Grain Losses Incurred During Different Post-harvest Rice Systems.

벼의 여러 收穫後 作業技術體系에서 發生하는 穀粒損失

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摘 要

우리나라 벼 收穫作業에 適用되고 있거나 適用될 것으로 展望되고 있는 慣行乾脫穀 및 生脫穀收穫體系, 바인다 乾脫穀 및 生脫穀體系와 콤바인 收穫體系등 5種의 收穫作業體系에 對해 日本型品種인 아끼바레 品種과 統一系品種인 水原251號를 供試하여 收穫時의 穀物含水率에 따른 收穫損失量을 分析하여 우리나라 實情에 알맞는 收穫作業體系를 設定하기 위하여 綜合的으로 檢討한 結果를 要約하면 다음과 같다.

1. 아끼바레 品種의 收穫損失은 5種의 體系가운데 콤바인體系에서 가장 큰 값을 보였으며 大體的으로 穀物含水率이 減少함에 따라 減少하는 傾向을 보였다.

또한 慣行乾脫穀 및 生脫穀, 바인다乾脫穀 및 生脫穀과 콤바인體系에서의 平均 總損失率은 0.80, 0.59, 0.68, 0.69 및 1.51% 였으며 統計分析結果 損失量은 穀物含水率, 收穫體系 및 이 두 處理間의 交互作用에 있어서도 高度의 有意性이 認定되었다.

2. 水原 251號品種의 경우 慣行乾脫穀, 慣行生脫穀 및 콤바인 收穫體系에 있어서의 平均損失率은 各各 2.72, 0.91 및 2.64%로서 아끼바레品種의 경우와는 若干 다른 경향을 보이고 있다.

3. 바인다의 乾脫穀 및 生脫穀體系에서의 放出損失은 各各의 總損失量의 27~40% 및 40~64%였다. 이러한 損失量은 各體系에 있어서 充分히 고려해야 할 量이며, 바인다를 收穫作業에 利用하기 爲하여서는 볏단에 加해지는 충격량을 줄일수 있도록 바인다의 放出裝置改善이 要望된다.

4. 生脫穀 體系에서는 乾脫穀 體系에서 보다 損失量이 많았는데 이것은 在來의 脫穀機의 選別裝置가 生脫穀에는 適合치 못하기 때문인것으로 判斷되었다.

5. 慣行乾脫穀 體系에서 發生하는 損失量을 줄이기 爲해서는 慣行生脫穀體系 또는 바인다生脫穀體系로의 技術的 전환이 强力히 要望된다. 收穫適期內에 收穫作業이 完了된다고 假定할 境遇, 慣行生脫穀體系에서는 慣行乾脫穀體系에서 發生하는 損失量을 55~63%程度 줄일 수 있으며 바인다生脫穀體系에서는 慣行乾脫穀體系에서 發生하는 損失量의 10~17%程度를 減少시킬 수 있을 것으로 期待된다.

I. Introduction

Traditional paddy harvesting system in Korea should be very primitive in the light of the degree of qualitative as well as quantitative inputs in the powered machinery. There are involved too many processes from cutting operations to threshing ones. They are performed mostly by manual methods for an extended period of time.

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Recently, however, this traditional system is being faced with increasing modifications with a view to accomodating to socio-economic changes and agricultural technology development. One of the illustrative and serious problems is the shortage of rural labor, consequently, being accompanied by a rapid increase of the farm wage. Farm mechanization may be a present and final solution to the problem. But it will be difficult to answer relevant questions such as what kind and size of farm machinery may be adaptable and adoptable in view of the present situation and many years to come.

Another problem might be related to the cultivation and production of High-Yielding Varieties (H.Y.V.) of rice, now covering more than 70% of the total paddy land of Korea. The HYV requires a little different technological innovations compared to those involved with the Japonica-type because of differences in their varietal characteristics.

Grain losses incurred during the post-production period of the HYV may be a very serious problem, especially when the harvest technology is adopted with the traditional one that has been long practised for traditional rice varieties, historically. The sources and extent of the grain losses should be clarified and determined to profitably serve any efforts in modifying the present system, to be replaced with by the new one. Accordingly, it may be pertinent to determine the grain loss not merely for the traditional post-production system, but also for the new system which may be developed by the application of the modern farm machinery in near future. For this, needless to mention, a research must be conducted.

This study was conducted to experimentally find out sources and extent of grain losses incurred in the traditional pappy harvesting system and some other modified systems that would give a reduced grain loss and that would solve the labor shortage constraint.

Ⅱ. Expenmental Methodology

1. Experimental materials and design

The experimental work was carried out in a farmer's private paddy field located in Anwha-Ri, Pyungtaik-Gun, Gyonggi province, during the paddy harvesting season of 1977.

The paddy varieties planted were the AKIBARE(Japonica) and the SUWEON 251 (TONGIL sister-line). Agronomic data of the two varieties are shown in Table (1).

Table (1). Agronomic data of the rice varieties tested for the experimental harvesting operation

Variety		AKIBARE	SUWEON 251
Sowing		April 17, 1977	April 17, 1977
Transplanting		May 29, 1977	May 30, 1977
Harvesting	Begin	Sept 23, 1977	Sept. 22, 1977
	End	Oct. 17, 1977	Oct. 11, 1977

As shown in Table (1), the two varieties were all sown in nursery field on April 17, 1977, and transplanted on May 29, and 30, respectively. The experimental work for the AKIBARE variety began from September 23 and finished on October 17, and for the SUWEON 251 variety, from September 22 to October 11.

The total area of the test fields was about 5,000m^2 for the AKIBARE variety and 3,000 m^2 for the SUWEON 251, respectively. Test fields were divided into equal blocks of the size of 0.96m x 11.0 m. So as to enable researchers to conduct each experimental harvest operation without hinderance and to give a free wide path for the binder and combine the field was opened up the plants in the neighborh ood of each block.

Five harvesting systems as shoown in Table (2) were tested for five grain moisture levels at cutting.

Table (2). Five harvesting tested in this study.

System	Description
I	Traditional harvesting system to which the dry-material threshing was applied
II	Traditional harvesting system to which the dry-material threshing was applied
III	Binder harvesting system to which the dry-material threshing was applied.
IV	Binder harvesting system to which the wet-material threshing was applied
V	Combine harvesting system

For the convenience of comparison between varieties and among harvesting systems, following abbreviations were used in the henceforth:

ATD: System I applied to AKIBARE variety

ATW: System II applied to AKIBARE variety

ABD: System III applied to AKIBARE variety

ABW: System IV applied to AKIBARE variety

AC : System V applied to AKIBARE variety

STD: System I applied to SUWEON 251

STW: System II applied te SUWEON 251

SBD: System III applied to SUWEON 251

SBW: System IV applied to SUWEON 251

SC : System V applied to SUWEON 251

Table (3). Specifications of the experimental equipment and measuring instruments.

