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Development of a Belt Pick-up Type Two-row Sesame Reaper

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Abstract

Purpose: *The purpose of this study is to develop a walking-type two-row sesame reaper, which can simultaneously perform the cutting and collecting of sesame plants and other crops like perilla and soybean.* **Methods:** The factors involved in reaping sesame were determined experimentally in order to design a prototype of the sesame reaper. The prototype is made up of four parts for cutting, conveying, collecting, and running. The height of two disc-plate saw blades on the cutting part is adjusted by an adjusting wheel, and peripheral speed is adjusted in accordance with the running speed. The conveying belt of the conveying part can be tilted from 0° to 90°. The collecting part extracts a predetermined amount of transferred sesame plants. The prototype was used to evaluate the performance at different working speeds, so that the work efficiency can be calculated. **Results:** The center of gravity of the sesame plants was 900 mm, measured from the end of the cut stem. The diameter of the disc-plate saw blade was determined to be 355 mm, peripheral speed was 20.4–32.7 m/s, and the picking height of the conveying belt for sesame was 130 mm. The performance of transfer and collection of the sesame, when the insertion angles were 60° and 90°, proved to be excellent. However, when the angle was over 120°, the performance was only 75-80%. The performance was at 100% efficiency when the ratio between running speed and conveying belt speed of the prototype was 1:2, which seems to be the ideal ratio for the sesame reaper. **Conclusions:** A sesame reaper was developed, which can integrate the processes of cutting, conveying, and collecting, by investigating and considering various factors involved in the reaping process. The sesame reaper can reduce the costs for yielding and producing sesame due to its highly efficient performance.

Keywords: Crawler, Harvest, Pick-up belt, Reaper, Sesame

Introduction

The demand for sesame is constantly increasing, but cultivated areas have decreased by approximately 43.3% from 44,331 ha in 2000 to 25,139 ha in 2015 (Kosis, 2016). Sesame imports have also increased from 70,000 to 77,000 tons/year since 2000 while unit prices rose by approximately 257% from $0.7 /kg in 2000 to $1.8 /kg in 2015 (Kati, 2016). Likewise, while the demand and price of imported sesame is constantly rising, the self-sufficiency rate of domestically grown sesame has fallen to as low as less than 20%. Therefore, improving the self-sufficiency of domestically grown sesame is essential (Jun et al., 2012).

The scale of sesame cultivation is small, approximately 0.16 ha/farm. Labor costs account for approximately 58.3% of total production costs since most cultivation work relies on manual labor. To stabilize the self-sufficiency of domestically grown sesame and reduce labor costs, mechanized sesame cultivation is required.

Machines such as reaper binders, threshers, and grain selectors (Noh, 2014) have been developed for harvesting sesame (Lee and Kim, 2009; Lee and Noh, 2015). Among these machines, the reaper binder is available as a walking-type two-row binder with a rated output of 3.4 PS, which is used for harvesting rice. However, this reaper binder

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cannot be applied to sesame crops inclined at an angle of less than 60°. The force applied by the cutter bar also causes threshing loss (Lee et al., 1997). While a single-row bean reaper (Jun et al., 2006; Jun et al., 2008) is available in the market, a two-row bean reaper has yet to be commercialized because of unstable operating performance (Jun et al., 2011).

A walking-type bean reaper has been developed that extracts a predetermined amount of beans to the side of the machine after cutting, so that reaping is carried out while the machine turns around from the edge to the inside (Ichikawa et al., 1981; Sugiyama et al., 1981). In other countries, the combine harvester is the most widely used for harvesting sesame. In Korea, the development of machines for small-scale sesame farming is needed. Therefore, in this study, a sesame reaper for small-scale farms was developed that can improve harvesting efficiency by integrating the processes of cutting, conveying, and collecting.

Materials and Methods

Cultivating pattern and agronomic characteristics

The cultivating pattern for sesame is shown in Figure 1, featuring two-row cultivation on a flat-bed ridge. The ridge and furrow widths are 800 mm and 400 mm, respectively, and covered with a vinyl film. The row and hill spacings are 300 mm and 400 mm, respectively.

Table 1 lists the agronomic characteristics of sesame. The length of the Ansan species is 1800 mm, with the center of gravity approximately 900 mm. The length of both the Sunheuk and Pyeongan species is 1250 mm, with the center of gravity ranging from 600-660 mm. The results show that the growth of sesame was greatly influenced by climate. Therefore, to continuously pick up and transfer the sesame with long plant lengths, an auxiliary conveying belt is required to support the process. The height at which the auxiliary conveying belt should be installed is approximately 900 mm from the main conveying belt, so that the auxiliary transfer can maintain the same height as the conveying belt, when the sesame is picked up and transferred by the conveying belt.

