Development of Soybean Rolling Injection Planter

Rattana Karoonboonyanan*, Nopparat Seehawong and Kadit Kwrangtrakul

Department of Mechanical Engineering, Faculty of Engineering, Naresuan University, Phitsanulok 65000, Thailand.
*Corresponding author. E-mail address: rattanakar@nu.ac.th (R. Karoonboonyanan)
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Abstract

This project was designed to develop a soybean rolling injection planter mounted on a power tiller to be used in untilled fields from which paddy had just been harvested without burning. The planter was modified from a double row of rolling injection planter operated by human power. The modified prototype had an increase in length of puncher from 6.5 cm to 8.5 cm that can penetrate the soil of a field with rice straw. The prototype dimensions were 100 cm in width, 94 cm in length and 52 cm in height. It was a double row seeder with variable inter-row spacing of 30 to 75 cm and hole-to-hole spacing of 20 to 30 cm. The prototype was set with an inter-row spacing of 50 cm and the hole-to-hole distance of 25 cm. It was tested in an untilled field after harvesting rice. The field capacity of the planter was 0.12, and 0.15 ha/h at traveling speeds of 1.4, and 1.7 km/h, in field with unburnt and burnt straw, respectively. The corresponding field efficiencies for the two fields were 86% and 90%, respectively. The fuel consumption rate was 4 liter/ha. The seed application rate was 56 to 69 kg/ha. Seed damage rate by the planter was 1.5%. The break-even area for planter compared with the traditional method was computed to be 0.7 ha.

Keywords: Soybean planter; Rolling injection planter; No-tillage planter; Direct drilling machine

INTRODUCTION

The conservation tillage system is defined as "any tillage or seeding system that maintains a minimum of 30% residue covering on the soil surface after planting or maintains at least 1100 kg/ha (1000 lb per acre) of flat small-grain residue equivalent on the soil surface during the critical erosion period" (American Society of Agricultural Engineers, 2000a). Tillage is a major operation, which significantly contributes to the total cost of soybean production (Shukla et al., 1990). Conservation tillage, especially no-tillage, is one of the possibilities to reduce the cost of soybean production (Hernanz et al., 1995) while maintaining the yield level (Virakul, 1992). In Thailand, it was estimated that land preparation was 19.5% of the total cost of soybean production (Chamsing, 1996). Sonkam (2001) conducted experiments to evaluate the operation cost for planting soybean in four different methods: 1) conventional tillage (plowing, harrowing and broadcasting); 2) no-tillage (broadcasting without land preparation); 3) direct seeding by inverted-T seeder; and 4) direct seeding by double-disk opener type seeder. Compared to the convention tillage method, the operation cost was reduced by 92% for no-tillage, 43% for inverted-T seeder, and 68% for double disk opener type seeder. The conservation tillage had the advantages of increased yield, reduced labor and farm fuel requirement, and improved water management compared to conventional tillage (Tesatthaburt & Smitobol, 1989). Swan et al. (1996) found that the surface residue reduced soil heat accumulation by reducing soil heat flux and conserved soil water by reducing evaporation rate, and reduced weeds (Sonkam & Sing, 2003). Also as stated by Prior et al. (2000), increased losses of CO_2 and water vapor were directly related to the increase in soil disturbance. They suggested that selecting planting equipment that maintained surface residue and minimized soil disturbance could help to conserve soil and water needed for successful seedling establishment. The percentage of seed emergence was found to be higher under direct drilling method than in broadcasting (Sonkam, 2001).

The no-till seeding implements mounted on a power tiller for soybean seeding, commonly used in Thailand, were the inverted-T seeder and the double disk furrow opener (Udom-Anusorn, 1989). Sonkam (2001) conducted experiments in the unburnt field and found that the straw got stuck in the front of the inverted-T furrow opener and prevented the seeds from being drilled into the soil. On the other hand, the double disk furrow opener could not sufficiently penetrate into the soil in the excessively thick straw covered area. The rolling injection planter is one of the possibilities that can solve this problem. International Rice Research Institute (IRRI) developed the IITA-IRRI rolling injection planter, which penetrated the soil opener through residue and left the seeds into the soil. However, the IITA-IRRI rolling injection planter was operated by human power and was labor-intensive.

The direct drilling machine has many advantages in reducing production costs, but it still needs some modifications for effective utilization in rice straw covered field. To investigate this, this study modified the manually power rolling injection planter to one power by a power tiller and used it in an untilled field with rice straw covering.

