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A Study on Improving the Performance of the Planting Device of a Vegetable Transplanter

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Abstract

Purpose: Due to the growing demand for vegetables all year round, the use of vegetable transplanters has become widespread in agricultural production. However, the type of planting device used for the transplanter affects its overall efficiency. Problems such as inaccurate planting angles and inefficiently wide transplanting hole diameters of the planting device has limited the efficient use of some vegetable transplanters. Our goal in this study was to improve the efficiency of the transplanter by analyzing and modifying the linkages of the planting device of a vegetable transplanter. **Methods:** Because of its widespread usage in Korea, a linkage-type planting device was used for the experiment, which was divided into three parts. In the first part, the physical trajectory of the tranplanter was extracted using a CCD (charge-coupled device) camera and analyzed. In the second part, a simulated trajectory was developed using Recurdyn 3D software. The simulated and actual trajectories were then compared and analyzed. In the third part, based on the results of the comparison, improvements were made on the linkages of the transplanter and a demonstrative exercise was conducted. Finally, in experiment B, the performance was evaluated through an exercise using both the existing and improved planting devices. **Results:** The results demonstrated that the average planting angle was improved by 4.96 mm, the soil intrusion diameter was improved by 11.30 mm, and the planting depth was improved by 0.68 mm. **Conclusion:** It was concluded that the efficiency of a vegetable transplanter can be improved by modifying the linkages through simulations and field demonstrations.

Keywords: Linkage-type, Planting device, Simulation, Trajectory, Transplanter

Introduction

Vegetables play an important role in human nutrition, especially in Asia but also in other parts of the world (Ness and Powles, 1997). According to Lee (2010), daily consumption of vegetables in Korea increased by 14.4% from 1998 to 2005. This survey provides justification for the mechanization of vegetable production to meet the growing demand. Srivastava (2000) found that mechanized cultivation, along with other improved crop production practices, can effectively increase both crop yield and quality. In mechanizing vegetable production, vegetable transplanters are important for reducing manual labor.

Vegetable transplanters are used for transferring vegetable seedlings from the nursery and planting them into the soil. A vegetable transplanter has a component referred to as the planting device, and Min (2015) described it as functioning simply by dropping seedlings into the soil. At present, domestic transplanters are categorized as either semi-automatic or automatic (Park et al, 2004). Automatic transplanters mechanically feed seedlings into the planting device whereas semi-automatic transplanters require that the seedlings be fed into the planting device manually by the farmer. The semi-automatic transplanter has a limited operating speed due to the need for the manual feeding of one seedling cell at a time and is therefore unsuitable for continuous operation over a long period of time. The fully automatic transplanter allows for high-speed operation and effective laborsaving, because seedlings fed automatically by the machine itself can be planted

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directly (Zhou et al, 2014). Depending on the farmer and size of the farm, both types of transplanter are equally important in field vegetable production.

Essentially, four different types of planting devices have been developed for transplanting vegetables. These include the wheel-type, rotary-type, linkage-type, and the four-linkage cam-type planting devices (Kang et al., 2014). During the transplanting process, when the planting device inserts seedlings into the soil, loosely circular-shaped holes are generated. When the repulsive force of the soil pushes the planting hopper back, a hole is formed in the soil. The repulsive forces and the geometry of the hole cause a defective transplanting posture. The magnitude of the soil reaction force is influenced by machine speed, planting device operating speed, and planting device static trajectory. Some planting devices operate on a structure of linkages, which moves the planting hopper in a trajectory pattern that can be set to a constant rate of motion. However, a few modifications to the linkages responsible for the trajectory may significantly improve the working ability and efficiency of the transplanter by solving the problem of defective transplanting orientation. Some work has already been carried out on the subject of vegetable transplanters. For example, Moon et al. (1997) studied the transplanting performance of a semi-automatic transplanter by analyzing the performance of a real transplanter through a demonstrative experiment, rather than by analyzing the trajectory of the device.

The objective of this study was to improve the performance of a domestic vegetable transplanting device through simulated trajectory analysis, which subsequently assisted in modifying linkage length and minimizing soil load area.

Materials and Methods

Experimental site and research tool

This research was conducted in a soil bin facility at Gyeongsang National University, South Korea. The soil bin comprised a stationary bin, a common carriage that supported the planting device, the power transmission system, control unit, and other components. The soil bin was rectangular with dimensions of length 5 m, width 2 m, and height 1 m, and was used to provide a repeatable soil condition for the experiment. The USDA (United States Department of Agriculture) textural classification of the experimental soil was sandy loam, which comprised of 57.2% sand, 17.2% clay, and 25.3% silt.