Nomenclature	Type/Model	Capacity/Dimension	Remarks
Combine	Iseki TARO-700	Cutting width: 750mm Drum Dia:444mm	Drum speed for paddy: 450rpm
Binder	Suzue B260 A	Cutting width: 570mm	
Moisture Meter	Kett SP-1	Range:11-30%	Electric Resistance Type
Tachometer	Smiths Industries Venture ATH6	Range: 0-10,000 rpm	

The moisture content of grains in plants was measured between 1 and 2 P.M. each day. The samples were obtained from various sections within the block to be tested. The moisture contents were taken from the

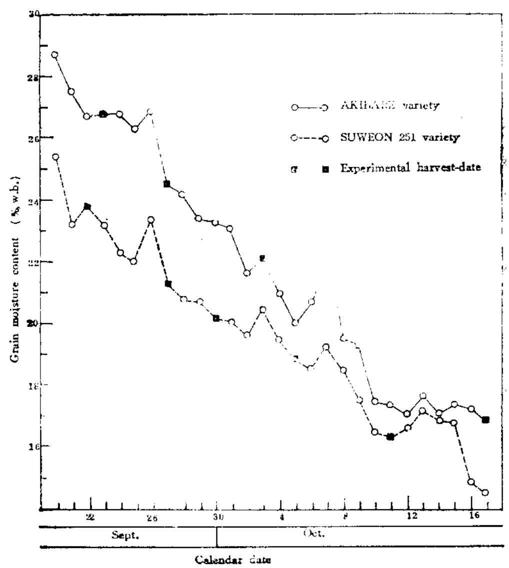


Fig. (1). Moisture variations of standing stalk grains exposed to natural environment during the rice harvesting season.

average of ten times measurements. An electric resistance-type moisture meter was used for the measurement of the grain moisture content.

As shown in Fig.(1), average reductions per day in the grain moisture were 0.44% for the AKIBARE, and 0.40% for the SUWEON 251 variety, respectively. There was no rainfall during the test period, but a dense fog was encountered three times.

The specifications of the equipments and measuring instruments used are shown in Table(3).

2. Experimental Methodology

A. Classification of Grain Losses and Collection:

For the classification of grain losses known to occur during harvest processes, standardized methods of measuring techniques have not been yet established in Korea, because not many research undertakings similar to this study have been conducted in the past. A comparison of some domestic reports (5) (7) (8) and the Japanese standard methods produced some differences in classification of grain losses and methods of the measurement. Therefore, in this study, the classification of grain losses and the method of its measurement were rationally determined with special reference so the domestic reports and foreign standards available.

1) Traditional harvesting systems: Grain losses incurred during traditional paddy harvesting system were classified into several categories: (a) the cutting loss by the impact force of sickle, (b) the handling loss during bundling and shocking processes, and (c) grain loss incurred during threshing operations. This classification is schematically presented in Fig. (2).

Only the drum loss, sand-witched loss, and dust-outlet loss were included in threshing loss items. In a study conducted in Japan(12), stalk-outlet loss was included as one of threshing loss items, but in Korean traditional harvesting operation the stallk-outlet loss can be recovered by spreading straw-mats or vinyl sheet around the threshing site. Accordingly, stalk-outlet loss was excluded from containing in this study as an item.

The dust-outlet loss was colllection-wise measured by counting the number of grains blown off from the dust-outlet of the thresher with the draff which was treated twice in the thresher as Korean farmers customarily do.

The transporting loss may vary according to the employed methods, distances, etc. In this study, the measurement of the transporting loss was not possible simply because the threshing operation was carried out in the field. To make free from the transportation loss while being hauled within the test field, the bundles of stalk paddy were wrapped in vinyl sheet.

After the cutting operation simulated by a well experienced farmer on the test block, three small plots with one square meter in size were selected at random and the fallen grains within the plots were collected. The grains collected were regarded as the cutting loss. The number of collected grians was converted into the weight in kilograms per hectare by comparing it with the weight of 1,000 sound grains measured at the 14% moisture content on the wet basis.

In order to carry out the experiment using the wet-material threshing method, the cut plants were threshed right after the cutting by transporting it to the threshing site.

For the experiment of the dry-material threshing, paddy bundles were shocked wit-

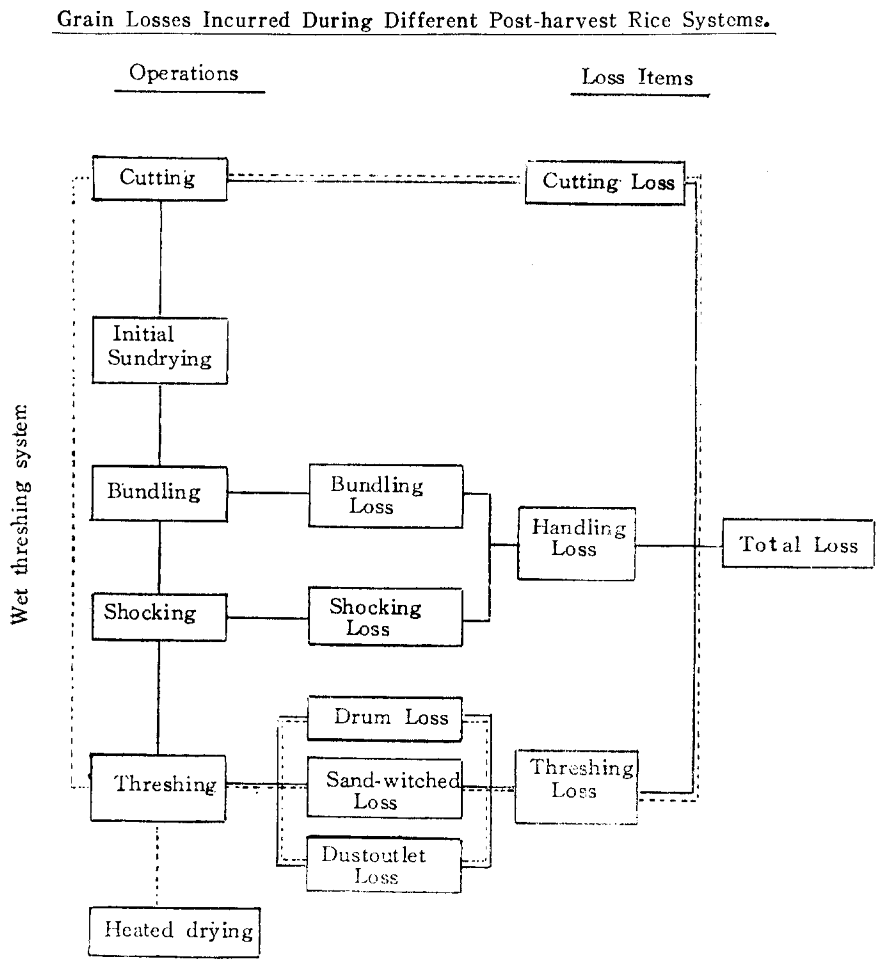


Fig. (2). Classification of grain losses occuring during the traditional harvesting system with dry-marerial threshing and wet-material threshing, respectively.

hin the test plots for about three to seven days of the sun-drying in the field. The drying was continued until the bundles dried down to have about 14% of the grain moisture, depenidng upon the moisture of grains at cutting. An area of one square meter was selected at random within a test block to collect grains lost during the bundling operation. After removing bundles from the selected area, lost grains were collected. And the number of collect kernels subtracted by the number of grains collected for measuring the cutting loss was regarded as the bundling loss. The number of grains thus obtained were converted into the weight of the loss per hectare.

After the shocked plant bundles were hauled to the threshing site, grains fallen on the site of shocking operation were collected to get the number of grains lost during the shocking process. The number of counted grains was converted into the weight in kilograms per hectare. This grain loss was regarded as the shocking loss.