MATERIALS AND METHODS

The rolling injection planter

IITA-IRRI rolling injection planter operated by human power (Figure 1) was designed for seeding in fields with zero tillage. The process could be divided into three steps: 1) drilling, 2) seeding and 3) hole closing. During the drilling step, the opener was attached to the puncher by the action of the opener counterweight while the puncher penetrated into the soil. The hexagonal, rather than circular, shape of the planter provided impact force in this step. Seeding was done by the splitting action of the opener and the puncher when the seeds from the hopper were dropped into the holes through the metering device. After being seeded, the holes were closed by a narrow press wheel. The planter could seed six holes in one revolution.

The IITA-IRRI rolling injection planter was preliminarily tested in the field and found that the 6.5-cm long puncher were to short to penetrate the soil, due to the thick layer of rice straw covering on the field. Another important problem was that the weight of the machine was so low that it could not penetrate the soil sufficiently.

The planter was modified to be mounted on a power tiller (Figure 2). The prototype was 100-cm wide, 94-cm long and 52-cm high. It was a double row planter with variable inter-row spacing of 30 to 75 cm, varied by adjusting the sleeve arrangement. The puncher was increased in length from 6.5 cm to 8.5 cm, to enable it to penetrate the unburnt rice straw and reach the soil. The hole-to-hole spacing could be adjusted from 20 to 30 cm by changing the diameter of the metering wheel. The metering roller with brush-off was designed for three to five seeds of soybean for each hole with 12-mm diameter and 6.5-mm depth – 6 holes for each roller. The capacity of the seed hopper was 4 kg for each roller.

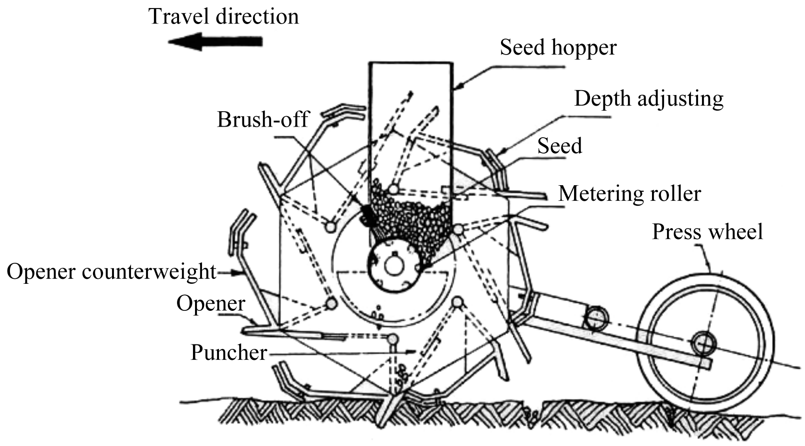

Figure 1. The mechanism of IITA-IRRI rolling injection planter (Krishnasreni, 1997).

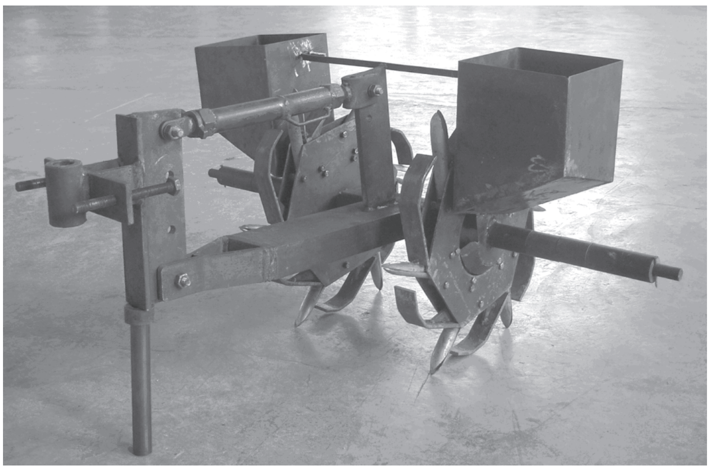

Figure 2. Soybean rolling injection planter for mounting on a power tiller.

Experimental procedure

The experiment was carried out at a field in Phitsanulok Province, Thailand. The experimental site was previously under rice cultivation and harvested by a combine harvester. After the rice crop was harvested, two straw managements were applied: 1) burnt rice straw, and 2) straw as left by the combine harvester. Straw that still remained on the field was collected from a sample area of 1x1 m^2, with three replications for each field, to determine the straw yield. It was analysed after drying in an oven at 103 ^oC for 24 h as per ASAE S358.2 (American Society of Agricultural Engineers, 2000b).

Soil samples were collected to determine the soil moisture content and the soil bulk density. Soil samples were taken randomly from 0 to 5 cm and 5 to 10 cm soil depths; three samples were collected from each plot. Weight of the soil was first recorded. Then the soil was dried at 110 5 ^oC for 24 h as per ASTM D2216-90 (American Society for Testing and Materials, 1991); thereafter the dry weights were recorded. The soil moisture content and soil bulk density were calculated from this data. The soil penetration resistance was measured on the day of planting by using pocket penetrometer CL-700A that measured at 7 mm of soil depth.

