Development of a New Combine Equipped with Screw Type Threshing and Separating Mechanisms

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At present, 2 types of combines, a Japanese type (head feeding) combine, and a foreign type large combine, are widely used in Japan. The former is a harvester developed to be used for mainly japonica rice, and it cuts crop plants and supplies heads (from panicle tip to about 60 cm below) of the cut plants to the threshing chamber to carry out the threshing operation. It is now working on about 70% of the total rice-cropped area of paddy fields with its number reaching about 1 million. It is also widely used to harvest wheat and barley. However, it has several shortcomings such as that due to a complicated mechanism its durability is low compared with the foreign type large combine, and also its harvesting operation for other crops than rice, wheat and barley (such as soybean, buckwheat, etc.) is not satisfactory.

On the other hand, the foreign type large combine is usually adaptable for harvesting many kinds of crops, because its working system is to supply the whole cut plants into the threshing unit, but its operating accuracy is not sufficient in harvesting japonica rice and soybean, causing a lot of grain losses and damaged grains, although it gives excellent operating accuracy for wheat and barley.

Historically, Japanese agriculture has developed centering on rice as a staple crop. Although this trend will continue in future, a new tendency in recent years is increasing the importance of upland crops like wheat, barley, soybean, etc. Farmers growing these upland crops in an integrated farming system centering on rice are increasing in number. For that farming system, particularly that adopted by farmers groups, it is examined to use head-feeding combines to harvest rice, foreign type large combines to harvest wheat and barley, and bean harvesters for soybean. To use harvesters specific to each crop makes highly efficient harvesting possible but it is apparently an over-investment, and not rational. Therefore, it is necessary and strongly desired to develop a highly efficient combine adaptable to many kinds of crops including rice.

With such a background, the authors developed a new combine which has screw type threshing and separating mechanisms and can be used for many kinds of crops.

Screw type threshing and separating mechanisms

The principal characteristic is that the new combine is equipped with the screw type threshing and separating mechanisms[3,4,5,6] of the axial-flow system, which have been studied and developed by the authors since 1978.

1) The screw type threshing mechanism

Since an axial-flow combine with twin rotor[8] and that with single rotor[1] were reported in U.S.A. in 1975 and 1977, respectively, many axial-flow combines[2] have been developed. The screw type threshing mechanism is different from the threshing mechanism of these axial-flow combines. In the former, crop plants supplied into the threshing chamber are conveyed by the screw type tooth (spiral vane) attached to the threshing cylinder, during the rotation of the cylinder, along the direction of the axis of the cylinder. During the conveyance, the threshing is done by the frictional force generated between the screw type tooth and the concave. Due to the fact that the screw type tooth has strong threshing force and conveying force, and that the threshing time (travel time) in the threshing chamber is long and can be adjusted, the highly efficient threshing performance can stably be obtained without being largely influenced by different kinds and conditions of crops to be harvested.

2) The screw type separating mechanism

After threshing, grains and straws which dropped down from the concave are conveyed by the screw auger in the direction of the auger and, during the conveyance they are separated through the separating screen. This system is superior to the conventional shaking-separation system in simplicity of mechanism and high durability due to less oscillation. In addition, it has a salient feature that it shows stable performance even when the combine inclines.

Structure and action of the new combine[7]

Plate 1 shows the appearance, Fig. 1 the sectional view, and Table 1 the specification of the new combine. First of all, standing crop was gathered up by the reel, and cut by the knife. The plants are gathered by the auger of the header unit, transferred to the elevator by fingers, and conveyed to the threshing unit. The axis of the threshing unit (screw type threshing mechanism) is the same as the moving direction of the combine, and plants are drawn into the threshing chamber by 2 vanes attached to the conical introducing drum. The screw type tooth (spiral vane) is attached on the surface of the threshing cylinder, under which the concave is located. Furthermore, peg tooth and agitating plate are attached to the screw type tooth, which assist threshing action and prevent clogging of the concave.

