Soybean Cultivation with Shallow Tillage and Barley Straw Mulch in the Warm Shikoku District of Japan

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The right time for seeding soybean in the field which was converted from paddy fields in warm districts of Japan has been regarded as late June. However, at this time of the year, the Bai-u front (seasonal rain front) becomes active every year, frequently causing a long spell of rainy weather or heavy rain[2]. It makes the seeding of soybean impossible, or even when the seeding is made at a lull in the rain, the seed germination and emergence are seriously retarded by heavy rain after seeding, making it necessary to seed again in many cases.

The warm districts are favored with warm temperature and plenty of solar radiation, and summer comes early and autumn comes late. In other words, the crop season with enough temperature is long. Therefore, air temperature can hardly be a major limiting factor for the growth and yield of soybean. Instead, the precipitation and its distribution during the Bai-u season and the following midsummer season strongly influence the growth and yield of soybean.

The water requirement of soybean linearly increases during a period from about 10 days before flowering to 20 days after flowering. As this stage coincides with the midsummer in case of the standard cultivation of soybean in this district, it is apparent that the propriety or not of the water supply at this stage markedly determines soybean yields.

Furthermore, most of the cropping system in the warm district is double cropping a year, i.e., barley—soybean. It is currently observed in this system that barley straw is burned on the field prior to the planting of soybean. This practice causes a serious problem to the maintenance and improvement of soil fertility. In addition, there are other technical problems to be solved, such as bird damage and how to control weeds, in order to achieve stable, high-yielding production of soybean. To solve these problems, the study group organized in Shikoku National Agricultural Experiment Station has investigated the method of soybean cultivation including the utilization of barley straw, and developed a very promising cultural method with shallow tillage and barley straw mulch. The outline is presented in this paper.

Aims of the shallow tillage and straw mulch

The major aim of this new method of cultivation is to make good use of straw of barley, the preceding crop, and to stabilize soybean emergence in a target area of the total 5–10 ha of a group of farmers. To make good use of straw in the labor-saving, wholly mechanized cultural system, the straw is returned to the soil as organic matter. This practice improves physical property (water retentivity) of soil, and stabilizes soybean emergence. Considering that this can be done by harvesting barley with the combine, followed by removing the straw scattered over the field, seeding soybean, and then using the removed straw for mulching, a study has been

Plate 1. The newly developed machine for shallow tillage and straw mulching, composed of a belt type rake, a rotary planter, and a herbicide duster, mounted on a tractor

carried out to develop a farm working machine capable of doing all these operations at the same time. As the result, the machine having such functions was developed (Plate 1). The structure, methods of operation, and characteristics of this machine are shown in Figs. 1, 2, and 3. Plate 1 shows outer appearance of the machine, which is a compound farm working machine. It has the belt type rake (working width = 1.60 m) to collect the straw, which was scattered on the field at the time of the barley harvest by the combine, and spread it onto the field where soybean seeding by this machine is just finished. The rake is attached to the front of the tractor (23 ps). At the rear of the tractor, the shallow-tilling rotary planter (tilling depth = 5–12 cm, tilling width = 70 cm × 2 rows) for tillage, fertilizer application, seeding, and weeding is equipped. The process of operation is shown in Fig. 1. When this machine moves forward, the rake of the machine collects barley straw scattered on the field in front of the machine and throw it to the right. As the result, the rotary planter works on the soil surface without plenty of scattered straw. Otherwise, the planter incorporates much straw into the soil, resulting in reduced accuracy and efficiency of the operation, and low rates of emergency of soybean. After the tillage and seeding, herbicide granules are dusted. Thus, after the passage of the machine, the bare soil surface remains, but to which straw mulch is applied by that machine in the succeeding passage along the seeded area. Fig. 2 shows a vertical section of the soil surface layer after the seeding by that machine. The tilling depth is about 5 cm for the seeding portion, while it is about 12 cm for the furrow, with the difference of about 7 cm. By using the tillage-cover, the top of the row was made ca. 10 cm higher than the furrow bottom. The adoption of the shallow tillage for the seeding portion has advantages, as compared with the usual rotary tillage over the whole area, such as energy saving, increased efficiency of the work, and prevention of the wet injury of soybean by collecting surplus rain water in deep-tilled furrows. The structure of the rotary planter for the shallow tillage is given in Fig. 3.