Grain losses occurred during the threshing operation of both dry and wet materials were identified and measured in the same way. During the threshing operation, three threshed bundles flowing out off from the thresher were sampled at random for an evaluation of the drum loss and sand-witched loss, respectively. Grains thus collected were counted and the number of counted grains was converted into the weight in kilograms per hectare.

The field yield was determined based on the weight of threshed grains from each block. And it was converted into the weight per hectare based on the 14% of the grain moisture content. The sum of field yield and total grain losses was defined as the total field yield.

In the dry-material threshing system, five kilograms of threshed paddy was sampled and it was redried in the sun. The same amount of the wet paddy was dried in the batch-type mechanical dryer with the heated air temperature of 37°C until the average grain moisture content reached to about 14%. The paddy samples thus dried were used for the milling test.

2) Binder harvesting systems

Loss items of binder harvesting systems are different from those of traditional harvesting system because both cutting and bundling operations are conducted mechanically. But, loss items and measuring technologies after bundling process were identical to those of the traditional harvesting system.

Loss items of the binder harvesting system were specified in Fig. (3).

The average forward operating speed for the binder was kept for about 0.91 meter per second with the second gear setting.

Cutting loss and uncut loss were evaluated as in the traditional harvesting system.

To measure the number of the grains lost during the cutting action of the binder, a

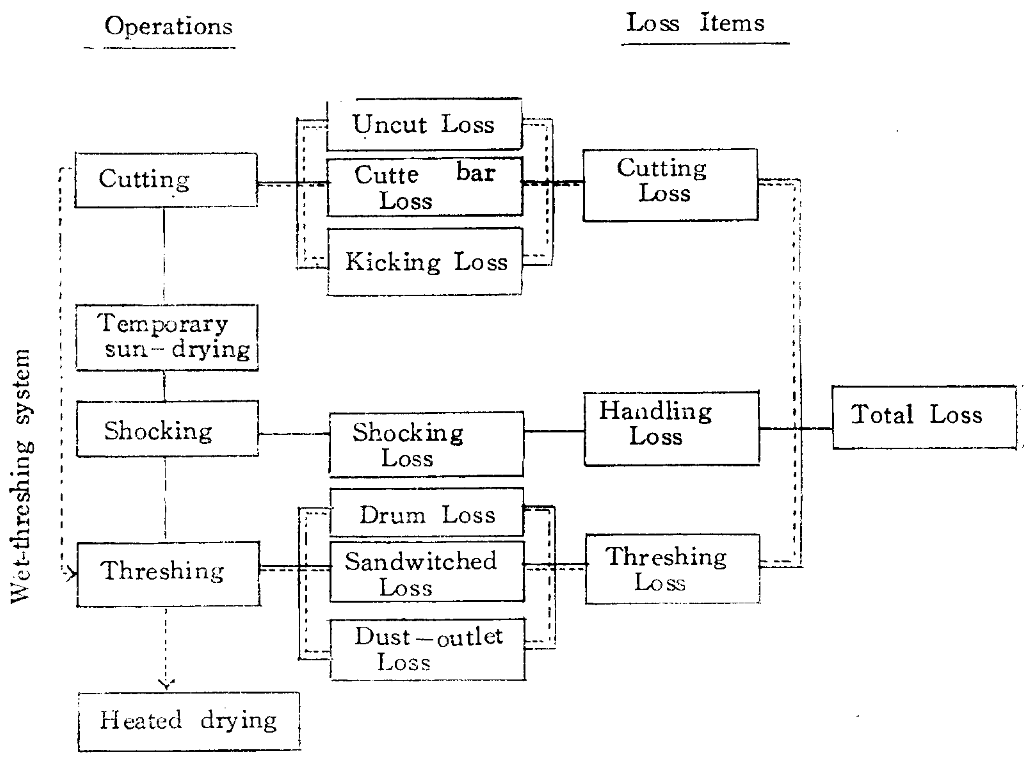


Fig. (3). The classification of the grain losses occuring during the binder harvesting system with dry-and wet-threshing.

polyethylen sheet, 3.6m×3.6m in size, was spread beside and along the row of standing plants to be cut before the operation of the binder. The plant bundles which were kicked off from the binder were removed from the vinyle sheet and the grains fallen on the sheet were collected. The number of collected grains was converted into the weight per hectare. This category of grain loss was regarded as the Kicking loss of the binder.

3) Combine harvesting system

The sources of grain losses incurred during the combine operation were classified into two major categories; the cutting loss and the threshing loss. The threshing loss included the following; (1) the drum loss, (2) the sandwitched loss, (3) the stalk-outlet loss, and (4) the dust-outlet loss. Differently from the traditional harvesting system, the stalk-outlet loss by the combine should be regarded as a loss item because the grains lost from stalk-outlet can not be recovered while the combine moves through.

Two helpers in the combining followed with a vinyle sheet on beside the operating combine to take an armful of threshed plants flowing out off from the combine and the threshed grains flowing out off from the stalk-outlet, respectively. Accordingly, the stalk-outlet loss could be made recovered, but it could not be discerningly separated out from the sandwitched loss. Thus, in this study, the sum of the stalk-outlet loss and the sandwitched loss were regarded as the sand-witched loss.

Loss items incurring during combine operation were classified as shown in Fig. (4). Collecting methods of the lost grains were same as used in the traditional and binder harvesting systems, respectively.

After combining and collecting the lost grains, field yields were evaluated. The wet paddy was dried in a batch-type dryer till the average grain moisture reached at the

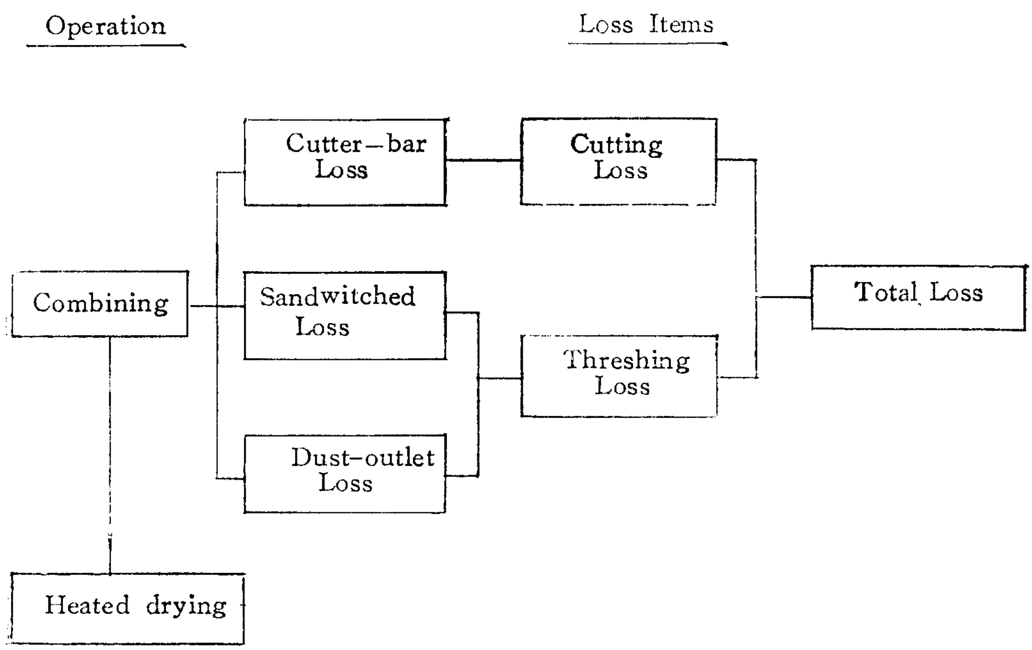


Fig. (4). The classification of the grain losses occuring during the combine harvesting system.