The research tool was a vegetable transplanter (model KTP–30, domestic K Company, Korea). The KTP-30 is a type of four-bar link transplanting machine whose operation and return is driven by rotating a crank. This model was chosen because it is a widely used vegetable transplanter in Korea and because (according to Min (2015)), the four-bar link transplanting device maximizes transplanting performance. There are five linkages involved in driving the device, including the drive crank itself. During operation, the planting hopper opens and drops the seedlings as it penetrates the soil. The whole cycle of operation is performed through a left-to-right rocking motion generated by the rotation of the drive crank, with the planting device operating with a constant trajectory. The trajectory of the device can be varied by adjusting the length of each linkage. Figure 1 shows a planting device with the manual feeding hopper and the rotating linkages.

The planting device was attached to the carriage as shown in Figure 2. The planting device had its own motor as a power source that was fixed at position B. The planting power equipment was fixed at position A. The pulleys on the shaft of the motor at position B and planting power equipment at position A were linked together using a V-belt for power transmission, such that power was transferred from the source to the drive crank.


(a) Planting device with hopper for manual feeding.
(b) The various linkages attached to the hopper.

Figure 1. Image of planting device.

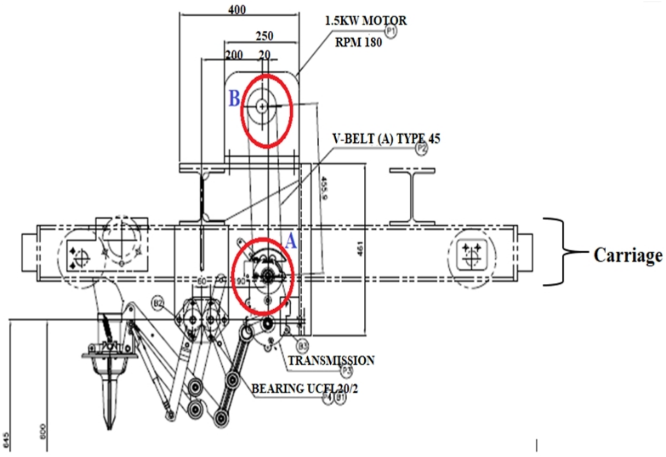


Figure 2. Diagram of planting device attached to soil bin carriage.

Soil hardness and water content

As the planting device performs intrusive work on the soil, knowledge of the correct power requirement was important. However, before establishing the power requirement, the soil hardness first had to be determined. Soil hardness is a measure of the compaction of the soil and is strongly related to its water content. The water content of the soil significantly influences the success rate of transplanting, and is widely used as a parameter for the transplanting performance test (Tian et al., 2010). Because soil hardness varies according to water content, the power of the planting device was set based on the soil water content that was measured using a soil moisture sensor (S-SMD-005, Onset Computer, Massachusetts, USA) and data was recorded using a data logger (U-30-NRC, Onset Computer, Massachusetts, USA). The soil was dried, and data was logged with soil hardness measurements performed under drying using a spring-gauge-type soil hardness tester (TYD-1 Soil Hardness Tester, Hinotek Group Limited, Ningbo, China). The water content was logged for 3 h in total, and the soil hardness was measured five times at 20 min intervals. Tables 1 and 2 display the detailed specifications of the soil moisture sensor and data logger, respectively.

Planting device power output

To determine the required power supply for the planting device, the rotational speed of the motor in rpm was first determined, followed by the torque produced.

The rotating speed of the motor was 180 rpm. However, according to WENtechnology (2002) the torque of a rotating speed is given by the equation

$$\text{Torque (N·m)} = (63{,}025 \times \text{Power (HP)}) / \text{Speed (rpm)} \qquad (1)$$

Table 1. Detailed specifications of the soil moisture sensor

Description	Specifications
Model name	S-SMD-005
Measurement range in soil	0 to 0.50570 m³/m³ (volumetric water content)
Resolution	0.0008 m³/m³ (0.08%)
Soil probe dimensions (megapixels)	(160 x 32 x 2) mm (6.5 x 1.25 x 0.08 in)
Weight	190 grams
Sensor operating temperature	0°C to +50°C (+32°F to +122°F).
Volume of influence	1 liter (33.8 oz)
Sensor frequency	70 MHz
Bits per sample	12
Cable length available	5 m (16 ft)
Length of smart sensor network cable	0.5 m (1.6 ft)

Table 2. Detailed specifications of the data logger

Description	Specifications
Model name	U30-NRC
Normal operating range	-20°C to 40°C (-4°F to 104°F)
Sensor inputs	5 standard; option to expand to 10
Smart sensor compatibility	Compatible with most Onset smart
Data channels	Maximum of 15
Size	17.8 x 11.7 x 19.3 cm
Weight	2 kg (4 lbs 10 oz)
Local communication	Full Speed USB via USB mini-B connector
Cable rechargeable battery service life	Typically 3 years to 5 years
Sensor network cable length	100 m (328 ft) maximum

Therefore, with a 2 HP motor and a speed of 180 rpm,
Torque = (63,025 × 2)) / 180 = 79.121 N·m.