Stability test for tilted conveying belt

A stability test of the conveying belt was conducted, as shown in Figure 2, when the sesame was transferred while the conveying belt was titled 90°, just like the single-row bean reaper (Jun et al., 2006; Jun et al., 2008; Jun et al., 2010). The stability test investigated the performance of the conveying belt, considering factors such as the distance (D) from the center of the roller (B), and the grabbing clearance between the

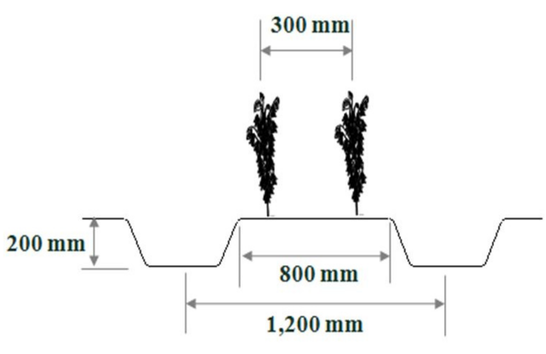

Figure 1. Cultivating pattern for sesame.

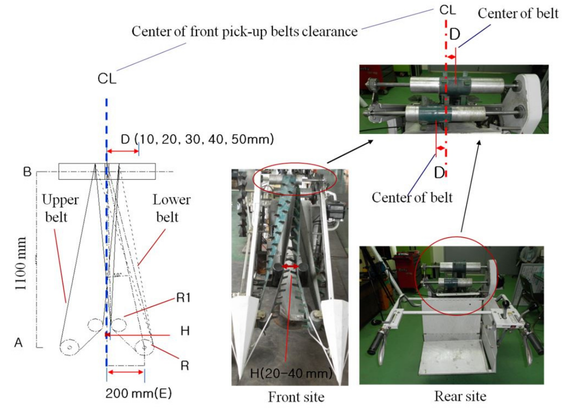

Figure 2. Stability test for twisted conveying belt.

Table 1. Agronomic characteristics of sesame

Species	Agronomic characteristics			
	Plant length (mm)	Plant Weight (kg)	Diameter of stem (mm)	Center of gravity (mm)
Ansan	1800±130	0.23±0.03	20±3	900±70
Sunheuk	1250±120	0.16±0.03	13±2	660±70
Pyeongan	1250±80	0.16±0.03	14±2	600±50

conveying belts (H), when the acquisition belt (R) of the conveying belt was spaced 200 mm (E) away from the center of acquisition. The distance between roller A and roller B was 1100 mm.

Manufacture of prototype

The prototype sesame reaper was designed to fit the flat-bed ridge, which is the most common cultivating pattern for sesame. The prototype is composed of cutting, conveying, collecting, and running parts, as shown in Figure 3. Its specifications are listed in Table 2.

The cutting part consists of guides for feeding sesame plants into the disc saw blades and two disc-plate saw blades. The cutting part was mounted with adjustable wheels on both sides so that cutting height can be adjusted in accordance with the ridge height for cutting the sesame. The diameter of the disc-plate saw blades used was 355 mm, based on the cutting position and peripheral speed (Jun et al., 2010). The peripheral speed of the saw blades can be changed depending on the running speed of the reaper, ranging from 20.4-32.7 m/s.

The conveying part comprises a pair of conveying belts for transferring the sesame severed by the cutting part to the collecting part, and an auxiliary conveying belt for supporting the topside of the sesame being transferred. The shape of the conveying belt is shown in Figure 4, which prevents the loss of sesame plants. As shown in Figure 5, the sesame can be picked up by the conveying belt as soon as the crop is severed, at a height of 130 mm from the bottom (Jun et al., 2010). The collecting part

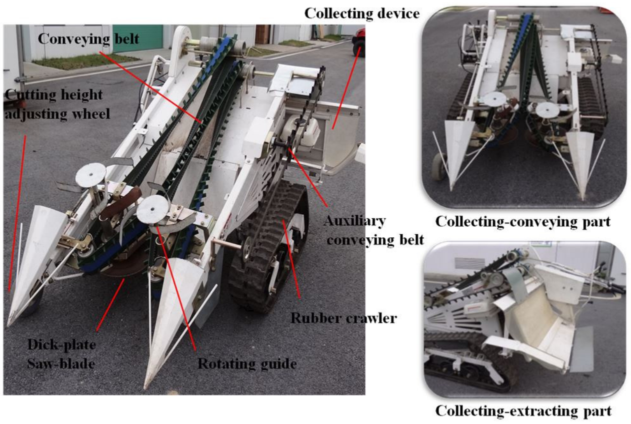

Figure 3. Prototype structure.