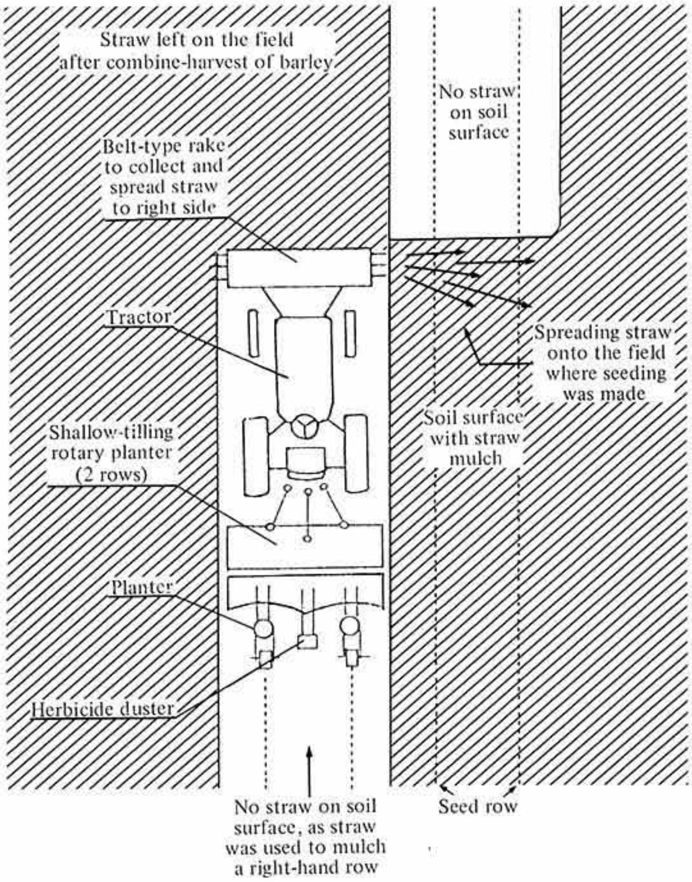

Fig. 1. Structure and functions of the newly developed machine

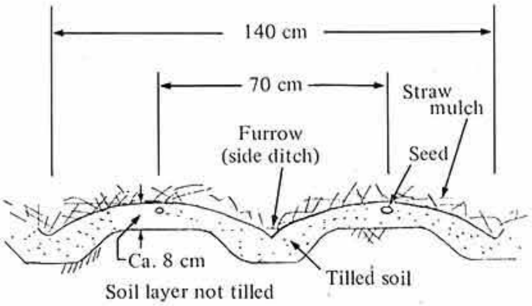

Fig. 2. Soil profile after seeding
Distance from soil surface to seeds (soil cover) : ca. 3 cm.
Distance from seeds to the bottom of tilled layer : ca. 5 cm.
Difference in the bottom of tilled layer between rows and furrows : ca. 7 cm.

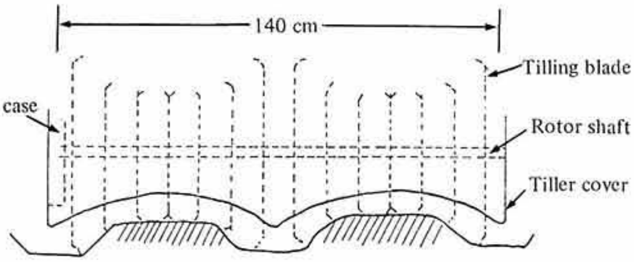

Fig. 3. Tilling blades of the rotary planter for shallow tillage

Characteristics and effects of the shallow tillage — straw mulch cultivation

The characteristics of the soybean cultivation using the machine for shallow tillage and straw mulching are as follows:

1) The function of the belt type rake is to make smooth and efficient disposal of a large amount of barley straw.