15% wet basis. About five kilograms of the dried paddy were sampled and used for milling test.

Ⅲ. Results and Discussion

The grain loss could be presented either in the absolute amount in terms of the weight of the grain lost per unit area, or in the relative amount as the percentage of the grain loss for a given area to the total yield for the same area. The former may be inconvenient in comparing the grain losses between varieties which may have considerable difference in yield due to different harvesting systems or operations.

Thus two indexes were all used in this study in discussing the grain losses, paying a major attention to the covenience of comparison operations.

AKIBARE variety: The relation between grain losses and grain moistures at harvest were shown in Fig. (5) to Fig. (9). Total grain loss of the AKIBARE vairety incurred during the traditional dry-threshing operations showed little differences at each grain moisture at harvest, respectively.

The total amount and the percentage of grain losses were 50.15-58.24kg/ha and 0.80-0.86%, respectively, and the average grain loss for five grain moisture levels was 54.27 kg/ha and 0.80%, respectively.

The average percentages of the cutting, handling and threshing losses were 0.10, 0.23, and 0.47%, respectively, presenting about 60% of the total grain loss as the threshing loss. The total grain loss determinded in this study was much smaller when compared to that of the 1.32% reported by Kim, et al. in 1972 (8), and corresponded to about half of 98.4kg/ha by Kang, et al. (5) tested for the same variety and methods in 1976.

In the traditional wet-threshing system (ATW), the total grain loss was 30.68-60.13kg/ha, which corresponded to 0.46-0.86%

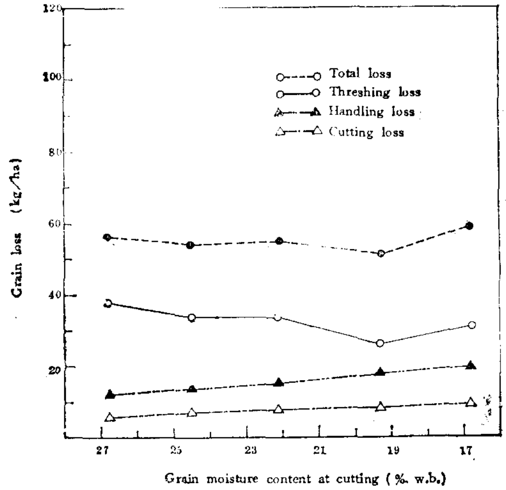


Fig. (5) Total threshing, handling, and cutting losses of AKIBARE variety by the tranditional harvesting system to which dry threshing was applied. Moisture contents of grains were measured at the time of cutting operation.

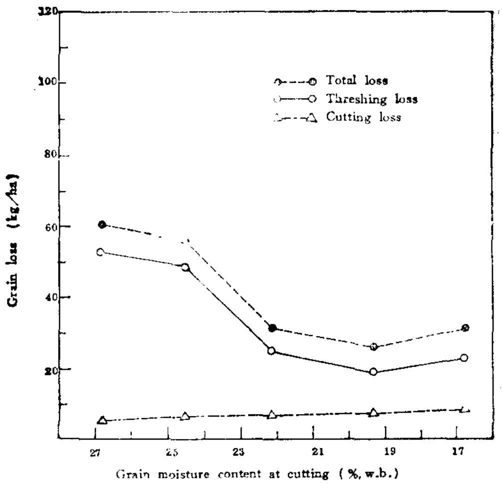


Fig. (6) Total, threshing, and cutting losses of AKIBARE varietv by the traditional harvesting system to which wet-threshing was applied. Moisture content of grains were measured at the time of cutting operation.

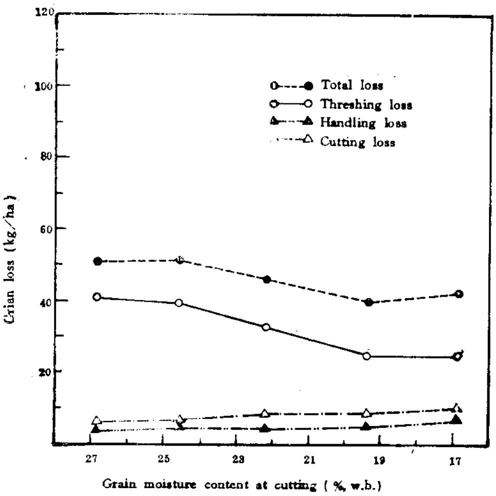


Fig. (7) Total threshing, handling, and cutting losses of AKIBARE variety by the binder harvesting system to which dry-threshing was applied. Moisture content of grains were measured at the time of cutting operation.

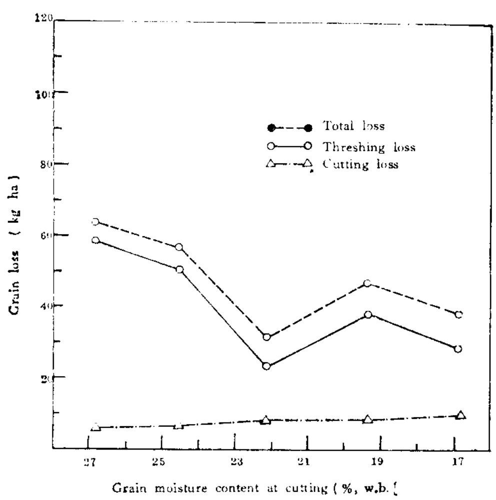


Fig. (8) Total threshing and cutting losses of AKIBARE variety by the binder harvesting system to which wet-threshing was applied. Moisture content of grains was measured at the time of cutting operation.

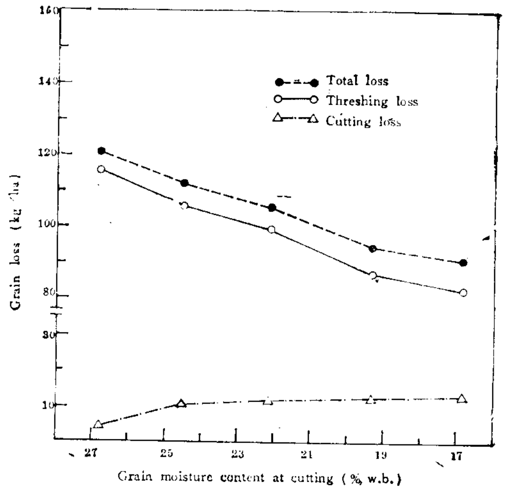


Fig. (9) Total threshing and cutting losses of AKIBARE variety by the combine harvesting svstem when combining was performed at different levels of grain moisture content.

of the total field yield. The loss was decreased to about half of the initial loss as the grain moisture content at harvest reduced from 26.8 to 16.9%. This result was considered to be attributable to the fact that the threshing loss proved to be the major factor of the total loss, was considerably decreased as the grain moisture get reduced, and that the cutting loss was gradually increased as the grain moisture at harvest reduced.

Comparing the harvesting loss between the ATD and the ATW systems, the grain loss of the ATD system at the grain moisture content of 26.8% at harvest. This finding may be explained by the fact that the threshing and separation functions of the thresher could be lowered at the higher moisture contents. The result was consistant with that of the study by Ikihara (1972) (17) et al., which reported that the grain loss of the ATW system was minimum at the grain moisture range of 19-22%.