The plants in the threshing chamber are threshed while they are conveyed, showing spiral movement, in the axial direction of the threshing cylinder by the screw type tooth. Grains and a part of straws drop down through the concave but the majority of straws are disposed from the straw outlet. The grains and straws which dropped through the concave fall down into the screw type separating mechanism. There, they are separated, while they are conveyed by the screw auger in the axial direction: grains drop down through the separating screen, whereas long straws are disposed from the tip of the screw auger. Then, the

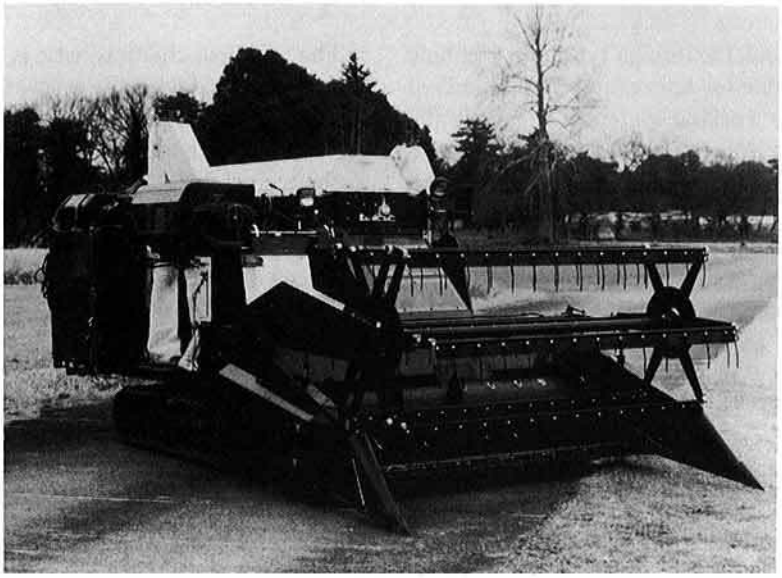

Plate 1. The newly developed combine with reel type header

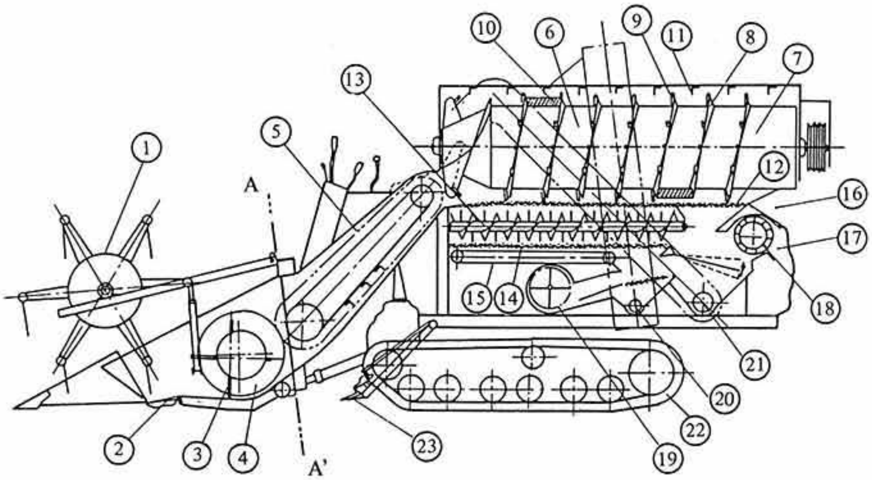

Fig. 1. Sectional view of the newly developed combine
①Reel ②Knife ③Finger ④Auger ⑤Elevator ⑥Screw type threshing mechanism ⑦Threshing cylinder ⑧Screw type tooth ⑨Peg tooth ⑩Agitating plate ⑪Baffle plate ⑫Concave ⑬Screw type separating mechanism ⑭Separating screen ⑮Belt conveyor ⑯Straw outlet ⑰Chaff outlet ⑱Suction fan ⑲Cleaning fan ⑳Clean-grain auger ㉑Tailings auger ㉒Locomotion unit ㉓Re-cutting unit

Table 1. Specifications of the newly developed combine

Dimension			
Overall length		(mm)	5090 (5000*)
Overall width		(mm)	2440 (2130*)
Overall height		(mm)	2220
Overall weight		(kg)	2950 (3000*)
Engine output		(kW/rpm)	39/2500
Cutting width		(mm)	2134
Threshing unit			
Cylinder	Diameter	(mm)	500
	Length	(mm)	2245
	Speed	(rpm)	296–828
Screw tooth	Height	(mm)	60
	Pitch	(mm)	150
Concave	Meshes	(mm)	18×18 (Crimp net)
Separating unit			
Screw auger	Diameter	(mm)	177
	Pitch	(mm)	135
	Speed	(rpm)	150
Screen	Meshes	(mm)	12×12 (Crimp net)

