Development of a New Combine for Harvesting Soybean in Japan

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Recently, the areas planted soybean are increasing due to the implementation of a new national program, the Reorganization of Paddy Field Utilization, started in 1978. The cultivation of soybean to the fields converted from paddy fields has particularly increased. In regard to mechanical harvesting of soybean, Ichikawa et al. already presented three papers in JARQ[5-7] dealing with soybean reapers, threshers and combines. To promote soybean production, it is necessary to establish an efficient harvesting technique, especially with a system that can do cutting and threshing in one operation (combine harvesting).

Generally, the combine harvesting of soybean in Japan has to be done only under cloudy weather or in early morning or evening because varieties grown in Japan are not resistant to pod shattering which is liable to occur under less humid conditions. As a result, the threshing is done with plants of high moisture content. It causes several problems such as seed contamination with plant sap and soil.

Although the combine harvesting in Japan is being carried out experimentally, it still has not gained popularity throughout the country. In view of such a situation, the author attempted to develop a new compact soybean combine suitable to cultural conditions of soybean in Japan, particularly small field area, as a means of establishing the soybean harvesting technique.

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Soybean harvesting practices in Japan

An outline of soybean harvesting and post-harvest handling practices in Japan is shown in Fig. 1. (A) and (B) in Fig. 1 represent the major harvesting system of soybean. There are some reports[1,8,9,11] on combine harvesting in Japan because some trials were made by using foreign combines or Japanese ones designed for other crops. These head-feeding combine tested were found difficult to use for soybean and impractical due to large mechanical losses[10].

Problems related to combine harvesting of soybean

1) Characteristics of threshing

A significant problem found in combine harvesting is seed contamination. It occurs during the threshing of reaped plants with high moisture content. The mechanism for it is not clear. To solve this problem, characteristics of threshing of fresh crop plants were investigated[3,4]. Five types of threshers were examined to know their threshing performance and effect on product quality. When the threshing was made immediately after reaping, seed contamination was found with all the types of threshers. However, no contamination was detected, even immediately after reaping, when soybean plants over-matured or were dried by being left stand-

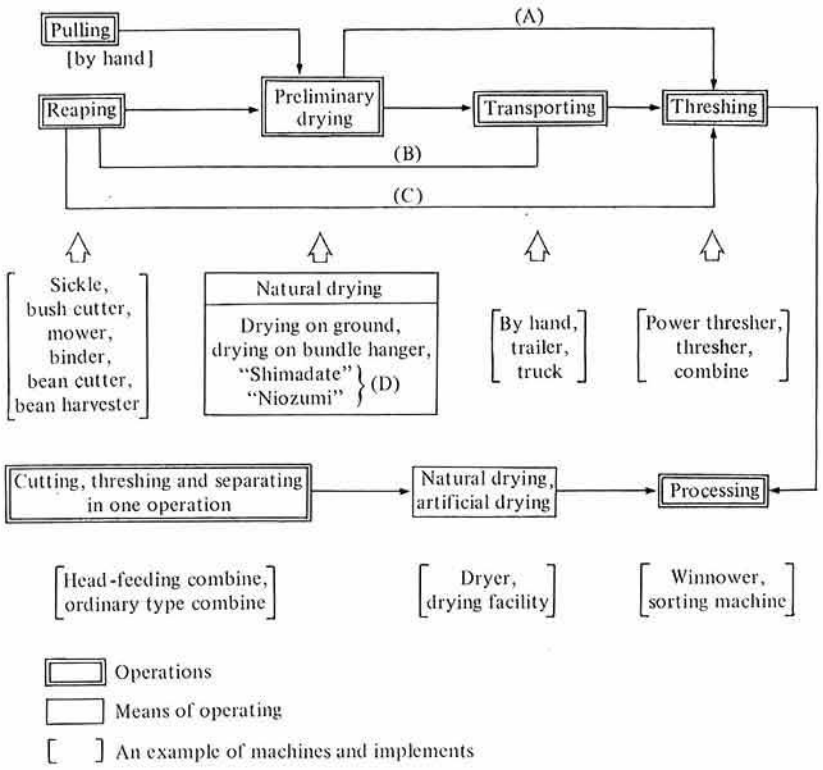


Fig. 1. Schematic illustration of the work sysem of harvesting of soybean in Japan

(A) The self-propelled soybean thresher is employed.