The power in kilowatts is given by

$$\text{Power (kW)} = (\text{Torque (N·m)} \times \text{Speed (rpm)}) / 9.5488 \quad (2)$$

Therefore, power output = (79.121 × 180) / 9.5488 = 0.17 kW.

Experimental procedure

The experimental stage of the study was divided into two parts; experiments A and B. The purpose of experiment A was to ascertain the reliability of the working efficiency of the transplanter by comparing the actual and simulated trajectories. For the real trajectory, a CCD camera (STC-CK152A, IEEE Global spec, Albany, NY, USA) was used to capture the trajectory motion of the transplanter at low speed and constant distance for one full rotation. Table 3 shows the detailed specifications of the camera used. The low-speed photographs obtained were grouped together using AutoCAD 2016 software, and a simulated trajectory of the planting device was accomplished using Recurdyn V9R1 software. The actual and simulated trajectories were compared to find the error or difference, and to make corrections on the existing planting device.

Actual trajectory photography

As shown in Figure 3, the images were captured in 120 frames and imported into a 3D design program (Auto CAD, 2016). The actual trajectory was subsequently determined by following the ends of the working part between the separate images.

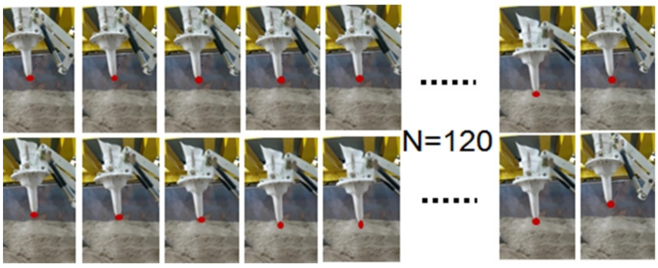


Figure 3. Actual trajectory extraction method.

Simulated trajectories

The simulated trajectory was accomplished by first creating a 3D model of the existing planting device using AutoCAD software and then imported to the Recurdyn software for dynamic analysis of the simulated model. The step-by-step implementation of the simulated trajectory motion is shown in Figure 4. In the planting device itself, the link of each part oscillates according to the rotation of the drive crank, forming a locus at the working end. The oscillating joints are designated as Revjoint 1, Revjoint 2, and Revjoint 4, as shown in Figure 5. To improve the performance of the existing transplanter through minimal design changes, the factors that affected the efficiency of the transplanter were identified through dynamic analysis performed during the simulation exercise.

The oscillating angle of the planting device is influenced by various parameters, such as the length of the linkages, angles between linkages, crank, and eccentricity. In this experiment, it was identified that the performance of the planting device could be improved by changing the link lengths. The change in link length that affected the adequate change of the suggested Revjoint value was successfully determined, and by using algebraic position analysis, the value of the suggested Revjoint was then converted to a linkage length value. Figure 6 shows the algebraic position of the Revjoints of the planting device. The length of each link and crank angle was substituted into the formula in Figure 6(b) and the resulting change in the values of α_1 and β_1 was confirmed. Next, we confirmed which linkage had the greatest influence on the formation values of Revjoint 4(α 1, β 1) through statistical analysis, which was performed using the SPSS (Statistical Package for the Social Sciences) program and

Table 3. Detailed specifications of the CCD camera used

Description	Specifications
Camera model	STC-CL152A CCD camera
Camera function	Still, Video
Monochrome/Color	Monochrome
Maximum frame rate	15 fps to 19 fps
Performance	Progressive Scan
Resolution	8 bits, 10 bits
Lens mount	C- Mount
Width/Height /Length	28 mm/28 mm/40 mm
Operating temperature	23°F to 113°F

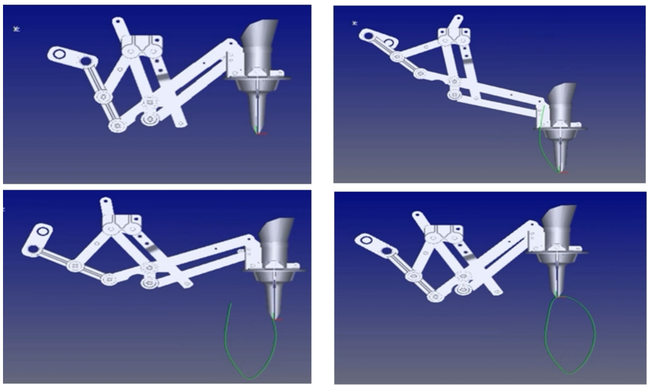


Figure 4. Planting device trajectory.