Soybean seed was Chiang Mai 60 variety. Germination percentage was 81% and hundred-seed weight was 12.7 g. Emergence data were recorded by counting the number of seedling emerged compared with the total number of seeds dropped in holes along a 60-hole continuum, 10 rows of each treatment.

The soybean rolling injection planter was tested in the laboratory to determine the seed application rate and seed damage rate by the planter. Also, it was tested in the field with the inter-row spacing of 50 cm and the hole-to-hole distance of 25 cm (Figure 3). The field capacity, field efficiency and fuel consumption were recorded.

Economics analysis was carried out from the fixed cost of power tiller and the operating cost of the planter. The break-even area for soybean rolling injection planter was then calculated.

RESULTS AND DISCUSSION

General observation of the experiment

It was observed that in the burnt straw plots, the stubble was not completely burnt. The rice straw residue dry matter was 1.5 ton/ha and 9.6 ton/ha in burnt and unburnt field, respectively.

The soil physical properties are shown in Table 1. The burnt straw plots had higher soil penetration resistance and lower moisture content than the unburnt ones. This agreed with the conclusion by Phillips &Young (1973) and Borressen (1999) that the mulch could reduce evaporation substantially.

The rolling injection planter was set at the hole-to-hole spacing of 25 cm and 3 to 4 seeds per hole. The data (Table 2) shows that the hole-to-hole spacing was lower than the design, which may be due to wheel slip. The wheel slip was 9.2% and 4.0% in burnt and unburnt rice straw field, respectively. The operating depth ranged from 3 to 5 cm that was suitable for soybean planting. The recommended number of seeds per hole for Chiang Mai 60 soybean was three to five. It was found that only 43.6% of holes in the burnt field contained three to five seeds compared with 62.6% in the unburnt field. The most plausible underlying reason was the obstruction of soil in the puncher while opening the burnt field.

The performance test of rolling injection planter was recorded and shown in Table 3. In the unburnt plots, the traveling speed and the fuel consumption the power tiller was lower than burnt ones. The seed rate and field efficiency was found higher in the unburnt plots. The percentage of emergence was not well justified because the field received rain about three days after planting and was flooded, which highly impaired the germination.

Figure 3. The rolling injection planter being tested in the field.

Table 1. The soil physical properties

	Soil penetration resistance (kPa)	Soil moisture content (% db)		Soil dry bulk density (g/cm^3)	
		0-5 cm soil depth	5-10 cm soil depth	0-5 cm soil depth	5-10 cm soil depth
Burnt straw	220.0±2.6	51.0±1.7	41.4±2.2	0.9±0.0	1.2±0.0
Unburnt straw	77.3±1.4	55.2±2.7	51.6±2.2	0.9±0.0	0.9±0.0

Note. Data represent mean±SEM.

Table 2. The operating data of rolling injection planter

	Hole-to-hole spacing (cm)	Operating depth (cm)	Number of seed per hole (seeds)	Percentage of emergence (%)
Burnt straw	22.7±0.0	4.5±0.0	2.6±0.1	61.6±6.0
Unburnt straw	24.0±0.0	4.2±0.0	3.5±0.1	59.6±3.2

Note. Data represent mean±SEM.

Table 3. The performance of rolling injection planter

	Travel speed (km/h)	Seed rate (kg/ha)	Fuel consumption rate (liter/ha)	Field capacity (ha/h)	Field efficiency (%)
Burnt straw	1.7±0.0	57.5±4.8	4.3±0.3	0.1±0.0	86.3±0.0
Unburnt straw	1.4±0.0	71.2±2.4	3.8±0.4	0.1±0.0	90.2±1.0

Note. Data represent mean±SEM.

Economic analysis

Based on the performance of the rolling injection planter operating in the unburnt field, the cost analysis was calculated and compared with the manually operated AIT-Jab seeder (Sing & Kaewprakaisangkul, 1991). The brake-even area was 0.7 ha.

CONCLUSIONS

Based on the experiments conducted in a rice field, the following conclusions could be drawn:

1) Compared to the burnt rice straw field, the unburnt field had higher soil moisture content and lower soil penetration resistance.

2) Higher field efficiency was found in unburnt field compared with that in the burnt field.

Additionally, it was observed that the soybean rolling injection planter mounted on a power tiller can work in the paddy field harvested by a combine harvester and straw covering the field without removing or burning it. The thick layer of straw may entangle with the hexagonal plate wheel, and soil clods can obstruct the puncher. Further investigation to reduce this straw problem by using rolling puncher should be conducted.

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