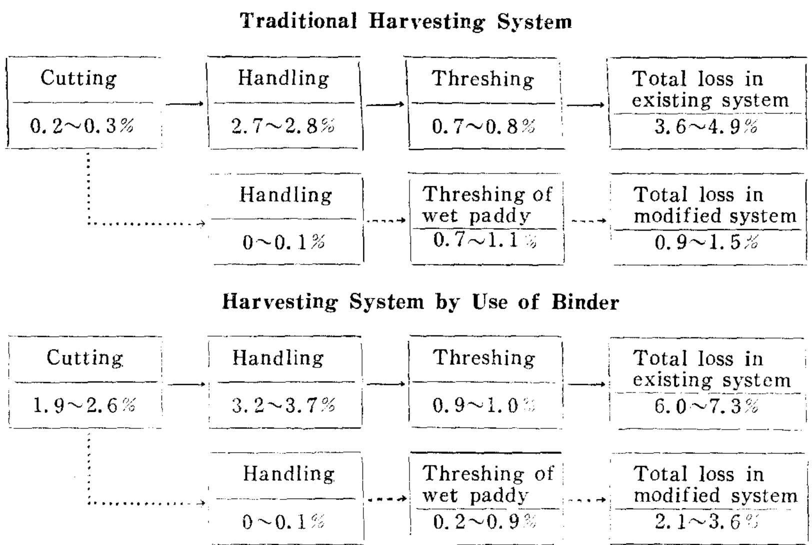

Fig. 24. Grain losses of Tong-il variety expected from modified traditional haversting system and system by use of binder.

1) According to Han(1971), et al., (14) about 0.7~1.1 per cent and about 0.2~0.9 percent of Suweon 215 (sister line of Tong-il) paddy grains are lost when the rice variety threshed just after cutting by sickle and by binder, respectively. Up to about 0.1 per cent of grains were lost during the handling process for both harvesting systems.

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要　約

本硏究는, 在來品種(아끼바레)과 新品種(統一) 두 品種에 對하여 慣行收穫作業 體系를 비롯한 바인더 및 콤바인 收穫作業體系에 關한 各 工種別 穀粒損失의 特性과 量을 測定하여, 最大數量의 槪念에서 各 體系別 收穫適期를 判定하고 穀粒損失減少를 期할 수 있는 慣行 및 機械化 體系의 樹立에 必要한 基本資料를 提示하는데 있었다. 그 結果를 要約하면 다음과 같다.

1. 在來種(아끼바레) 品種의 收穫總損失은 刈取時 穀粒含水量이 約 24%에서 15%까지 變化할때 慣行作業體系에서 1.1~1.5%, 바인더作業 體系에서는 2.1~4.8%, 콤바인 作業體系에서는 約 2.8~4.3%로 나타났다. 搗精收率面에서, 바인더 作業體系가 74.8~75.7%, 慣行作業 體系가 74.3~75.0% 콤바인 作業體系가 73.8~75.0%로 바인다 作業體系가 若干 높았고, 完全米收率은 機械的 乾燥方法을 採擇한 콤바인 作業體系가 餘他體系보다 越等히 優秀하였다.

2. 統一品種의 收穫作業 總損失量은, 收穫作業時 穀粒含水量이 28-16%의 範圍에서, 慣行作業方法에서 3.8~5.0%, 바인더 作業體系에서 5.2~10.0%, 콤바인 作業體系에서 約 3.0~5.0%였다.

3. 統一벼의 搗精收率은, 慣行方法에서 72.3%~73.6%, 바인더 作業體系에서 73.2~75.0, 콤바인 作業體系에서 73.0%~74.6%로서 慣行方法이 餘他方法에 比하여 낮다고 判斷되었다.

4. 統一벼의 完全米收率은, 慣行方法에서 58.0~61.5%, 바인더 作業體系에서 約 62.1~64.9%, 콤바인 作業體系에서 63.4%~64.8%로서 역시 慣行作業體系가 낮음을 判斷할 수 있었다.

5. 統一벼의 慣行作業總損失의 約 70%는 取扱損失(結束, 運搬, 줄가리損失)이므로 이 作業의 簡略化, 例컨데 刈取後 即時結束, 生脫穀의 技術開發을 通하여 損失減少策의 마련이 必要하다고 判斷되었다. 이와같은 改善慣行收穫體系가 適用되면 適期收穫 總損失量을 現實의 3.6~4.9%에서 約 1.0~2.0%範圍內로 減少시킬수 있다고 推定되었다.

6. 統一벼의 바인더 作業에서의 큰 損失量은 主로 結束된 볏단의 機械放出損失과 慣行方法에 準하는 取扱損失이므로 이의 減少策으로서, 衝擊力減少를 期하는 機械的 補完硏究와 生脫穀의 技術開發이 切實함을 判斷할 수 있었다. 取扱工程을 省略하는 改善바인더 收穫作業體系가 適用되면 適期收穫 總損失量은 現實의 6.0~7.3%에서 2.1~3.6%로 減少시킬 수 있다고 判斷 되었다.

7. 最高收量의 槪念에서, 各 作業別 收穫適期를 總搗精量(圃場收量×搗精收率)에서 決定하면 統一벼는 刈取時 穀粒含水量이 大體로 26-19%의 範圍內에서, 또 아끼바레 品種은 大體로 20-16%의 範圍에서 나타났다.