The figures with * mark show the dimensions equipped with soybean header.

grains are carried by the belt conveyer to the cleaning unit and winnowed, while the long straws disposed from the tip of the auger are sucked by a suction fan and discharged from the chaff outlet. In this system, the meshes of the separating screen are smaller than those of the concave in the threshing unit, so that the above-mentioned separation to grains and long straws can be done for a certainty. The agitating rods attached to the screw auger act to prevent clogging of the separating screen.

Baffle plates attached to the inner surface of the upper cover of the threshing chamber act to regulate travel speed of plants in the chamber. Opening and closing angle of the baffle plates against the

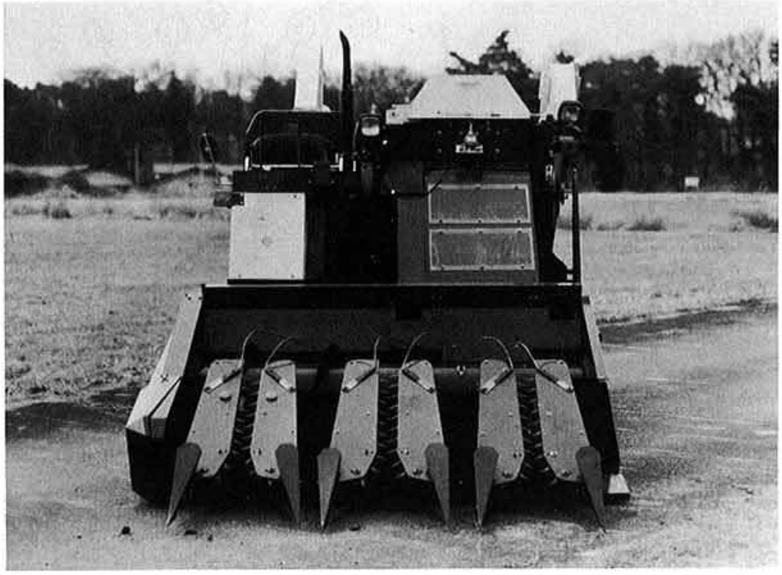

Plate 2. The newly developed combine with soybean header

axial direction of the chamber can be regulated according to conditions of the plants. Furthermore, the re-cutting unit located between the locomotion unit and header unit aims at re-cutting stabbles left standing on the field, when harvesting is made by cutting crop plants at a high portion in order to reduce the load to the threshing unit.

By only regulating the speed of the threshing cylinder and angle of the baffle plates, the combine can be used for different kinds of crops. However, for soybean, the reel type header in Fig. 1 can be replaced by the soybean header at the cross-section A-A'. This soybean header is for 3 rows, and it conveys cut plants to the auger of the header unit by 2 steps of tined chain. Plate 2 shows the new combine to which the soybean header is attached.

Performances of the new combine[7)]

The target of the performance is total grain loss rate lower than 3% and percentage of damaged grains less than 1% for wheat and barley, rice, and soybean. Results of the field tests conducted in 1984 and 1985 are summarized below. Conditions

Table 2. Crop conditions

Crop	Wheat	Barley	Rice			Soybean
Variety	Norin 61	Kashima-mugi	Milyang 30	Musashi-kogane	Mineyutaka	Tama-homare
Plant length (cm)	86.9	91.5	107.1	94.0	105.9	64.1
Ear length (cm)	8.0	4.1	20.3	16.2	18.6	—
Interrow space (cm)	60.0	13.3	30.0	30.0	30.0	60.0
Average yield (kg/10 a)	318	481	777	711	701	317
Moisture contents of grain (%)	22.3	18.1	23.0	18.0-21.8	20.9-26.4	—
Moisture contents of straw (%)	40.0	53.6	63.0	63.9-67.6	65.4-68.1	—

Yields of rice are shown in terms of paddies.

of crops used for the tests are given in Table 2.