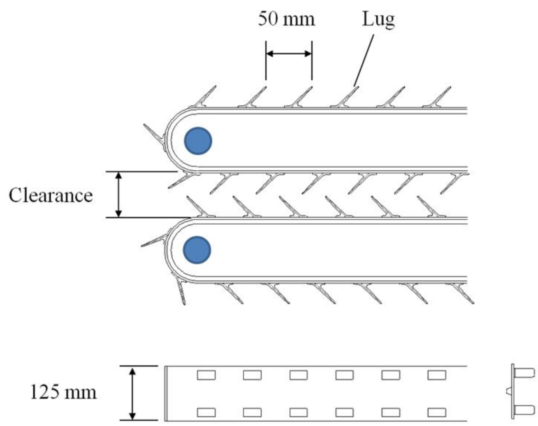

Figure 4. Shape of conveying belt.

Table 2. Prototype specifications

	Item	Specification
	Total size, mm (L × W × H)	2,800 × 1,300 × 1,200
	Total weight, kg	404
	Engine type and Power	Gasoline, 4.8 kW
Disk-plate saw blade (metal tipped)	Diameter, mm	355
	Thickness, mm	2
	Number of teeth	80
	Rotating peripheral velocity, m/s	20.4–32.7
	Cutting height, mm	0–300
Conveying belt	Width/Lug length, mm	125/30
	Tilt angle of conveyor, °	30–35
	Speed ratio (travel: conveying belt)	1:2
	Length of Auxiliary conveyor, mm	1,300 (Lug type V-belt 2ea)
Collecting device	Size, mm (L × W × H)	385 × 900 × 485
Running device	Crawler size, mm (L × W)	900 × 180
	Distance between crawlers, mm	1,000
	Travel speed, m/s	0.15–0.5
	Transmission stage	forward 2, reverse 2

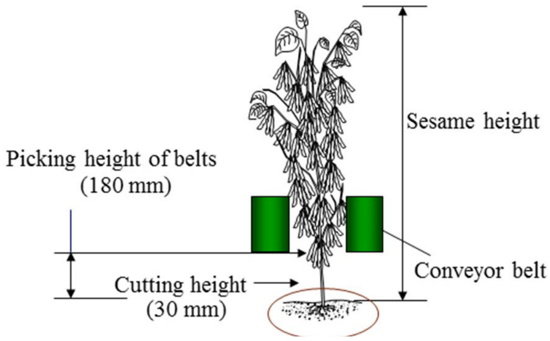

Figure 5. Picking height of conveying belt.

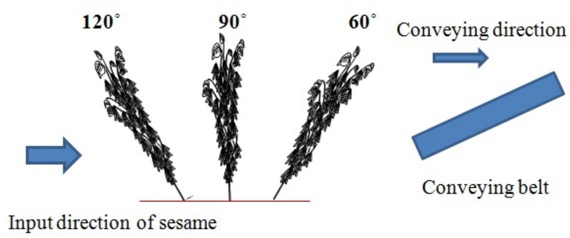

Figure 6. Input angle of sesame into conveying belt.

extracts a predetermined amount of sesame, continuously, and the determined amount is charged. The running part is a crawler type, which facilitates the running.

Performance test of prototype by changing the insertion angle of sesame

The performance at different angles for inserting sesame plants into the conveying belt was measured. The angles at which sesame plants were inserted into the conveying belt were 60°, 90°, and 120° from the ground, as shown in Figure 6. The conveying rate based on the number of sesame plants inserted into the conveying belt (as one stem and two stems) was also measured. The conveying rate, which is the total number of sesame plants collected divided by the total number of sesame transferred to the conveying belt, was calculated using Eq. (1).

$$\text{Conveying rate (\%)} = (\text{number of sesame transferred}/\text{number of sesame inserted}) \times 100 \quad (1)$$

Field performance

A field performance test was conducted to evaluate the cutting and transfer performance as well as the operating efficiency of the prototype at different working speeds. The running speeds of the prototype ranged from 0.16-0.51 m/s while the speeds of the conveying belt were 0.6 and 1.0 m/s. The ratios between the running speed and the speed of the conveying belt during the test were 1:2 and 1:4 (Table 3). Therefore, the field test was conducted at four levels by measuring the cutting rate and transfer collection rate in order to evaluate the performance of the prototype at different working speeds.

Table 3. Speed ratio between working speed and conveying belt speed

Working speed (A), m/s	Conveying belt speed (B), m/s	Speed ratio (B/A)
0.16 0.24	0.6 1.0	1:4
0.30 0.51	0.6 1.0	1:2

Table 4. Work stability according to the distance between the tilted conveying belts

Grabbing clearance of belts (mm)	Distance between the centers of conveying belts (D)(mm)					
	0	10	20	30	40	50
20	×	○	○	○	○	×
40	○	○	○	○	○	○

Footnote : ○ Fine performance of conveying belt, × Conveying belt deviated

The field test of the prototype was conducted at the maximum working speed of 0.51 m/s. During the test, the ridge width was 1100 mm, field length was 100 m, and turning time was 20 s.

