Agri. & Biosys. Eng. Vol. 5(2):40-44(2004)

Developmemt of Chain Conveyor-type Spinach Harvester

H. J. Jun, J. T. Hong, Y. Choi, Y. K. Kim

Abstract: This study was conducted to solve the problem of spinach harvesting done by manpower at the outdoor field during the cold winter season. Prototype spinach harvester was designed to dig, pick-up, and collect in a continuous operation for harvesting outdoor field-planted crawling type spinach. In the field test, two types of blades (Type A : angle of 150°, Type B : straight) were used for measuring the cutting loads of spinach and chain conveyor with lugs was used for picking up the root cut spinach. Prototype's vibrating blade reduced the digging power of the fixed blade by 46%. The loss was also very little (0.7%) with a digging depth of 4 cm, an oscillation frequency of 748 rpm, and an oscillation distance of 33 mm. The working performance of the prototype spinach harvester was 38 hour/ha resulting to 96% labor cost reduction compared to the conventional harvesting.

Keywords: Spinach, Chain Conveyor, Spinach Harvester, Agricultural Machinery

Introduction

Spinach is one of the popular vegetables to consumers because it has plenty of nutritive substance. In Korea, the cultivated area of spinach was increased from 6,600 ha in 1999 to 7,900 ha in 2001 (KSAM, 2003). Most spinach plants are mainly sown using the method of manual seed broadcast; thus, these are not evenly distributed in the field.

Accordingly, there has been lots of difficulty in mechanizing spinach harvest because of its weak leaf and intermittent harvesting times.

However, it is necessary to mechanize harvesting of spinach because the crawling type spinach raised outdoors is mainly harvested under intense cold weather in winter. Moreover, harvesting of spinach takes a lot of times, as harvesting alone needs 46% of total production time (NAMRI, 2002).

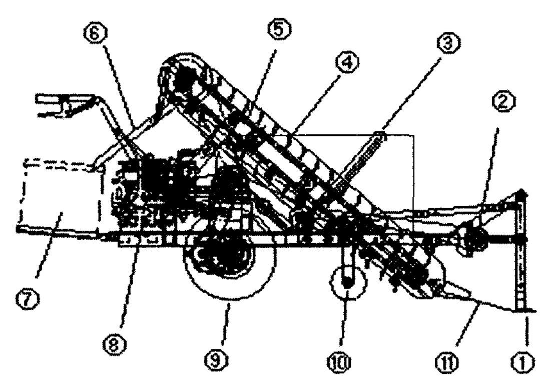
Recently in Japan, studies have been conducted to develop a spinach harvester that digs, picks with belts, and collects spinach in a continuous operation. This study tried to develop a spinach harvester using cutting blade, chain conveyor, and container for crawling type spinach.

The authors are **Hyeon Jong Jun**, **Jong Tae Hong**, **Yong Choi**, and **Young Keun Kim**, Research Agricultural Engineer, Div. of Production Machinery Engineering, National Institute of Agricultural Engineering, RDA, KOREA. **Corresponding author:** Hyeon Jong Jun, Research Agricultural Engineer, Div. of Production Machinery Engineering, National Institute of Agricultural Engineering, RDA, KOREA; e-mail: hjjun@rda.go.kr

Materials and Methods

1. Design and Manufacture of the Prototype Spinach Harvester

The basic method of harvesting spinach by machine is that as the vibrating blade in the field goes forward under a fixed depth from the soil surface, cutting the root of spinach and cracking soil into small particles, the chain conveyor with lugs picks up the spinach from the soil surface and conveys it only to the container, separating soil



① Blade
② Cam
③ Rods, controlling height of conveyor
④ Lugs on chain rods
⑤ Chain Conveyor
⑥ Guiding Plate
⑦ Container
⑧ Engine
⑨ Wheels
⑩ Roller, controlling cutting depth
⑪ Guiding rods on blade

Fig. 1 Schematic diagram of prototype spinach harvester.

clusters from the conveyor in the conveying procedure. In designing the prototype spinach harvester, its ability to perform root cutting, picking up, conveying, and collecting in a continuous operation was considered.