(B) Soybean plants are reaped in the field after reducing moisture content, and then threshed after transporting.

(C) As soon as soybean plants are reaped in the field, the self-propelled power thresher threshed them.

(D) Shimadate and Niozumi are traditional methods of drying crops.

Shimadate: Harvested plants (stalks and pods) are compiled as bundles, and left standing on the field.

Niozumi: Plants are piled up as large stacks.

ing on the field. Since pod moisture content influences the occurrence of seed contamination, the threshing must be done quickly to prevent the occurrence. For this purpose, the mechanical structure of the thresher should be simplified.

2) *Adaptation of the fine-cutting-threshing-in-one-operation system*

As soybean fields in Japan, particularly those converted from paddy fields are of small size, the use of large agricultural machinery is difficult.

In designing a soybean combine, the small size and compactness must be taken into account. To simplify the threshing mechanism, the "fine-cutting-threshing-in-one-operation system" with a disc type straw cutter (rotary cutter) in which, material is conveyed to the threshing unit and separating unit was tested experimentally. As shown in Fig. 2, the result indicates that the higher the moisture content of the seeds the higher the percentage of damaged seeds. It implies

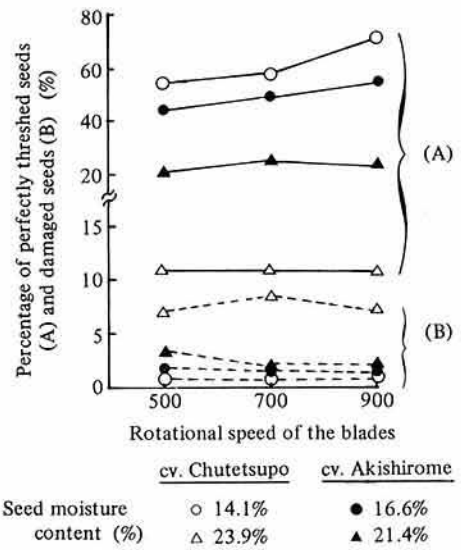


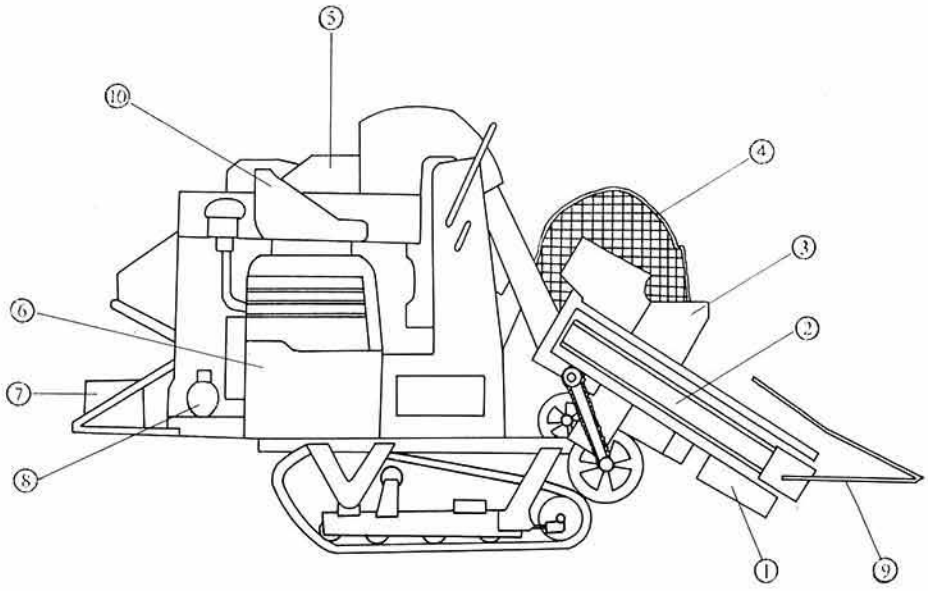
Fig. 2. Effect of seed moisture content on percent damaged seeds

that the percentage of perfectly threshed seeds without causing damage increase at low moisture content of seeds.