The total grain loss of the ABD system began to increase at the moisture content of grains at harvest lower than 19%. And it ranged from 39.66 to 50.65kg/ha, 0.56-0.79% of the total field at the grain moisture level applied.

The increasing trend of the total loss for the ABD system was found resulting from a large amount of reduction of the threshing loss, as the grain moisture centent at harvest reduced in contrast to a slight increase of the cutting and handling loss, respectively.

The total loss of the ABW system, which decreased as the grain moisture content at harvest reduced, ranged 31.21-63.54 kg/ha, and 0.44-0.94% of the total field yield for the varied grain moistures at harvest. The threshing loss was the major component accountable for the total loss of the ABW system, and it was decreased significantly as the grain moisture at harvest was reduced.

In Korea, not many research papers researched to determine the grain loss of Japonica varieties for the ABW system. Kim et al. (1972) conducted a similar study to this one on the ABW system as defined in this study. However, he did not include the sandwitched and throwing losses in the measurement of the grain loss. Therefore, a direct and immediate comparison of the two research results may not be made meaningfully and realistically. When compared the common items of the losses, the cutter-bar loss and the drum loss, respectively, of the two studies, the present study showed a greater amount of grain losses than that found by Kim, et al. quoted in the above.

Differences of the average loss within the limits of drum speed and grain moisture applied which could be ascribed to the differences between the ATD and ATW systems, 1.7 kg/ha and those between the ABD and ABW systems were 6.98kg/ha. These two summary findings of the threshing loss in physical terms, were less than 0.1%, respectively.

The total grain loss of the AC system ranged from 90.87 to 120.89kg/ha, which corresponded to from 1.31 to 1.81% of the total field yield. This loss was found much more than those of the ATW and ABW systems, respectively, and showed considerable differences when comparing it to the one reported by other researchers (5) (8).

The total loss of AC system was decreased as the grain moisture at harvest reduced. The total loss was mainly affected by the threshing loss rather than the cutting loss. The range of reduction of threshing loss as the maturity of grains progressed was wider than that of the increase in the cutting loss.

In Fig. (10), total losses of grain having different moisture contents at harvest for five harvesting systems tested were shown. The AC system of these five systems had the highest grain loss of all, and had the same tendency as the ABW system. The three remaining systems showed little different trends, that is, the total loss of the ATD, the ATW, and the ABD system decreased as the grain moisture reduced and it began to increase when the grain moisture reached at around 19%. And the total loss of the ABW and the AC systems decreased as the grain moisture at the grain moisture at harvest reduced.

Comparing the total loss of each harvesting systems, the following concluding points may be noticed: the total loss of the ATD and the ATW systems, respectively, were almost same when the grain moisture at harvest was kept relatively higher. But it showed sizable differences as the grain moisture at harvest reduced. The total loss of the ATD system was not affected so much as on the ATW system by the reduction of moisture content of paddy at harvest. And the difference of the total loss between the ABD and

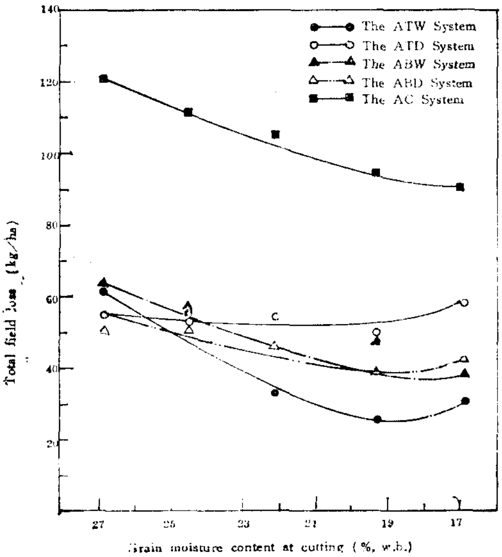


Fig. (10) Total losses of AKIBARE variety in accordance with five harvesting systems which operated at different grain moisture levels.

the ABW system was almost the same at each of the five grain moisture levels at harvest, respectively.

There were also some differences of the total loss between the ATD and the ABD system and between the ATW and the ABW system, the major effect of which seemed to come from the throwing loss of the binder. In view of the significance of the problem and few or no available research studies in Korea, further studies on the prevention of the throwing loss of the binder should be made as soon as possible.

An analysis of variance for the total loss of the AKIBARE variety showed that the differences among harvesting systems, moisture levels and the interaction of the two were statistically highly significant.

SUWEON 251: As shown in Fig(11)-Fig.(15) grain loss of the STD system was varied from 183.24 to 304.10 kg/ha for the grain moisture at harvest tested, percentage wise, it accounted for 2.02-3.34% of total field yield. The loss was increased as the grain moisture reduced because of a notable increase in the handling loss, while cutting loss and the threshing loss decreased slightly, respectively, due to the reduction of the moisture content of paddy at harvest. The reason as to why the handling loss was so high could be explained in terms of the shattering characteristics of SUWEON 251. This was much more sensitive when handled the material in the dried state. On the other hand, the threshing loss was decreased as the grain moisture reduced. This was because of the decrease in the drum loss and sandwitched loss, which consisted of the major portion of the threshing loss. In addition, it was found that the threshing and separation performance were greatly improved due to the reduction of the moisture content.

The total loss of the STW system, of which, the handling operations were practically omitted, was 81 kg/ha on the average for the grain moisture levels tested. Of the total field yield, this corresponded to about 0.9%. The loss was decreased slightly due to the reduction of the moisture content of paddy as shown in Fig. (12). The threshing loss and cutting loss in the STW system for the varied grain moisture at harvest had about the same trend and amount as those for the STD system.

The dust-outlet loss of the STW system

measured and reported by Choi (1973) (7) et

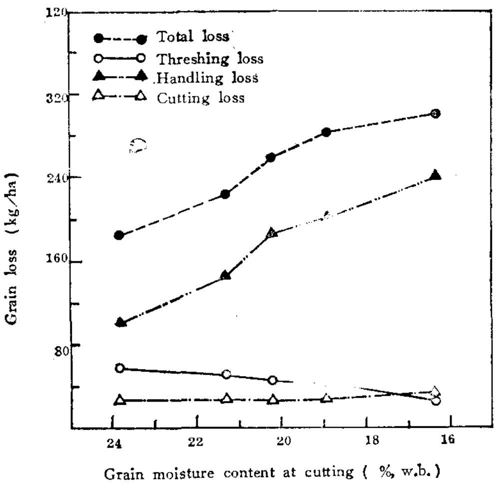


Fig. (11) Total, threshing, handling, and cutting losses of SUWEON 251 variety by the traditional harvesting system to which dry-threshing was applied. Moisture content of grains were measured at the time of cutting operation.

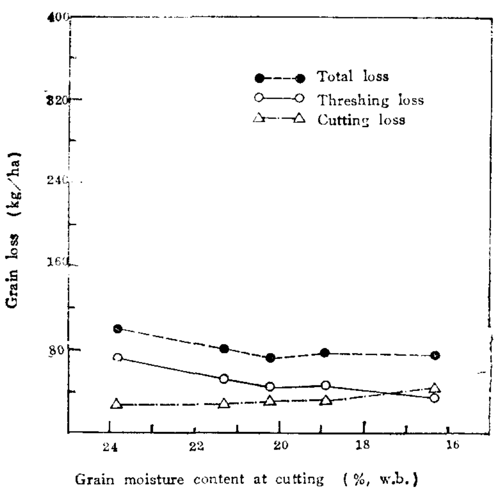


Fig. (12) Total, threshing, and cutting losses of SUWEON 251 variety by the traditional harvesting system to whch wet threshnig was applied. Moisture content of grians were measured at the time of cutting operation.

al. was about two times bigger than that of this study. But the collecting method of grain loss through the dust-outlout was different from each other.