Moreover, the prototype has a vibrating blade for reducing the cutting load of the blade under the soil, the chain conveyor with lugs for picking up the spinach cut by the blade, the guiding plate for collecting spinach fell down from the conveyor, and the driving device for transmitting power to each device. In Fig. 1, the prototype spinach harvester consisted of the root-cutting device to cut the root of spinach with a vibrating blade, conveying and collecting device to pick up and convey the root-cut spinach with a chain conveyor, and driving and power-transmitting devices to travel and transmit power to the each device. The overall dimension of the prototype was 2,400 mm×700 mm× 1,000 mm (L×W×H).

(1) Root-cutting device

Root cutting device was made to vibrate the blade by the cam rotation and control the oscillation distance of the blade from 0 to 65 mm by exchanging several eccentric cams with each other. The length of the blade was fixed at 800 mm longer than the width between wheels so as not to put spinach under the wheels.

Moreover, the width and thickness of the blade were fixed at 4 mm and 8 mm, respectively, to reduce cutting load and the guiding rods were set at 4 mm space each on the end of the blade to separate soil and pick up spinach efficiently. The roller attached to the main frame under the conveyor can control the depth of root cutting in the field.

The width of the chain conveyor of the picking-up device was 550 mm for picking up the root-cut spinach by the blade and the space between the rods of the chain conveyor was 40 mm. Each lug was 60 mm long and located on every other rod of the chain conveyor with a size of 90 mm ×90 mm and bended at 60° for easy picking-up of spinach. The inclined angle of the chain conveyor was controlled at 25° to 32° considering power transmission and driving devices and spinach delivered at the end of chain conveyor was collected in a container as soon as they fell down on the guiding plate.

(2) Driving and power transporting device

Working of the prototype was done by the power from a 5 PS engine loaded on the main body of the prototype, and the power was transported to the cutting device, conveying device, and wheels through the reduction gear. The oscillation frequency of the blade and the velocity of the chain conveyor were changed through exchanging belt-pulleys with various diameters and the travel velocity of the wheel was controlled through shifting gear and accelerator.

2. Experimental Procedures

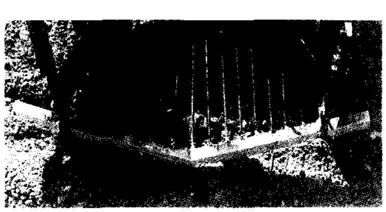
(1) Cutting-load measurement of the blade

To find the optimum condition of the vibrating blade, the test for cutting-load measurement of the blade was performed using the prototype shown in Fig. 1 in the artificial field covered with loamy sand soil as Table 1.

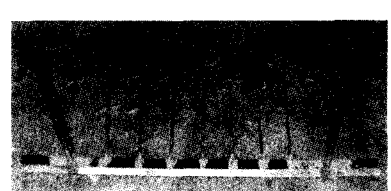
The two types of blades (Fig. 2) - type A (angle of 150°) and type B (straight) were made of SK-45 material. Both blades were have sizes of 800 mm in the cutting width in length, 40 mm in width, 8 mm in thickness, and the blade's edge angle of 30°. The blades were adjusted with oscillation distance from 0 to 65 mm and rotational frequency of the cam from 449 rpm to 1123 rpm. In the test, the cutting load

Table 1 Soil conditions of the man-made test field

Classification of soil	Rate of water content (%, d.b.)	Soil hardness by depths (N/cm^2)		
		0 cm	5 cm	10 cm
LS	18.3	37	42	30



Blade type A



Blade type B

Fig. 2 The shapes of two types of blades.

for each blade was tested at the cutting depth of 40 mm and 80 mm below the soil surface.