Trial construction of new soybean combines

1) Outline of trial construction

The head-feeding combine presently being used for rice and wheat was adopted as a prototype for the trial construction of compact soybean combines. Modification was made mainly in the manner of cutting, transporting and threshing unit. The "nokome-type edge" (saw-type edge) was found most suitable for the cutting unit from the standpoint of power requirement for cutting per unit cross sectional area of stalks and pod shattering ratio[2]. Therefore, the "nokome-type edge" was adopted in the trial construction. A preliminary field experiment showed that more seed loss occurred in a section in which material was conveyed to the fine-cutting and threshing (in one operation) units. In the trial combine No. 2, the two-step transporting unit including soft rubber belts and feed chains was used. In the transporting unit

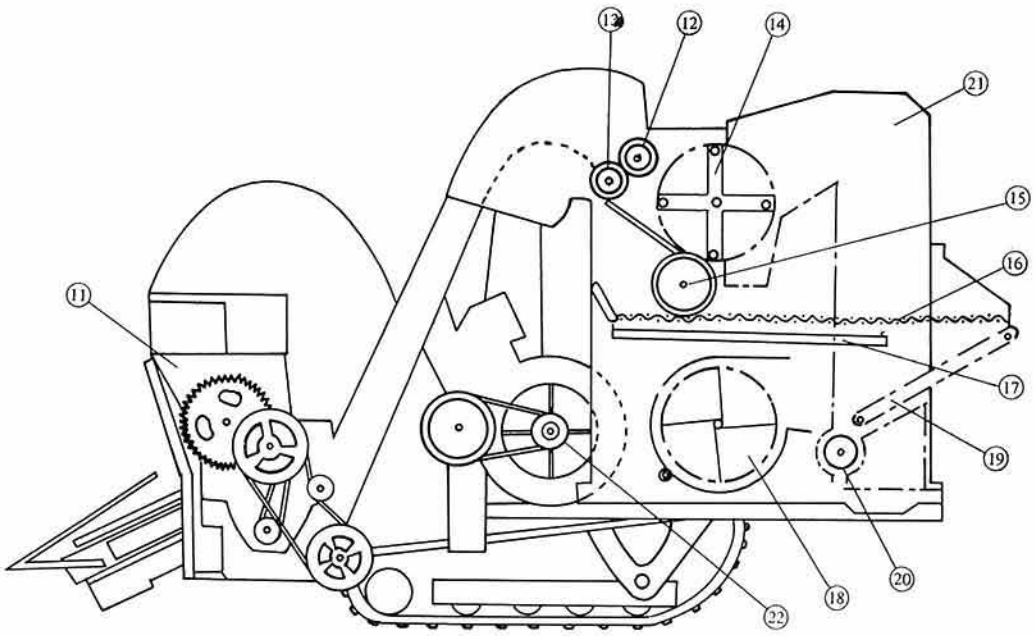


1. Cutting unit
2. Transporting unit
3. Fine-cutting and threshing unit
4. Protecting cover of bean scattering
5. Threshing unit
6. Engine
7. Outlet 2
8. Hydraulic pump
9. Side divider
10. Driver seat

Fig. 3. A side view of the trial combine No. 2

Table 1. Main specifications of the trial soybean combine No. 2

Overall dimension (mm)	Length: 3290
	Width: 1850
	Height: 1630
Total weight (kg)	970
Cutting unit	Cutting row: 1
	Cutter: "Nokome" type edge
Transporting unit	No. 1: Soft rubber belt
	No. 2: Feed chain
Fine-cutting and threshing -in-one-operation device	1: Disc cutter
	2: Two rubber rollers and four horizontal bars
	3: Cleaning fan, oscillating walker (grain pan) and separating belt
Engine output (kw)	4.8



11. Fine-cutting unit
12. Upper rubber roller
13. Lower rubber roller
14. Horizontal bars
15. Threshing cylinder
16. Crimp sieve
17. Small sized straw rack
18. Cleaning fan
19. Inclined separating belt
20. Screw auger
21. Bucket conveyor
22. Fan

Fig. 4. Cross-sectional view of the threshing unit and the separating unit (the trial combine No. 2)

for finely cut materials, a blowing system provided with a fan was adopted. As the threshing unit a commercially available soybean thresher which was partly reconstructed was employed.