1) *Wheat and barley*

Processing loss rates as related to working speed ranging from 0.5-1.4 m/s are shown in Fig. 2. The processing loss rate is the ratio of weight per hr of free grains (discharged with straws from straw outlet and chaff outlet) plus unthreshed grains to the grain feed rate. The processing loss rate showed a tendency to increase with the increase of working speed, i.e., with the increase of total feed rate. However, the loss rate was quite low throughout all the tests, showing 0.5-0.8% for wheat and 0.8-1.3% for barley. The breakdown of the loss indicated that only free grains from straw and chaff outlets constitute the whole loss, without any unthreshed grains in any test plots. The average of gathering loss rate was 0.3% for wheat or barley, and percentage of damaged grains at the grain tank was lower than 0.1% in any plots.

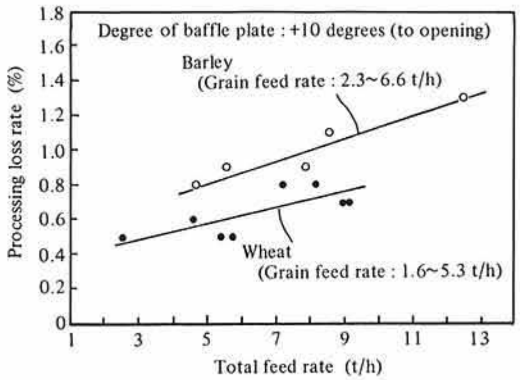

Fig. 2. Processing loss rate for wheat and barley

2) *Rice*

The result of performance test using 3 varieties at the working speed ranging from 0.3-0.7 m/s is shown in Fig. 3. Processing loss rate for Milyang 30, a japonica-indica hybrid variety with high threshability was as low as 0.4-0.7%. It increased only little with the increase of total feed rate. The average of gathering loss rate was 0.3%. The total loss rate (processing loss and gathering loss) was lower than 1% in any test plots. Percentage of damaged grains (husked and broken grain) at the grain tank was about 0.4%, and of grains with pedicels (longer than 10 mm) was about 4%.

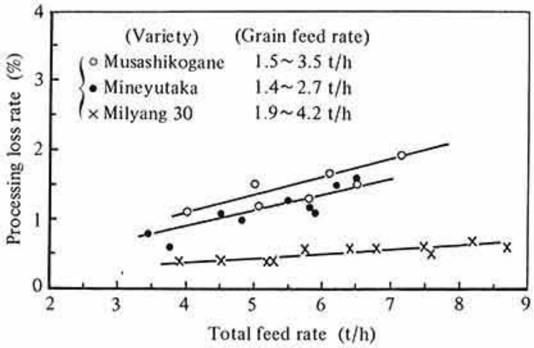

Fig. 3. Processing loss rate for rice
Degree of baffle plate
Musashikogane : 0 degree (right angle)
Mineyutaka : 0 degree
Milyang 30 : +10 degrees (to opening)

Musashikogane and Mineyutaka are typical japonica varieties with difficult shattering, so that they showed higher rates of processing loss as compared with Milyang 30. However, the rates were about 2%, even at a high feed rate. It indicates that the new combine is sufficiently adaptable to japonica rice. When a foreign type large combine conventionally used in Japan was tested with Musashikogane, it showed the processing loss rate nearly 10%.[9] Thus, it can be said that the performance of our new combine is far excellent.

Similar to the case of wheat and barley, unthreshed grains were not found, and the majority of the processing loss was free grains (mainly those with pedicels) discharged together with straws from straw outlet.

For both varieties, gathering loss rates were always lower than 0.1%, damaged grains at the grain tank 0.3-0.7%, and grains with pedicels about 8%.

3) *Soybean*

During a period from Nov. 17 to Dec. 1, 1984, performance tests were carried out periodically using the reel type header and soybean header. The working speed was 0.5 m/s, and grain feed rate and total feed rate were about 1.0 t/hr and about 2.1 t/hr respectively, on average.