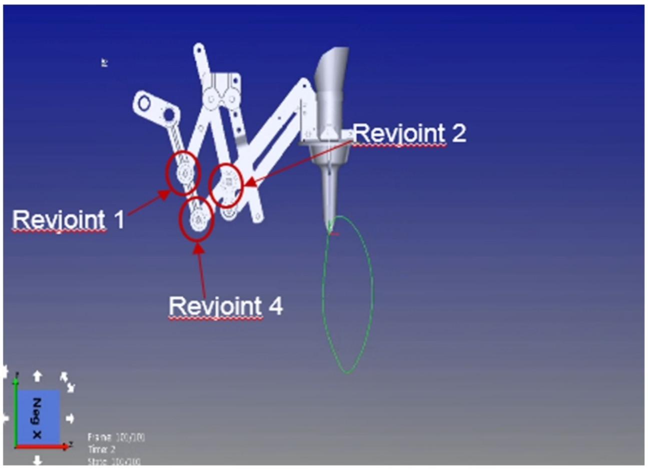
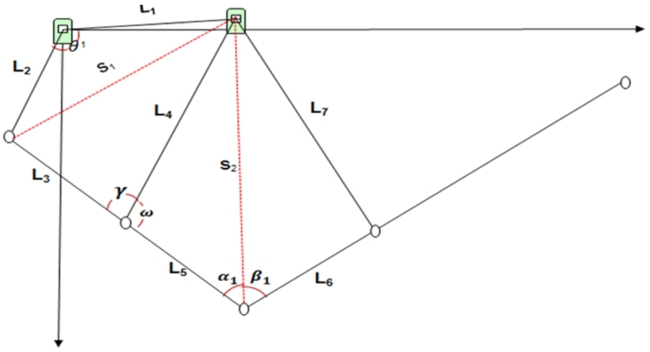


Figure 5. Oscillating joints of the planting device during simulation.



(a) Revjoint and crank angle positional analysis.

$$S_1 : \sqrt{L_1^2+L_2^2-2L_1^2L_2^2\cos\theta_1}$$

$$\gamma : \cos^{-1}\left(\frac{L_3^2+L_4^2-S_1^2}{2L_3L_4}\right)$$

$$\omega : 180^{\circ}-\cos^{-1}\left(\frac{L_3^2+L_4^2-S_1^2}{2L_3L_4}\right)$$

$$S_2 : \sqrt{L_4^2+L_5^2-2L_4^2L_5^2\cos\omega}$$

$$\beta_1 : \cos^{-1}\left(\frac{L_6^2+S_2^2-L_7^2}{2L_6S_2}\right)$$

$$\alpha_1 : \cos^{-1}\left(\frac{L_5^2+S_2^2-L_4^2}{2L_5S_2}\right)$$

(b) Equations describing the coordinated positions of the linkages.

Figure 6. Results of algebraic position analysis.

a simple regression analysis. From this analysis, the length of the linkages was found to have the greatest effect on the performance of the planting device. Therefore, the length of the real linkages were modified through cutting and welding. These alterations were made based on the results of the comparison between the simulated and actual trajectories in order to correct the error or differences that arose from the comparison.

Experiment B was performed to evaluate the performance of the improved planting device, after which the performance of the existing and improved planting devices was compared. Three main transplanting parameters were assessed: transplanting depth, soil intrusion diameter, and transplanting angle. The two planting devices (existing and improved), a soil bin, and additional measuring kits were used for the performance analysis.

Results and Discussion

Soil hardness and water content analysis

The results of the soil hardness test according to the water content of the soil are shown in Figure 7. As the soil moisture content decreased, the soil hardness increased. Figure 8 shows a statistical analysis based on the experimental results. The SPSS software was used for the statistical analysis, and a simple regression was performed. This analysis showed that soil moisture content and soil hardness were highly correlated with R^2 = 0.81457.

Results of experiment A

Simulated and actual trajectory analysis

Figure 9 shows a diagram of the real and simulated trajectories of the existing planting device, which exhibited a small difference of a 3.8 mm deviation. An improvement in the performance of the existing equipment through simulation is confirmed by the results of experiment A.