2) The trial combine No. 2

The main specification of the machine are shown in Table 1, the outline of construction is in Fig. 3 and a detailed drawing in Fig. 4. Soybean plants cut with a two-rotary cutter were continuously transported to an upper position by two soft rubber belts ②, and to the fine-cutting unit ⑪ by the feed chain. The stalks and pods which were finely cut were partly threshed and transported to the threshing unit equipped with a fan. In the threshing unit, the materials were threshed by two rubber rollers ⑫ ⑬, friction between horizontal bars ⑭, and a threshing cylinder ⑮. They were separated by a crimp sieve ⑯, straw rack ⑰, cleaning fan ⑱ and separating belt ⑲. Seeds were collected in the clean bean outlet by the screw auger ⑳ and the bucket conveyor ㉑. The outlet 2 (immature seed outlet) ⑦ was situated under the separating belt. The immature seeds were collected in it.

3) Performance of the trial combine No. 2

Field tests were conducted on November 19, 1982. The material used was cv. Akishirome. The main stem length, standing angle, minimum distance between the pod and ground and stem thickness were 52.0 cm, 50 degree, 13.5 cm and 7.9–9.0 mm, respectively. A rough estimate of seed yield was 250 kg/10 a. Accuracy of the operation of the trial combine was evaluated as follows: the travel length of the combine was set at 10 m for collecting seed samples. The head loss in the cutting unit was determined. Unthreshed seeds and scattered seeds in the threshing and separating unit, and all seeds left unreaped were collected. Seed loss was calculated as the ratio of each sample weight to the whole quantity. Soybean seed quality was assessed visually. Seed contamination was so slight

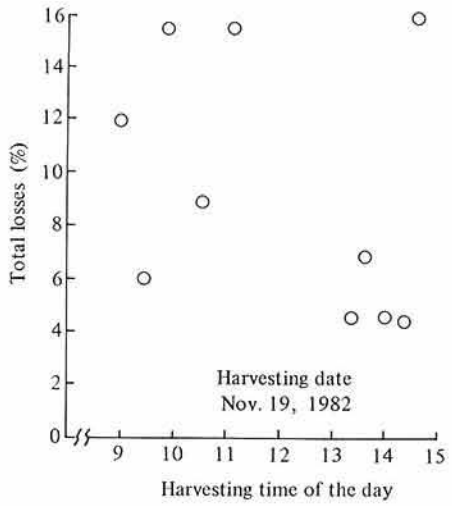


Fig. 5. Performance of the trial combine No. 2

even when spotted seeds were regarded as contaminated. The results showed that the head loss, stalk outlet loss and loss due to unreaped seeds were 0.6–9.2%, 1.3–10.7% and 0–5.2%, respectively, with the total loss amounting to 4.4–15.8% (Fig. 5). The percentage of damaged seeds of the outlets 1 and 2 was 2.7–5.0% in all. Seed contamination was so slight that only spotted beans were observed in the morning. The trial combine in operation is shown in Plate 1.

4) Performance of the trial combine No. 3

The trial combine No. 3 was constructed based on the trial combine No. 2, by newly adding the tailing-return device composed of an auger conveyor and a bucket conveyor. From the foregoing performance tests, it was shown that when the combine which consists of the fine-cutting unit and threshing unit is used, the harvesting must be done with less moist plants in order to reduce the occurrence of damaged seeds. Therefore, adaptability to soybean plants which had been exposed to natural drying in the field (over-matured plants) was examined with the combine No. 3. The results obtained with two cultivars, Akishirome and Tamahomare, showed heavy head loss (Fig. 6). The seeds collected at the