To measure the required load of blade under soil while digging the soil, as shown in Fig. 3, the load cell with a capacity of 4900 N (500 kg.f) was located between the cam and the blade, collecting the data using Dasylab 4.0 Program and the data acquisition system (DaqBook 200, Iotech, Inc) connected to the load cell.

Cutting load of the blade was repeatedly measured for the three times in each test and the average cutting load was calculated from the maximum cutting load out of each test. Soil moisture in the test field was measured first, choosing five points in regular distances and picking up three samples of soil at each point selected randomly and drying all soil samples in an oven with a temperature of 105±5℃ for 24 hours. After selecting three points randomly in the test field, soil hardness was measured by inserting a cone with a diameter of 12.5 mm and a height of 25 mm of the soil compaction meter (Spectrum Technology, Inc.) each 5 cm deep in each point.

Fig. 3 shows a schematic diagram of the root-cutting device for measuring the cutting load at the blade. The cutting load was calculated from formula (1).

$$(P\times a)-(M\times b)=0,\quad P=\frac{M\times b}{a} \tag{1}$$

P : Cutting load of a blade (N)
M : Load of load cell (N)
a : Distance from the center of hinge to the end of cutting blade (m)
b : Distance from the center of hinge to the connecting point of load cell (m)

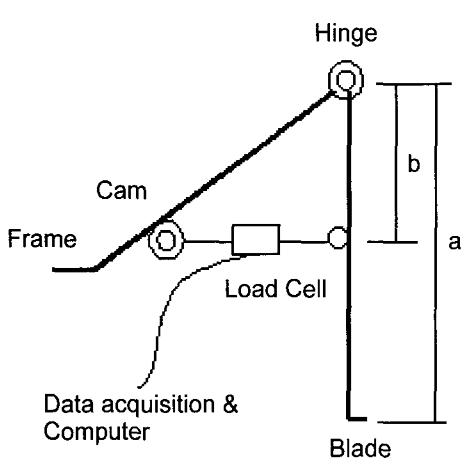


Fig. 3 Schematic diagram of the test device for measuring root-cutting load of spinach.

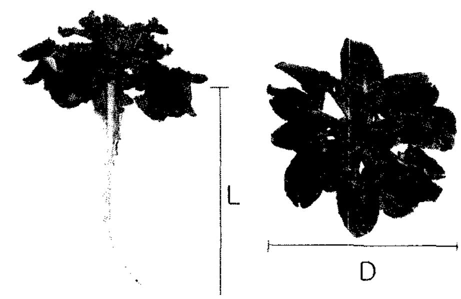


Fig. 4 The shapes and sizes of the crawling type spinach.

Also, the test for finding the characteristics of cutting load for the blade (type A) in fixed conditions of 4 cm in the cutting depth and 748 rpm in the oscillation frequency was done to measure the cutting load of the blade dividing the vibration distances into six levels between 0 and 65 mm in the crawling type spinach field in Shinan known as the chief producing district.

Field conditions for the performance test of the prototype included a good soil type, soil moisture of 17.5% (d.b.), soil hardness of 338 N/cm^2 on the surface, 290 N/cm^2 at 5 cm in depth, and 341 N/cm^2 at 10 cm in depth. The crawling type spinach used in the test as shown in Fig. 4 was mainly produced in Shinan and had 13~24 cm leaf length, 18~25 cm leaf diameter (D) and 15~23 cm root length (L).

(2) Performance test for the prototype

The prototype was operated for performance test on the conditions that the blade (type A) cut the root of spinach at the depth of 4 cm from the surface in the above-mentioned same field and the rate of moving velocity between the wheel and the lug of the chain conveyor was 1 to 4. Also, the rate of loss and the damage caused by operating speed through the performance test were investigated.

Results and Discussion

1. Cutting load of the two types blade in the man-made test field

As shown in Fig. 5, results of measuring the cutting load of two blade types by cutting depth, vibrating frequency, and oscillation distance showed that the more the oscillation distance and the rotational frequency of the cam are increased, the more that the vibration transmitted to the handle of prototype was also increased.