The total threshing loss of the STD and the STW systems were 45.21 kg/ha and 50.23 kg/ha in average of five moisture levels, respectively.

As seen in Fig. (13), the total loss of the SBD system was greatly increased from 235.22kg/ha to 504.44kg/ha, or from 2.60% to 5.56% of the total field yield, as the grain moisture at harvest reduced from 2.38 to 16.3%.

The composition of the total loss of the SBD system was 51% for cutting loss (including the cutter-bar loss and throwing loss), 37% for handling loss, and 12% for threshing loss, respectivly, which showed that the cutting loss proved to be a major portion of the total loss. Moreover, the average throwing loss for the grain moisture levels tested, was 130.98kg/ha composing of about 76% of the cutting loss and 36% of the total loss, was found to be one of the major loss items.

Paik (1978) (1) observed that the cutting loss and throwing loss of binder were 0.77-0.82% and 1.83-2.01%, respectively, and Kang et al. (1977) (5) reported that they were 0.33-1.21%, 1.30-2.89%, respectively, showing a lttle higher grain loss when compared to those of this study of 0.56% and 1.41%. The threshing loss, 61.57kg/ha at the grain moisture at harvet was almost the same as that reported by Kang et al. (1977) (7), 76.5kg/ha, showing no notable difference. But the difference was much considerable as the grain moisture at harvest reduced.

The total of the SBW system increased more than twice as much as the amount of the grain loss at 23.8% of moisture content at harvest as the moisture content reduced to 16.3%. Throwing loss was again the main portion of the total loss, which was about 55% of the total loss. The cutting loss increased heavily while the threshing loss decreased slightly due to the reduction of moisture content of paddy grains at harvest.

These research findings could be referred to with many reports published in Japan (16) (17) (19).

A comparison of the SBD with SBW system showed that threshing losses for both systems were decreased as the grain moisture reduced. But the decreasing rate of the SBD system was much greater than that of the SBW system.

The total loss of the SC system was ranged from 179.74 to 244.07kg/ha, for the grain moisture levels tested. In other words, it occupied 2.02% to 2.67% of the total field

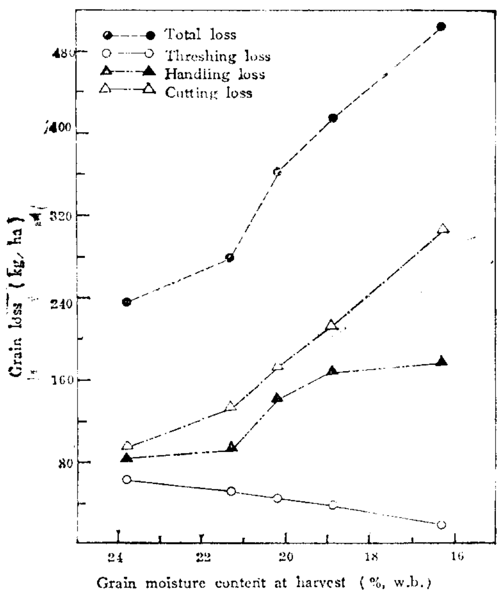


Fig. (13) Total, threshing, and cutting losses of SUWEON 251 variety by the binder harvesting system to which dry-threshing was applied.
Moisture content of granis were measured at the time of cutting operation.

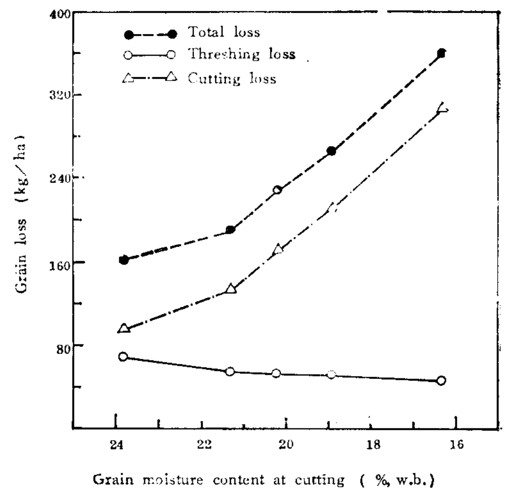


Fig. (14) Total, thresihug and cutting losses of SUWEON 251 variety by the binder harvesting system to which wet-threshing was applied.
Moisture content of grains were measured at the time of cutting operation.

yield. The total loss increased slightly as the grain moisture at harvest reduced. This increasing tendency might be accounted for the increase in cutting loss which was more than 50% of the total loss. On the other hand, the threshing loss decreased slightly as the grain moisture levels at harvest reduced.

The cutting loss for the SC system ranged from 53.84 to 171.86kg/ha, which corresponded to 0.61-1.88% of the total field yield as the grain moisture reduced from 23.8% to 16.3%. In addition to the cutting loss, a considerably high threshing loss was also incurred by the SC system.

Fig(16) shows the experimentally determined relationships between the total field loss and grain maturity at harvest for five different harvesting systems selected for this study.

As far as the grain loss is concerned, it

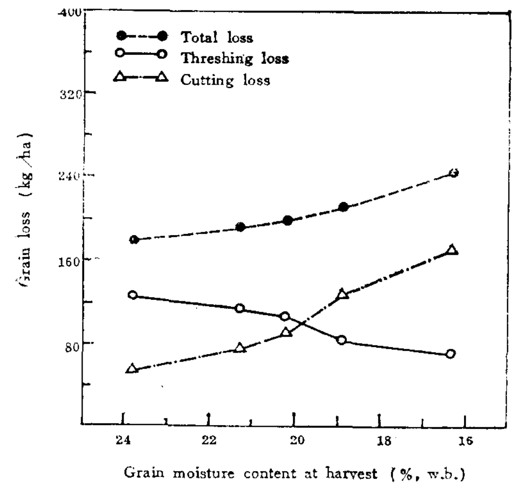


Fig. (15) **Total threshing, and cutting losses of SUWEON 251 variety by the combine harvesting system when combining was performed at different levels of grain moisture contents of harvest.**

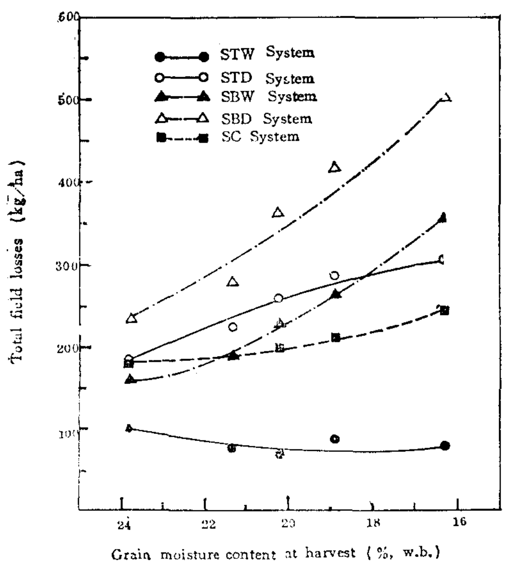


Fig. (16) **Total field losses of SUWEON 251 variety in accordance with five harvesting systems which operated at different grain moisture contents at harvest.**

is very clear that the worst system is the SBD system and the best, the STW. It was noticed that the SBW system had a comparable degree of the total grain loss with that of the STD and the SC systems, respectively, throughout the grain maturity tested, in spite of its great cutting loss incurred.