Fig. 4 shows moisture contents of pods, stalks and grains, and total grain loss rate on different harvesting dates. Generally, the total grain loss

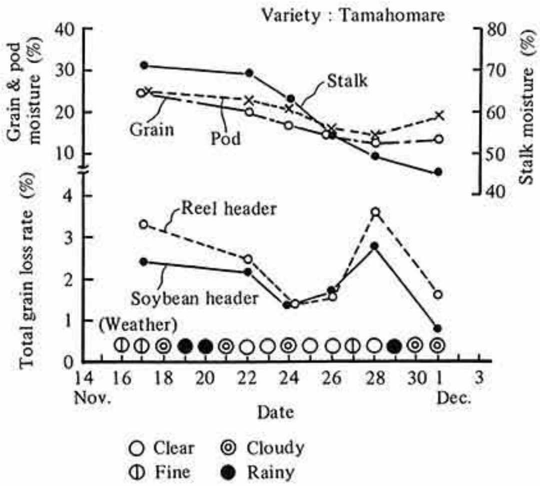

Fig. 4. Total grain loss rate for reel type header and soybean header

rate shows a tendency that it decreases with the decrease of soybean moisture, but after a certain date (Nov. 22), it turns to increase. This tendency is ascribed to the fact that processing loss rate becomes high when the moisture content is high, but gathering loss rate becomes high when the moisture content is low.

Comparison of the headers showed that the soybean header gave a lower rate of total grain loss, which was always less than 3%, than the reel type header. At the right time for harvest (about Nov. 24–28), gathering loss rate accounted for 70–90% of the total grain loss rate for both headers.

The percentage of damaged grains and result of germination test of the grains are shown in Fig. 5. The damaged grains included splits and cracks.

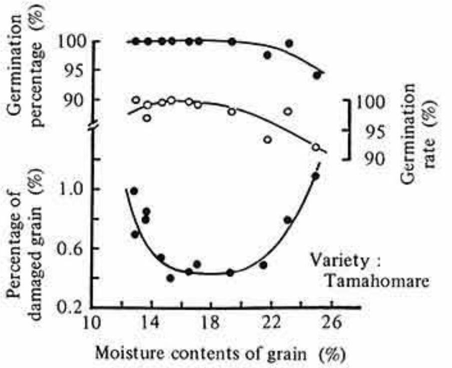

Fig. 5. Relation between moisture contents of grain and soybean qualities

Germination percentage was determined 7 days after seeding under constant temperature of 20°C, and germination rate was obtained 72 hr after seeding. The percentage of damaged grains was less than 1% in any plots, but it was shown that it increased when grain moisture was higher than 20% or lower than 14%. This tendency was corresponding to the result of germination test. Thus, it is evident that the grain moisture content of 15–18% is the most suitable condition for reducing damaged grains in combine harvesting.

Summary

A new combine equipped with screw type threshing and separating mechanisms, which is adaptable to not only rice, but also many other kinds of crops, was developed, and a series of field tests of harvesting wheat and borley, rice, and soybean were carried out. The results made clear that the harvesting performance of the new combine showed the total grain loss rate lower than 3% and percentage of damaged grains less than 1% for any of these crops. For further improvement of the performance, tests with more kinds of crops under more varied crop conditions will be carried out.

References

1) DePauw, R. A.: Engineering aspects of axial-flow combine design. *ASAE Paper*, 77-1550 (1977).
2) Heinz Dieter Kutzbach: Dresch-und trennsysteme neuer mähdrescher. *Landtechnik*, **6**, 226–230 (1983).
3) Ichikawa, T. & Sugiyama, T.: Soybean thresher in Japan and development of a new thresher. *JARQ*, **16**, 87–93 (1982).
4) Ichikawa, T. et al.: Studies on the development of a screw type soybean thresher (part I). *J. JSAM*, **46**, 35–42(1984) [In Japanese with English summary].
5) Ichikawa, T. et al.: Studies on the development of a screw type soybean thresher(part II). *J. JSAM*, **46**, 189–195 (1984) [In Japanese with English summary].
6) Ichikawa, T. et al.: Studies on the development of a screw type soybean thresher (part III). *J. JSAM*, **46**, 303–308 (1984) [In Japanese with English summary].
7) Ichikawa, T.: Studies on the development of a new combine equipped with the screw type threshing and separating mechanisms. *Paper* presented at the technical lecture meeting of Institute of Agricultural Machinery, 45–64 (1985) [In Japanese].

8) Rowland-Hill, E. W.: Twin rotor combine harnesses potential of rotary threshing and separation. *ASAE Paper*, 75-1580 (1975).
9) Saitama Prefectural Agricultural Experiment Station: Adaptability of a conventional combine for paddy. Paper presented at the conference on development and improvement of agricultural machines (1984) [In Japanese].

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