Cutting load of the type A blade was smaller than that of the type B blade. The cutting load by the vibrating condition rapidly decreased at the point of oscillation distance of 33 mm in both cutting depths of 4 cm and 8

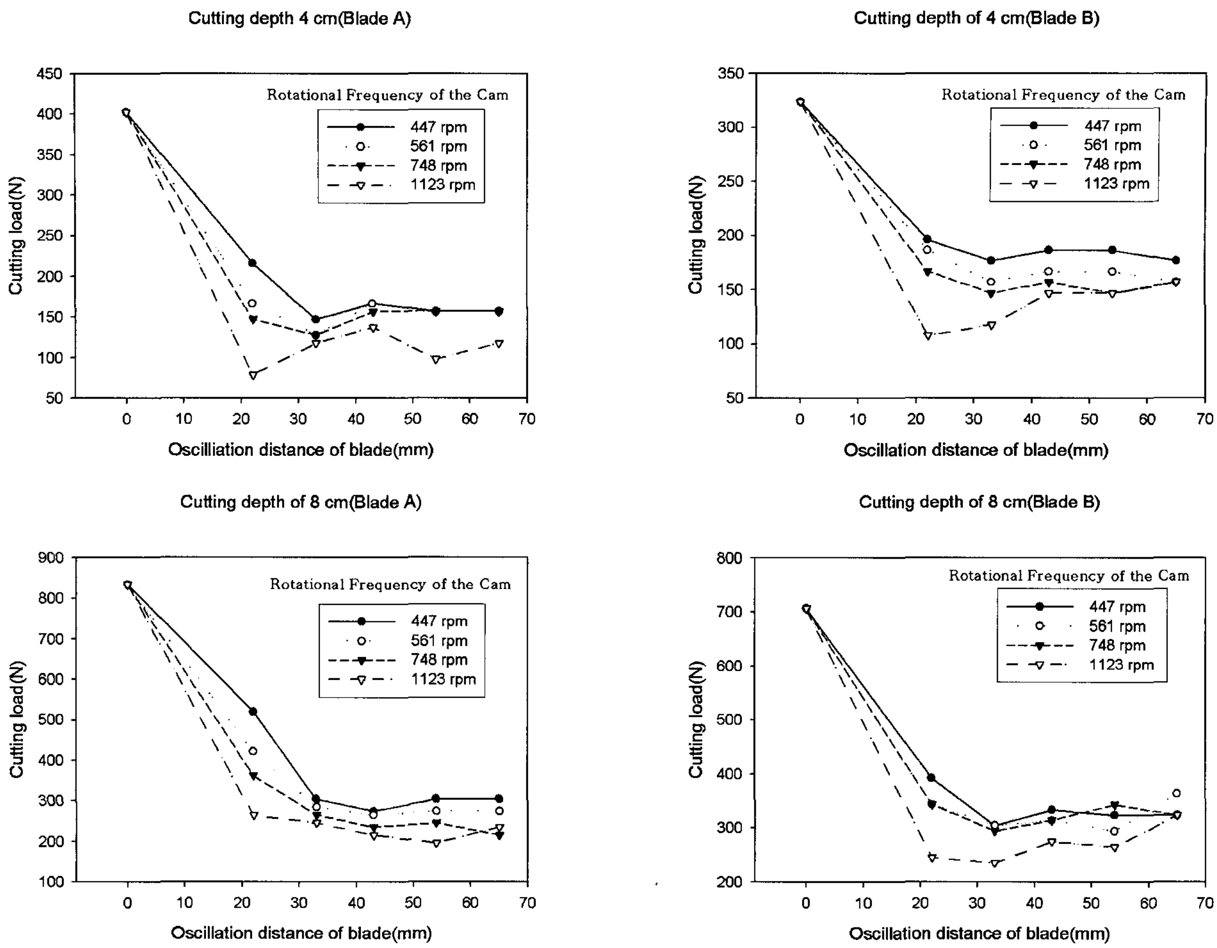


Fig. 5 Relationships of oscillation distance and cutting load of the blades by the rotational frequency of the cam.

cm. So, considering the feeling of vibration transmitted to the operator, the optimum oscillation distance of blades became 33 mm.