Considering the fact that the throwing loss of the SBD and the SBW systems which composed of a major portion of the total loss of the two systems, it may be desirable to conduct additional and follow-up studies on the improvement of the throwing mechanism of the binder with a view to reducing grain losses when the paddy be harvested by binder.

An analysis of variance for the total loss of SUWEON 251 rice variety showed that the difference among harvesting systems and grain moisture levels at harvest were significant and the interactions of the two variables were also highly significant.

Summary of Research Results on Grain Losses.

In the previous sections, major sources and extents of grain losses incurred during the operation of five different harvest systems were experimentally determined in relation to the grain maturity at harvest. The data on grain losses obtained would, of course, be subject to change to some extent under other conditions than the present study. However, these data would give sufficiently enough information necessary for assessing the actual harvest systems similar to the tested ones, and for giving approximate estimates of the grain losses for actual systems. Moreover, the information may also be useful in presenting a possible direction for the improvement of actual systems which would result in reduced grain losses.

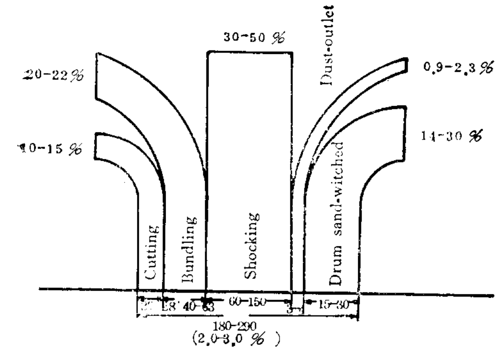
With a view to serving these purposes, an effort was rendered to summarize all the

Table (4). Summary of grain losses, in percentage of the total field yield, incurred during field harvest operations.

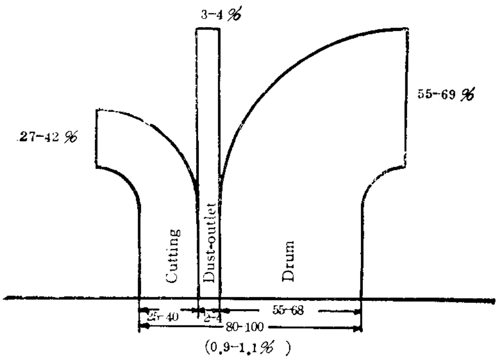
loss source / Systems	Cutting Loss		Handling Loss		Threshing Loss		
	Cutting(Cutterbar) Loss	Kicking Loss	Binding Loss	Shocking Loss	Drum Loss	Sandwitched Loss	Dust-Outlet Loss
ATD	0.10-0.11** (0.09-0.12)***		0.11-0.13** (0.11-0.18)	0.07-0.10** (0.07-0.11)	0.31-0.42** (0.42-0.52)		0.04-0.06** (0.03-0.06)
	0.02-0.10 (0.02-0.13)*		0.16-0.20* (0.16-0.24)	0.30-0.33 (0.29-0.30)	0.35-0.42* (0.36-0.44)	0.21-0.30* (0.24-0.41)	0.13-0.15* (0.04-0.16)
ATW	0.09-0.11 (0.08-0.20)**				0.25-0.07** (0.31-0.75)		0.03-0.04** (0.03-0.06)
	0.04-0.85 (0.03-0.93)*						
ABD	0.07-0.08** (0.07-0.09)	0.02-0.03** (0.01-0.05)		0.09-0.10** (0.07-0.11)	0.35-0.57** (0.31-0.54)		0.03-0.05** (0.03-0.05)
	0.01-0.09* (0.01-0.75)	0.08-0.18* (0.08-0.36)		1.10-1.42* (1.21-1.47)	0.52-0.65* (0.73-0.99)	0.14-0.37* (0.14-1.09)	0.03-0.06* (0.03-0.07)
ABW	0.07-0.08** (0.07-0.10)	0.03-0.06** (0.06-0.10)			0.49-0.52** (0.40-0.66)		0.04-0.05** (0.03-0.05)
	1.10-1.45* (1.12-1.48)						
AC	0.10-0.11* (0.07-0.15)				0.64-0.82** (0.64-0.96)		0.56-0.78** (0.54-0.78)
	0.14-0.78 (0.14-0.90)				0.25-0.43 (0.49-0.66)	1.71-1.78 (1.29-1·79)	0.37-0.74* (0.37-1.30)
STD	0.29-0.35** (0.29-0.38)		0.45-0.64** (0.45-0.84)	0.63-1.55** (0.63-1.81)	0.59-1.50** (0.59-1.63)		0.04-0.05** (0.04-0.05)
	0.43-0.65* (0.20-0.78)		1.95-2.0* (1.96-2.87)	0.71-0.70* (0.51-0.68)	0.15-0.21* (0.31)	0.49-0.65* (0.49-0.65)	0.03-0.04* (0.03-0.04)
STW	0.30-0.41** (0.30-0.47)				0.49-0.70** (0.40-0.77)		0.03-0.06** (0.03-0.05)
SBD	0.39-0.96** (0.32-1.25)	0.54-1.32** (0.60-2.22)		1.13-1.43 (0.92-1.96)	0.40-0.64** (0.18-0.64)		0.03-0.04** (0.02-0.04)
	0.27-0.42* (0.31-1.28)	1.42-1.21* (1.34-1.47)		2.89-2.74 (2.88-4.72)	0.20-0.28* (0.21-0.28)	0.49-0.54* (0.45-0.64)	0.06-0.07* (0.06-0.07)
SBW	0.32-0.73** (0.31-1.21)	0.65-1.42** (0.09-2.21)			0.52-0.73** (0.49-0.74)		0.04-0.05** (0.04-0.05)
SC	0.77-1.57** (0.61-1.88)				0.55-0.72** (0.54-0.75)		0.35-0.64** (0.25-0.66)
	2.02-2.10* (1.81-3.84)				0.42-0.56* (0.41-0.58)	0.75-0.79* (0.57-0.78)	0.13-0.14* (0.15-0.17)

* Refer to Refernece (3)
** Data obtained in this study
*** Range of grain loss in parenthisis denotes the grain loss within the optimum range of harvest time. Refer to reference (1)

available data on grain losses obtained by this study as well as those published by other researchers in the past in connection with the post-harvest systems in Korea. Table

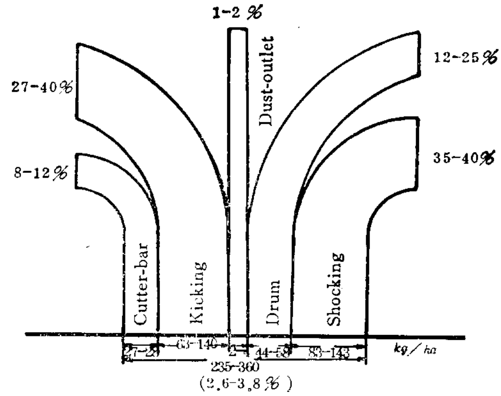


(a) The STD system

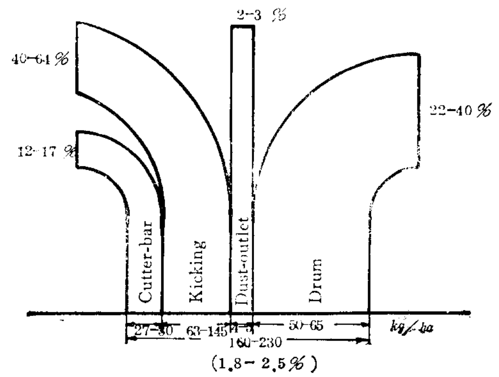


(b) The STW system

Fig. (17) Schematic diagram showing the proportion and amount of grain losses classified by each of major grain loss sources. (a) the STD system and (b) the STW system.