2) As the straw is applied as the mulch onto the soil surface, after seeding soybean, it exerts weed-control effect.

3) The straw mulch is effective in preventing excessive drying of the soil under continuous fine days. It also prevents crust formation of gray lowland soil widely distributed in Shikoku district. The crust obstructs soybean emergence.

4) As the straw is not incorporated into the soil, the seeder can work with high accuracy. In addition, due to the shallow tillage of the seeding portion, the tractor runs fast with high working efficiency.

5) Not only the soil surface shows high rows and lower furrows, but also the depth of tillage is shallow for the row and deep for the furrow, so that surplus rain water accumulates in the bottom of the furrow (side ditch). Even in the Bai-u season, the soil around the sown seeds is kept in favorable soil moisture condition.

By this method of cultivation, the amount of straw as much as more than 600 kg/10 a, left on the field, can smoothly be disposed as the mulching material, and the shallow tillage increased the working efficiency by about two times that of the conventional tillage on the whole area of the field. Furthermore, straw mulching enabled rapid and uniform germination of soybean seeds, resulting in the rate of emergence higher than 95%. Thus, the emergence was markedly stabilized. The rate of evaporation from the soil surface was found to be reduced to only about 15% by the straw mulch (800 kg straw/10 a) in a fine day. This fact indicates that the seedbed soil covered with the mulch is not dried so fast as bare soil, even under a long spell of fine weather, so that it can maintain moderate soil-moisture for a long period from

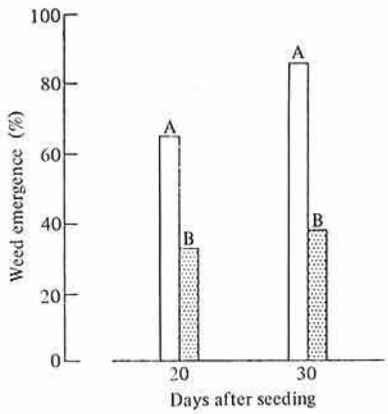

Fig. 4. Effect of straw mulch on the emergence of crabgrass
The number of emerged crabgrass is expressed in % to that of the control (without mulch).
A: 400 kg straw/10 a of mulch.
B: 800 kg straw/10 a of mulch.

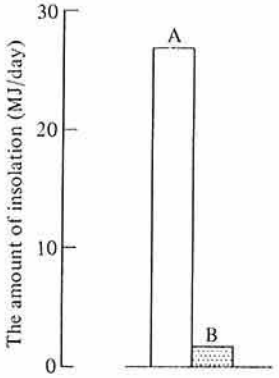

Fig. 5. Intensity of solar radiation on bare soil surface and under straw mulch (800 kg/10 a) in a fine day (June 18)
A: Bare land.
B: Under mulch.

sowing to emergence of soybean. On the other hand, the mulch prevents raindrops from directly hitting the soil surface, so that hard soil crusts are hardly formed. It facilitates and stabilizes the emergence.

Another effect of straw mulch is weed control. Fig. 4 shows the number of emerged crabgrass (*Digitaria sanquinalia* L.) in the plot without mulching, and the plots with mulching (800 kg straw/10 a and 400 kg straw/10 a). The effect of mulching to suppress weed emergence is apparently shown. The mulching with 800 kg of straw/10 a reduced the solar radiation reaching the soil surface by about 7% of that of bare soil, and daily maximum temperature lowered by about 9°C. Such an environment on the soil surface seems to inhibit the emergence and initial growth of the weed. From this result, it is considered that, in usual soybean fields, the adoption of some agronomic measures for weed control during the period until the soybean plants grow large enough to reduce the solar radiation reaching the field soil surface by less than 10% of the full radiation is an important factor for getting high yields of soybean[1]. As mentioned above, the effect of straw mulch to control crabgrass was good enough, show-