Plate 1. Harvesting test with the trial combine No. 2

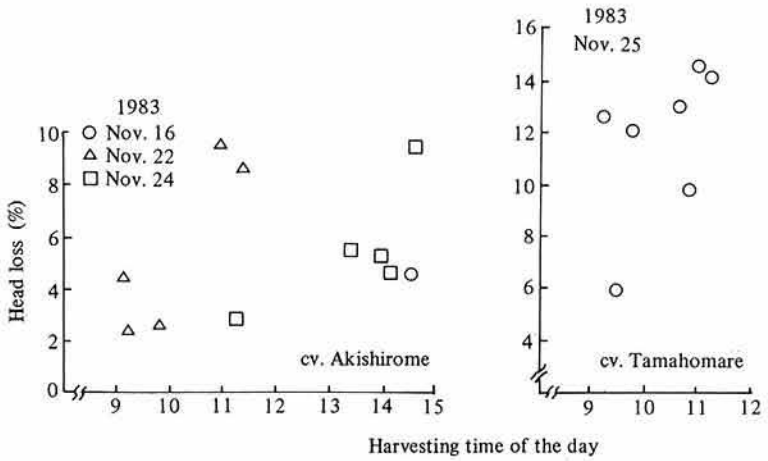


Fig. 6. Head loss shown by the trial combine No. 3 for over-matured plants

outlet 2 and at the stalk outlet were put together. It generally contained a high ratio of unthreshed and scattered seeds in the case of Akishirome and a high ratio of scattered seeds in the case of Tamahomare. The percentage of damaged seeds was 0.9–2.7% and 0.6–2.3% for Akishirome and Tamahomare, respectively. No seed contamination was observed.

Trial construction of the "all-in-one operation" harvester

A new type harvester with reaping, fine-cutting, and piling capability was constructed to decrease seed contamination and, to return soybean fields into bare ground after harvest, as efficiently as possible. The compact trial combines No. 2 and No. 3 were adopted as a prototype of the new type harvester. The modification was made mainly in both

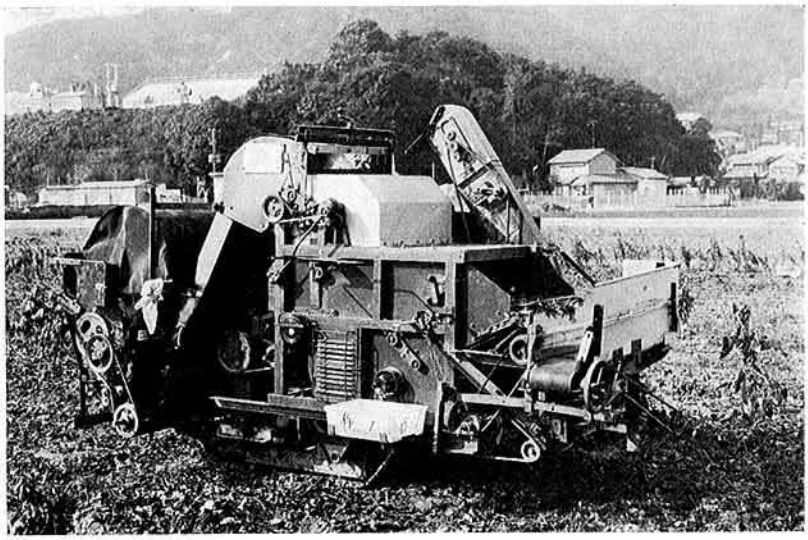


Plate 2. A rear view of the new type (all-in-one operation) harvester

fine-cutting unit and threshing unit. Plant materials which passed through the threshing unit were collected in the piling unit by a belt conveyor (Plate 2). This harvester gave a head loss of 0.8–4.4% and a total loss (head loss plus damaged seeds) of 3.6–7.7% for Akishirome. These values show only seed loss in the field, not including the loss by threshing and drying after harvesting. Though the performance of this new type harvester was not satisfactory enough, it was found that soybean fields were returned to bare ground very fast due to fine-cutting of reaped stalks.

Future problems

The purpose of the present study was to develop a combine system suitable for small soybean fields, particularly on uplands converted from paddy fields in Japan. The machine developed in the study gave satisfactory performances. However, the further study as well as improvement of its durability is required for the practical application. For the effective combine harvesting it is also necessary to develop soybean varieties resistant to pod shattering.

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