To correct the 3.8 mm deviation, the linkages were altered based on further analysis, such as soil load analysis. From the simulated analysis, the largest position change of all the joints occurred at Revjoint 4. Hence, the design factors modified based on Revjoint 4 were extracted.

Table 4 shows the results of the statistical analysis. The

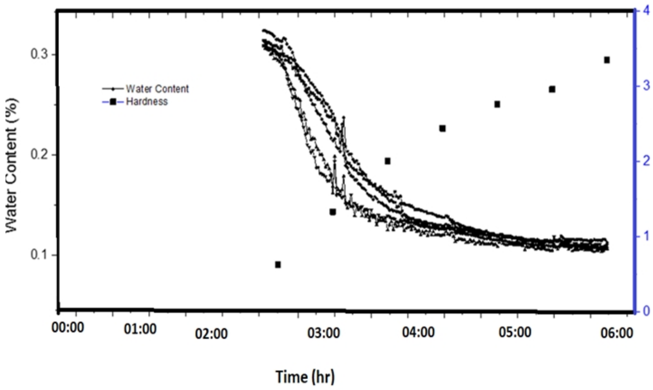


Figure 7. Relationship between water content and hardness with respect to time.

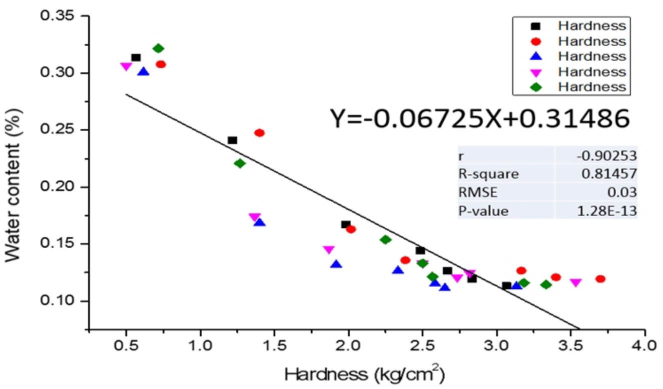


Figure 8. Statistical analysis of soil moisture content and soil hardness.

standardization coefficient, β , indicates the extent that the linkage influences the formation of the Revjoint 4 value. From the analysis, linkage L4 had the greatest effect on decreasing the value of Revjoint 4 with −87.5%. This was followed by linkage L7, which was confirmed to cause a 68.7% increase in the Revjoint 4 value.

Because links 4 and 7 undergo oscillating motion, their lengths were modified as follows.

When the transplanter is operating, the planting hopper is pushed by the soil due to the speed transfer. Figure 10 shows the soil load area produced by the trajectory during operation. This area changes according to the form of the trajectory and exerts a repulsive force on the planting hopper. The smaller the soil load area, the smaller the load on the planting hopper. Moreover, if the repulsive force of the soil is reduced, the transplant orientation can be improved. In this study, it was observed that reducing the soil load area improved the performance of the transplanter. Therefore, alterations were made to the linkage lengths of L4 and L7 to reduce the effective soil load area.

The changes in the soil load area corresponding to increasing and decreasing link lengths were confirmed. Specifically, link lengths were increased or decreased by percentages, and the soil load area value was confirmed in each case.

The soil load area of the existing planting device was found to be 168.9 mm^2. As the length of link 4 was

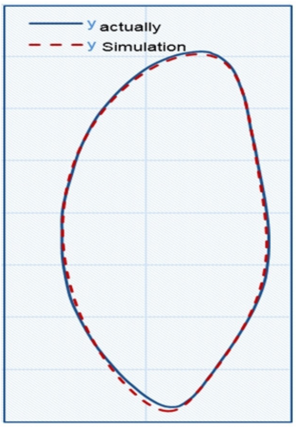


Figure 9. Actual and simulated trajectories of the existing planting device.

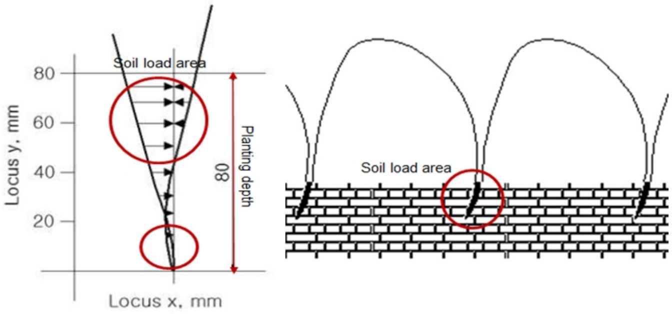


Figure 10. Soil load area and its dimensions.