Table 1. The wholly mechanized system of cultural operations, based on the shallow tillage and straw mulching

(Target: soybean yield 400 kg, labor hours 15 hr/10 a)

Operations	Working date	Materials & quantity	Machine used	Time required in field (hr/10a)	Number of persons	Total labor hours (hr/10a)
Tillage+seeding +weeding+mulching	Jun. 13	Satan Valor granular 4.0 kg/10 a	Belt type rake, Rotary planter, and Tractor (23 ps)	0.58	2	1.16
First intertillage +basal dressing	Jul. 14	Kumiai Kasei No. 13 85 kg/10 a	Riding type multiple-row crop-management machine	0.58	2	1.16
Second intertillage +top dressing	Jul. 19	LP-urea (70 day type) 28 kg/10 a	〃	0.58	2	1.16
Pest control						
(1)	Aug. 2	Parmation 1000 double solution 150 ℓ/10a	Power sprayer	0.11	3	0.33
(2)	Aug. 11	〃 〃	〃	0.11	3	0.33
(3)	Aug. 21	〃 〃	〃	0.11	3	0.33
(4)	Aug. 28	Kelthane emulsion 〃	〃	0.11	3	0.33
(5)	Sept. 8	EPN emulsion 〃	〃	0.11	3	0.33
Harvesting	Nov. 10		Combine for soybean	0.75	2	1.50
					Total	6.63

Variety: Akishirome, 3.8 kg/10 a.

Plate 2. Intertillage and ridging with the riding type multiple-row crop-management machine

ing that it is satisfactory agronomic measures. However, the large increase in the number of weed emergence observed in 10 days, from 20 days to 30 days after seeding (Fig. 4) indicates the need of intertillage to be practiced during that period mainly aiming at weed control.

The farm working system of the soybean cultivation with shallow tillage and barley straw mulch, which has many advantageous characteristics, as mentioned above, is given in Table 1. This is the system used in the demonstration test of the integrated cultural system using a variety Akishirome. The seeding operation, which achieves everything of straw removal, row-and-furrow formation, seeding, herbicide application, and straw mulching at the same time, required 0.58 hr/10 a (for works only in the field). Crop management practices, such as basal dressing and top dressing of fertilizer, intertillage*, ridging, etc., were done using the riding type multiple-row crop-management machine (Plate 2), and which required 0.58 hr/10 a × 2 times = 1.16 hr/10 a. For pest control, a power sprayer was used and 0.11 hr/10 a × 5 times = 0.55 hr/10 a was required. For harvesting (a combine for soybean is used) and post-harvest handling, 0.75 hr/10 a was required. Each of these works was done with 2 or 3 workers. Therefore the total labor time was 6.63 hr/10 a.

The basal dressing has to be done at the time of the first intertillage but not at the time of seeding, because 1) the seeding in mid June must be done as quickly as possible under the climatic condition of Bai-u season, and 2) to prevent soybean plants from overgrowth (excessively luxuriant growth), which is a problem specific to the warm area, particularly when early seeding is made (seeding in mid June is early seeding). However, the first intertillage should not be delayed. It should be done within 20 days after seeding.

In the conventional soybean cultivation, ammonium sulfate is applied as top dressing at the flowering stage. But in the wholly mechanized system of cultural operations including the shallow tillage and straw mulching, it is impossible to put any machine into the field at this stage. Therefore, a slow-release fertilizer, LP-urea of the 70-day type, is applied at the time of the second intertillage. In this case, the second intertillage must be done at the stage when root-breaks caused by the intertillage do not exert adverse effects on flowering and pod-setting, i.e., it must be done by two weeks prior to the flowering.

The cultural system described in the present paper enables to get soybean yields of 350–400 kg/10 a with stability.

* Hereafter intertillage and ridging is simply refered to intertillage, as intertillage is always followed by ridging.

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