The effective field efficiency of the prototype (Ce) was calculated using Eq. (2). The field efficiency (E_f) considered the moving time for the next phase of cutting, assuming that the length of a cutting lane was 100 m.

$$Ce = 0.36WVE_f \quad (2)$$

where,

Ce = Effective field capacity of prototype, ha/h
W = Working width of prototype, m
V = Working speed of prototype, m/s
E_f = Field efficiency (0.89)

Results and Discussions

Stability of conveying belt

The test on the performance of the conveying belt showed that the performance stability deviated when the distance

(D) between the centers of each conveying belt was 0-50 mm, and the grabbing clearance of the conveying belts were 20 mm and 40 mm (Table 4).

The optimal distance at which the rugs of the conveying belt did not overlap was determined as 20 mm. The suitable grabbing clearance was also determined as 30 mm, considering the diameter of sesame plant's stem and the length of the rug.

Evaluation of conveying performance of prototype for each input angle of sesame

The conveying performance of the prototype at each insertion angle for sesame plants was evaluated (Figure 7). When the insertion angles were 60° and 90°, the conveying rate for the sesame plants was 100%. However, when the angle was 120°, the rate was 75-80%. The sesame plants that fell toward the working direction of the prototype were cut prior to being grabbed by the conveying belt. Therefore, the conveying belt was either unable to grab the cut sesame plant or the grabbing was inaccurate.

Figure 7. Conveying performance test of prototype for different insertion angles.

Table 5. Sesame conveying rate of conveying belt

Number of sesame input (sesame/time)	Conveying rate (for each insertion angle of sesame) (%)		
	120°	90°	60°
1	80	100	100
2	75	100	100

Field performance of the prototype

Table 6 presents the results of the cutting and conveying performance of the prototype for each working speed. When the ratio between the running and conveying speeds was 1:4, the cutting rate was 100%. However, the conveying rate was 89% due to a bad conveying stance because the conveying belt pulled the stem of the sesame plant while cutting was going on. When the ratio between the running and conveying speeds was 1:2, both the cutting and conveying rates were 100%, which is an ideal figure.

The harvesting of sesame plants includes cutting, binding, drying, and threshing. According to 2012 figures on man-hours spent for sesame farming, the harvesting of sesame plants takes a total of 31.9 h/10a. Within this total, packing and drying takes 3.8 h/10a, threshing 12 h/10a, and cutting

Figure 8. View of working performance of the prototype.

Table 6. Cutting and conveying performances of prototype at different working speed levels

Working speed (A), m/s	Conveyor speed (B), m/s	W-C speed ratio (B/A)	Cutting ratio, %	Conveying ratio, %
0.16	0.6	1:4	100	89.3
0.24	1.0	1:4	100	88.9
0.30	0.6	1:2	100	100
0.51	1.0	1:2	100	100

Table 7. Required man-hours for harvesting sesame (based on traditional manual labor)

For each work	Cutting and binding	Field drying	Threshing
Unit time consumed for labor (hours/10a)	16.1	3.8	12.0

Table 8. Performance of prototype

Item	Working speed, m/s	Working width, m	Turning time, min/10a	Field efficiency (E_f)	Working efficiency, h/10a
Prototype	0.51	1.1	3	0.89	0.55

and binding takes 16.1 h/10a (q 7). The time it takes for cutting and binding is the longest of all.

The prototype's turning time was 3 min/10a when the working speed was 0.51 m/s and working width was 1.1 m for cutting and collecting. The work efficiency was 0.55 h/10a (Table 8). The efficiency of the prototype was over 96%, compared to the traditional manpower-based efficiency of 16.1 h/10a. Since the prototype enabled immediate and timely harvesting in a single sweep, by reducing both the labor and production time, production losses can be minimized. In addition, since the prototype extracted the cut sesame, which was collected up to every 5 m in length, the carrying and loading tasks for binding and drying became easier, which decreased the intensity of cultivation. Figure 8 shows the working performance of the prototype.

Conclusions

In this study, the major factors required for mechanizing sesame cultivation were investigated. A walking-type double-row sesame reaper, capable cutting and conveying sesame plants simultaneously, was developed.

(1) The prototype sesame reaper was designed to allow for stable and convenient work, making it suitable for the cultivating patterns of most farms. The height of the cutting part of the prototype can be adjusted depending on the height of the ridge. When a predetermined amount of sesame plants was accumulated at the collecting part, the collected amount could be extracted passively. The conveying pattern, conveying angle, and the speed ratio between the running and conveying of the conveying part were optimized in order to continuously convey and collect the sesame plants.

(2) The prototype showed excellent performance in cutting, conveying, and collecting. Its working efficiency was approximately 96% compared to traditional manual labor, which translates into huge reductions in total costs with respect to both time and labor.

Conflict of Interest

The authors have no conflicting financial or other interests.

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