Table 4. Results of statistical analysis

Linkage	Non-standardization factor		Standardization factor	t	Significance	Collinearity statistic	
	B	SD	β			Tolerance	VIF
L1	0.343	0.028	0.515	12.393	0.000	0.829	1.206
L2	−0.334	0.035	−0.400	−9.535	0.000	0.815	1.227
L3	0.104	0.032	0.153	3.259	0.005	0.647	1.544
L4	−0.621	0.041	−0.875	−15.318	0.000	0.439	2.280
L5	−0.484	0.034	−0.632	−14.208	0.000	0.724	1.381
L6	0.194	0.033	0.327	5.925	0.000	0.471	2.121
L7	0.455	0.031	0.687	14.547	0.000	0.642	1.559

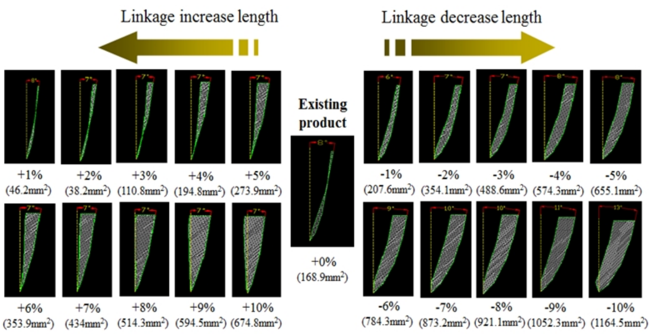


Figure 11. Results of change in length and corresponding change in soil load area.

Table 5. Decreasing length with corresponding changes in soil load area

Change in length (%)	Soil load area (mm^2)
−1	207.6
−2	354.1
−3	488.6
−4	574.3
−5	655.1
−6	784.3
−7	873.2
−8	921.1
−9	1052.3
−10	1164.5

Table 6. Increasing length with corresponding changes in soil load area

Change in length (%)	Soil load area (mm^2)
1	46.2
2	38.2
3	110.8
4	194.8
5	273.9
6	353.9
7	434.0
8	514.3
9	594.5
10	674.8

decreased, changes were observed, as shown in Table 5.

As can be seen in Figure 11, as the lengths of the linkages decreased, the soil load decreased. Conversely, increasing the length of link 4 in the existing planting device resulted in the changes shown in Table 6.

The changes in the soil load area resulting from increasing the length of the linkage only occurred under certain conditions. When the linkage length of the planting device increased from 1% to 2%, the soil load area decreased; however, when it was increased from 2% to 3%, the soil load area increased. Therefore, it was assumed that the minimum soil load area is achieved between a 1% and 2% change in length of linkage.

Additional tests showed that the minimum soil load area was 8.7 mm^2 when the length of link 4 was increased by 1.7%. Hence, the length of the real link 4 was increased by 1.7%, and that of link 7 was also increased by 1.7%.

Results of experiment B

Performance evaluation of the existing planting device

In experiment B, the performance of the existing and improved planting devices was compared. The improved planting device was prepared based on the results of experiment A. The experiment proceeded in the same manner as for the existing planting device.

In the experiment, the equipment was attached to the carriage as shown in Figure 12, and its performance was evaluated by performing a real task. Seedlings were fed manually into the planting hopper. The speeds of the planting device and the carriage speed were 30 rpm and 0.17 m/s, respectively, based on a transplanting distance of 35 cm. Because the seedlings were supplied by hand, misplants did not occur. However, it was confirmed qualitatively that the orientation of the seedlings was not upright. Figure 13 displays the images of seedlings transplanted by an existing planting device and a trace of the soil penetrations made by the planting hopper. For the raised seedlings, the upright ratio was not maintained at the planting angle, and the appearance of an incline in the direction of transfer was confirmed. In the case of soil intrusion, it was confirmed that the soil was pushed in the direction of progress.

Table 7 summarizes the data obtained from the experiment with the existing planting device. To analyze the planting features of the existing planting device, the planting angle, soil intrusion diameter, and the planting depth were all measured. The data were measured 20 times for the results of the transplantation work, and the average and its standard deviation was calculated. For examining the planting angle, the same seedlings were used. A protractor was used to measure the planting

Figure 12. Evaluation of existing planting device performance.