2. Cutting load of type A blade in the spinach field

As shown in Fig. 6, results of cutting load of blade (type A) for crawling type spinach in the field showed that the more the oscillation distance was increased, the more the cutting load was decreased. On the other hand, the vibration of prototype seemed to increase.

Also the cutting load was 755 N at an oscillation distance of 33 mm and 1393 N at an oscillation distance of 0 mm that was like a condition of a fixed blade. Moreover, it seemed that the cutting load in vibration was decreased to 46% of that when the blade had no vibration. As above, the effect of vibrating blade was similar to the results of papers (Kang and Halderson, 1991; Kang, *et al.*, 1989).

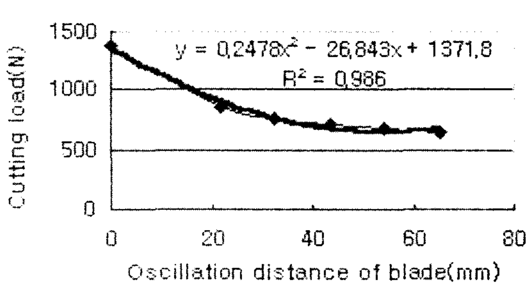


Fig. 6 Relationships of oscillation distance and cutting load of the blade (type A) at the 748 rpm of rotational frequency of the cam.

3. The performance evolution of the prototype

Result of the prototype performance test for crawling type spinach showed that the rate of loss was 0.7% at a working speed of 0.17 m/s and 1.2% at 0.25 m/s, and the rate of the damage was none. This showed that the more the working speed was increased, the more the rate of loss was also increased. In this study, the harvest loss for spinach that had a leaf length less than 8 cm was excluded from the total loss of spinach because of low quality.

Also, the performance of the prototype was 38 hours/ha at a working speed of 0.17 m/s, and it was efficient 29 times more than the 1,120 hours/ha of conventional manual labor and accordingly reducing 96% of labor cost.

Summary and Conclusions

This prototype was made to cut the root of spinach with a vibrating blade while digging soil, picking up the spinach using chain conveyor with lugs and conveying it to the container in a continuous operation. From the results of measuring the cutting load for two blade types by cutting depth, vibrating frequency, and oscillation distance, the cutting load by the vibrating condition rapidly decreased at the point of the oscillation distance of 33 mm. It seemed that the cutting load in a vibration distance of 33 mm was decreased to 46% of that when the blade had no vibration.

Result of the prototype performance test for crawling type spinach indicated 0.7% loss rate at a working speed of 0.17 m/s and 1.2% at 0.25 m/s and no damage. This showed that the more the working speed was increased, the more the rate of loss was also increased.

The performance of prototype was 38 hours/ha at a working speed of 0.17 m/s, and it was efficient 29 times more than the 1,120 hours/ha conventional manual labor and accordingly reducing 96% labor cost.

This chain conveyor type spinach harvester seems to be utilized for harvesting the greenhouse spinach through the partial improvement.

References

Korea Society for Agricultural Machinery. 2003. *Proceedings of the KSAM 2003 Summer Conference*. V. 8(2). p. 193-198.

National Agricultural Mechanization Research Institute. 2002. *The Papers of Research of National Agricultural Mechanization Research Institute in 2002 year*. p. 264-283.

Kang, W. S. and Halderson, J. L. 1991. A vibratory, two-row, potato digger. Applied engineering in agriculture. *Appl Eng Agric* Nov 1991. V. 7(6) p. 683-687.

Kang, W. S., Kim, S. H. and Hahm, Y. C. 1989. Development of an oscillating potato harvester. *Journal of Korean Society of Agricultural Machinery*. V. 14(1). p. 16-23.