(a) The SBD system



(b) The SBW system

Fig. (18) Schematic diagram showing the proportion and amount of grain losses classified by each of major grain loss sources, (a) SBD system and (b) the SBW system.

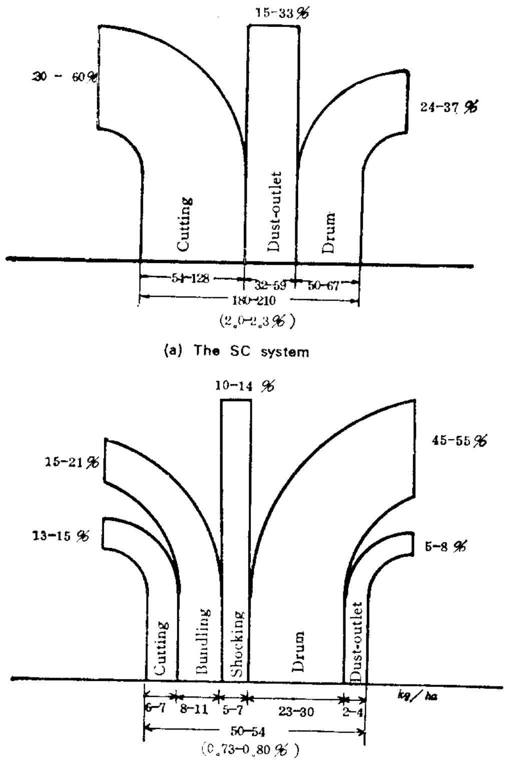
(4) shows the summary of the data classified according to harvesting systems, varieties and sources of grain losses.

As seen from the table, the HYV has much greater grain losses than the traditional variety in each of the comparable loss sources. To better understand the critical feature of grain losses in the HYV, the proportion of grain losses attributable to each of loss sources are analyzed and shown schematically in Fig. (17) to Fig. (19).

From Figures, (17), (18), and (19), it is very significant to note the following points;

First, about 30-50% of the grain loss in the STD system came from the shocking operation. And all the handling loss, that is, bundling plus shocking loss, is from 52 to 72% of the total loss.

One of possible measures to reduce such grain loss may be to adopt the STW system. If it could be done, about 55 to 63% of the grain loss known to be incurred in the STD system could be reduced. Howerver, the technological transfer from the STD to STW system would require the dissemination of ntew hreshers capable of performing the wet-



(a) The SC system

(b) The ATD system

Fig(19). Schematic diagram showing the proportion and amount or grain losses classified by each of major grain loss sources, (a) SC system and (b) the ATD system.

material threshing, and they can be easily moved from field to field. In addition, a modern technology of grain drying should be adopted to replace the present sun-drying by the shocking operation.

Second, a majority of grain losses in the SBD system were incurred by shocking and kicking losses which were amounted to about 35 to 40% and 27 to 40% of the total loss, respectively.

Substitution of the binder in the cutting and bundling operations of the STD will increase the performance rate greatly. But the SBD system could result in more total grain loss by 26-30% than the STD system. This fact should be assessed as the most critical point in the SBD system. For the binder to be used successfully in the harvest operation of the HYV, it is urgently needed to develop a new kicking device such that the kicking loss could be reduced.

Third, if the technological transfer from the STD system to the SBW one is undertaken, about 10 to 17% of the total grain loss in the STD system could be avoided. Furthermore, an additional amount of grain loss is also expected to be reduced, should the improvement on the kicking mechanism be made. As in the case of the STW, however, new threshing and drying technologies are necessary in getting the STD system replaced by the SBW system.

Fourth, the transfer from the STD system to the SC one may generally reduce the overall grain loss by about 0 to 20 percent usually incurred in the STD system. The major grain loss item in the SC system is the cutting loss which ranges from 30 to 60% of the total loss. This item may not be expected to be reduced unless the readily shattering characteristics of the HYV be improved.

In summary, the STD system should be improved with a view to reducing the grain loss. As proven clear from this study, the appropriate technology to be replaced by the STD system should be either the STW system or SBW one. A further study relating to implementing the technological transfer is urgnetly needed.

Ⅳ. Summary and Conclusions

In this study. rice harvesting losses were determinded for two rice varieties and five harvesting systems for each rice variety. Rice varieties used for the experiment were the AKIBARE(Japonica-type) and the SUWEON 251 (high yielding TONGIL sister-line variety). The harvesting systems studied by the experimental work of this study were traditional system with both the wet-material and dry-material threshing, system by use of binder with both the dry-material and wet-material threshings, and system by use of combine. All the possible sources of grain losses known to incur during each of these harvesting systems were identified and measured under actual operations, respectively.

The results may be summarized as follows:

1. The harvesting loss of the AKIBARE variety was the highest in the combine harvesting system of the five systems tested. The total harvesting loss for the five systems were generally decreased, as the grain moisture content at harvest decreased, respectively. Within the range of grain moisture varied in this experiment, the average total grain loss was 0.80% for the traditional harvesting system with the dry-material threshing, 0.59% for the traditional harvesting system with wet-material threshing, 0.68% for the binder harvesting system with the wet-threshing, and 1.51% for the combine harvesting system, respectively. A statistical analysis of the total loss showed that levels of the grain moisture at harvest, harvesting systems, and the interaction of the two, respectively, proved highly significant at 1% level.

2. Within the range of the grain moisture varied in the study, the average total loss of the SUWEON 251 was 2.72% for the traditional harvesting system with the dry-material threshing, 0.91% for the traditional harvesting system with the wet-material threshing, and 2.24% for the combine harvesting system, respectively.

3. The kicking loss incurred during the operation of the SBD and SBW systems ranged from 27 to 40 percent and 40-64 percent of their respective total loss, respectively. This fact should be taken as a critical point for both of the systems. To successfully apply the binder to these systems, it is urgently needed to improve its kicking device so that a high impact force exerted on bundles could be reduced.

4. The higher loss of wet-material threshing systems compared to the dry-material threshing was resulted in when the wet paddy was threshed. This should be ascribed to an inadequate separating performance of the thresher under wet-threshing conditions.

5. To reduce field grain losses incurred during the operation of the STD system, technological transfer toward either the STW system or the SBW system is strongly recommended. Under the assumption that the harvest operation is accomplished within the optimum period, the STW system could save 58-67 percent of the grain loss incurred in the STD system. And the SBW system is expected to save about 29 to 32% of the grain loss incurred in the operation of the STD system.

6. In implementing the STW and SBW systems, technological innovations on the threshing and drying operations are essential. The thresher, for example, should be capable of performing the wet-threshing with ease mobility from field to field.

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