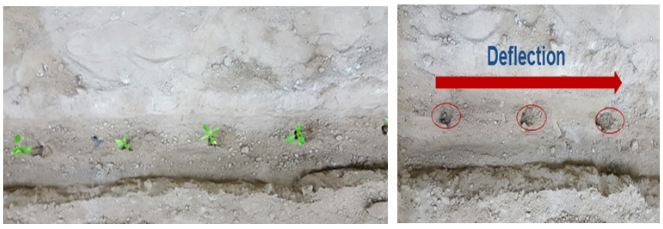


Figure 13. Qualitative performance evaluation of existing planting device.

Figure 14. Evaluation of improved planting device performance.

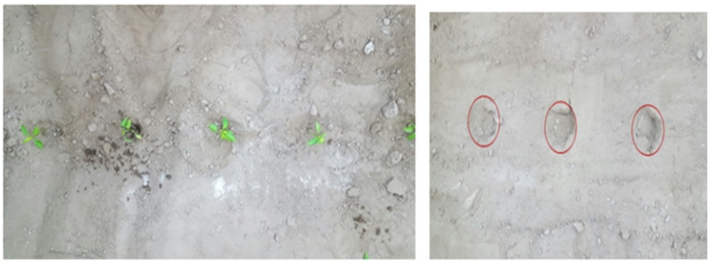


Figure 15. Qualitative performance evaluation of improved planting device.

angles and the average data was recorded. The seedlings transplanted in a fully upright vertical state were defined as planted at a planting angle of 0°. In this experiment, the seedlings demonstrated an average-planting angle of 8.77°. The standard deviation was 0.61, and the planting angles were similar throughout the experiment. A tape measure was used to measure the planting depth after the seedlings were removed from their holes. The soil intrusion diameter was measured and the mean value of 61.38 mm was obtained, with a deviation of 4.42. This may have occurred due to different soil conditions used in the experiment. The base of the planting device was fabricated based on a planting depth of 70 mm, according to the initial design. However, because of the curvature of the soil surface, transplanting was not consistently performed at a level of 70 mm. The results of the transplanting operation were similar to the average of 68.24 mm, with a standard deviation of 1.71 mm.

Performance evaluation of improved planting device

The improved planting device was physically realized by increasing the length of linkage 4 by 1.7%. The planting device was attached as shown in Figure 14, and its performance was evaluated by testing it with actual work. For the existing device, the seedlings were manually fed into the planting hopper. The speed of the planting device and carrier were also 30 rpm and 0.17 m/s, respectively, based on the same transplanting distance of 35 cm. Again, because the seedlings were supplied manually, misplants did not occur.

The transplant orientation of the seedlings was not consistently upright, but it was confirmed that the posture yielded by the improved planting device was better than that produced with the existing planting device. Figure 15 shows the images of seedlings transplanted by the improved planting device and a trace of the soil penetrations made by the planting hopper.

Table 8 summarizes the data obtained from the experiment carried out with the improved planting device. Measurement factors and methods were the same as for the existing planting device. Furthermore, the experiments were conducted in the same environment, the only difference being that the linkage lengths were modified. For the planting angle, the seedlings transplanted in the vertical state were measured at 0°. In this experiment, all seedlings displayed an average planting angle of 3.81°. The standard deviation was 0.61, and the planting angles were similar throughout the experiment. The soil intrusion diameter was measured to be 50.08 mm on average. Because the soil conditions were different for each section, it was confirmed

Table 7. Results of the demonstration of the existing planting device

Variables	Unit	Measure										
Planting angle	(°)	9.4	8.5	8.9	8.8	8.2	8.1	9.6	9.1	9.8	8.1	8.77 ± 0.61
		8.1	9.1	9.6	8.3	9.4	7.8	8.4	8.8	9.7	8.4	
Soil intrusion diameter	(mm)	61.7	58.3	55.5	64.8	68.3	55.4	55.8	54.9	57.6	62.4	61.38 ± 4.42
		67.1	66.6	58.7	60.4	59.1	68.8	66.7	63.6	61.0	60.9	
Planting Depth	(mm)	68.1	70.0	67.8	68.7	67.9	67.8	62.7	69.8	67.2	67.3	68.24 ± 1.71
		68.6	68.4	67.2	68.1	69.8	71.8	67.5	68.4	67.8	69.9	

Table 8. Results of demonstration of the improved planting device

Variables	Unit	Measure										
Planting angle	(°)	3.4	3.9	5.2	3.4	3.2	4.1	3.6	3.7	4.0	4.8	3.81 ± 0.51
		4.1	3.6	3.6	3.3	4.4	3.8	3.4	3.8	3.7	3.2	
Soil intrusion diameter	(mm)	51.3	48.7	45.5	50.3	55.8	48.4	45.6	50.1	53.6	48.6	50.08 ± 2.58
		52.3	49.6	53.7	51.4	47.1	48.3	50.3	48.3	51.8	50.9	
Planting depth	(mm)	67.3	68.5	69.3	68.8	68.5	70.1	70.0	68.3	71.2	68.5	68.92 ± 1.05
		67.5	67.6	68.7	68.8	70.3	70.3	68.7	69.9	68.4	67.7	

that the level of deviation was relatively high (2.58 mm).

As before, the base of the planting device was fabricated assuming a planting depth of 70 mm, as in the initial design. However, because of the soil surface curvature, transplanting was not practically carried out at the 70-mm level. The results of transplanting operation were similar to the average of 68.92 mm and standard deviation of 1.05 mm.

Conclusion

In this study, the planting device of a linkage-type vegetable transplanter was analyzed and careful mechanical alterations were implemented in order to improve its working efficiency. Linkage-type planting devices cause soil repulsion during transplanting. Therefore, we attempted to improve the performance of the device by changing the link lengths to make improvements based on a simulated trajectory that was compared to the actual trajectory of the planting device.

From experimental data, the difference between the actual and simulated trajectories was determined to a maximum error of 3.8 mm. The linkages of the transplanter were improved accordingly, and the performance of the existing and improved planting devices in undertaking actual work was compared. The results showed that the average planting angle of the existing device was 8.77° ± 0.61°, its soil intrusion diameter was 61.38 ± 4.42 mm, and its planting depth was 68.24 ± 1.71 mm. The planting angle of the improved device was found to be 3.81° ± 0.51°, with a soil intrusion diameter of 50.08 ± 2.58 mm, and a planting depth of 68.92 ± 1.05 mm. From the analysis, it was confirmed that the improved planting device reduced the average planting angle by 4.96° by reducing the soil load area, which consequently reduced the soil intrusion diameter by 11.3 mm.

Conflict of Interest

The authors have no conflicting financial or other interests.

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References

Lee, J.S. and J.Kim. 2010. Vegetable intake in Korea: data from the Korean National Health and Nutrition Examination Survey 1998, 2001 and 2005. British Journal of Nutrition 103(10): 1499–1506. https://doi.org/10.1017/S0007114509993527

Kang, J. K. 2014. A Research on a 4 bar Link-Cam Type Transplanting Device for an Onion Transplanter. Unpublished MS thesis. Jinju, Korea: Department of Biosystems Engineering, Gyeongsang National University.

Min, Y.B, J.K. Kang and C.S Ryu. 2015. Development Onion Transplanter: Analysis a Transplanting Locus on the Type of Transplanting Devices for a Vegetable Transplanter. Journal of Agriculture and Life Science 49(6): 289-294. https://doi.org/10.14397/jals.2015.49.6.289

Moon, S.D., Y.B. Min and J.C. Park. 1997. Effect of the Hopper of the Plug Transplanter and Moisture Content, Compaction Method, and Initial Irrigation of the Soil on the Seedling Survival rate at Transplant of Plug Seedling. Journal of Bio-Environment Control 6(4): 258-263.

Moon, S.D., Y.B. Min and J.C. Park. 1997. Analysis of Working Capacity of a Hand-fed Transplanter. Journal of Bio-Environment Control 6(3): 9.

Ness, A.R. and J.W. Powles. 1997. Fruit and vegetables, and cardiovascular disease: A Review. International Journal of Epidemiology 26(1): 1-13. http://dx.doi.org/10.1093/ije/26.1.1

Park, S.H., S.C. Cho, J.Y. Kim, D.K. Choi, Kim CK and T.Y. Kwak. 2004. Motion Analysis for 4 bar Link type of Transplanting Device. The Korean Society of the Agricultural machinery 9(2): 155-159.

Tian, S., L. Qiu, N. Kondo and T. Yuan. 2010. Development of Automatic Transplanter for Plug Seedling. IFAC Proceedings Volumes 43(26): 79-82. https://doi.org/10.3182/20101206-3-JP-3009.00013

Srivastava, N.S.L. 2000. Animate energy in agriculture. Agricultural Engineering Today 24(2): 13-34.

WENtechnology, 2002. User Guide, Raleigh, NC, USA. WENtechnology Inc

Zhou,M., Y.Gaohang, Z. Yun, H. Haijun, L.Zhenpiao and Z. Xiong. 2014. Parameter optimization and test on pick-up mechanism of planetary gear train with ellipse gears for vegetable plug seedling. Transaction of the Chinese Society of Agricultural Engineering 30(9): 13-21 (In Chinese with English Abstract)