

## REVIEW

# Development of a Table-top Cultivation System for Robot Strawberry Harvesting

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### Abstract

Cultivating a greenhouse strawberry system for a harvesting robot should help profitability by boosting yields and labor-saving. We have developed a high-density cultivation system utilizing movable hanging beds that hold 1.5 times the number of plants of conventional table-top systems. With the proposed system, nine beds could be placed in a greenhouse 8 m wide, whereas only six beds would fit into a conventional system. The hanging beds move parallel to each other on a two-wheeled frame travelling on a greenhouse beam approximately 2 m above the floor. Although the usual greenhouse aisle width between strawberry beds is 0.5 m, this automatically expands to approximately 1 m when the robot enters the aisle. The operation is currently performed manually by pressing a switch. The strawberry yield achieved with the mobile system was 1.5 times that obtained with fixed hanging beds. Our next project involves developing a low-clearance moving platform on which a robot can move.

**Discipline:** Agricultural machinery

**Additional key words:** high-density cultivation, low-clearance platform, movable hanging-bed, pesticide spraying, yield

### Introduction

Strawberry cultivation is an important high-earning industry in Japan. Strawberry farm income, which is about 2.4 million yen/10a, is about 2.5 times that of tomato farms. However, the working hours required for strawberry cultivation, namely about 2,000 hours/10a, are about twice the figure required for tomatoes. Table-top systems have become increasingly popular for the greenhouse cultivation of strawberries because they are more ergonomic for farm workers. About 40 table-top systems had been developed by prefectural agricultural experiment stations and agricultural material manufacturers as of 2000.

Recently, a circulating-type movable bench system for strawberry cultivation has been developed to realize high-density cultivation<sup>2</sup>. The system, which has No.

aisle, consists of two longitudinal and lateral conveying units respectively. The planting density obtained using this system is roughly 2 to 2.5 times the plant density obtained via conventional cultivation. The circulating-type represents a reasonable approach for high productivity, although the mechanism is more complex than a conventional table-top system.

We have developed a high-density cultivation system, which consists of movable hanging beds and can crop about 1.5 times more plants than conventional table-top systems<sup>1</sup>. The beds are hung from beams of the greenhouse and move parallel to each other. Since a strawberry harvest robot will soon be ready for practical use, we must improve the movable hanging bed to accommodate robot harvesting.

We will report on the experimental results with our trial model of the movable hanging-bed system and the low-clearance moving platform on which a robot can

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move when cultivating greenhouse strawberries.

## Materials and methods

### 1. Outline of the movable hanging-bed for strawberry cultivation

The movable hanging-bed system, shown in Figure 1, has been developed for cultivating greenhouse strawberries. To install it, a greenhouse would need to accommodate 75 × 45 mm cross-section beams attached at intervals of about 3 m and about 2 m in height. Nine beds could be placed in a greenhouse 8 m wide, whereas only six beds could be accommodated in a conventional system. The hanging beds move parallel to each other on a two-wheeled frame traveling on the beam. In case of a greenhouse 6 m wide, seven beds could be placed in it.

The aisle width between strawberry beds is about 0.5 m, but this automatically expands to approximately 1 m when the robot enters the aisle. In addition, the automatic expansion can be operated manually with a push-button switch at the entrance to the aisle. The hanging

bed, which is moved by a rack and pinion attached under the beam, is driven by a DC24V gear-motor (rated output: 34W). The gear-motor is suitable for use in a humid environment, since it is generally used to roll up the side film on the greenhouses (Figure 2).

Table 1 shows the specifications of the movable

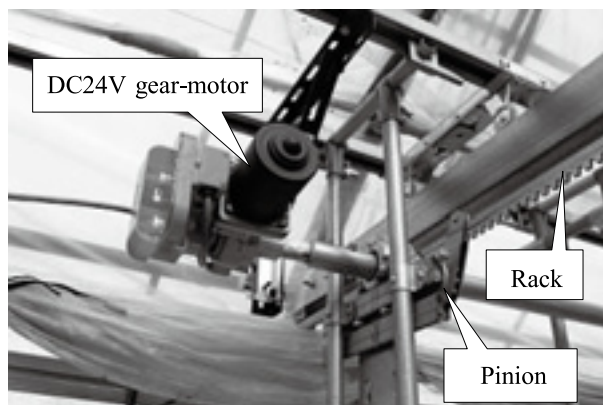


Fig. 2. Rack and Pinion driven by gear-motor

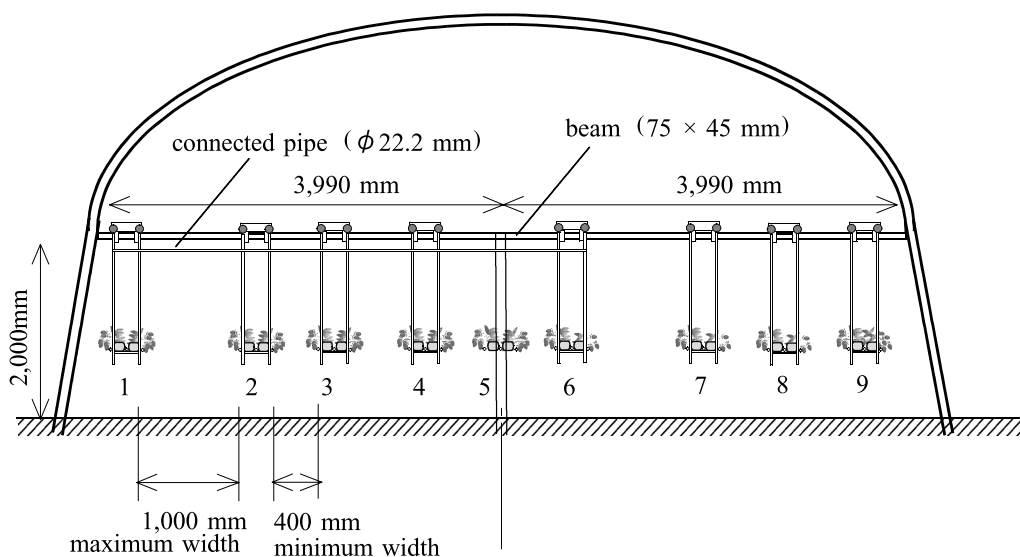


Fig. 1. Configuration of hanging beds

Table 1. Specification of movable hanging-bed system

Hanging-bed	Number of beds : 9
	Size: 35.0(L) × 0.4(W) m
	Height: 1.0 m
	Number of gear-motors : 4 (DC24V, 34W)
Planting bench	Volume: 0.4L/plant
	Planting bag volume: 0.3L/plant (45(L) × 10(W) cm)
Control Unit	Sequence control by programmable logic controller (PLC)
	Aisle opening with a button switch placed at the aisle entrance

hanging-bed system, which is 8 m wide and 35 m long and was installed in a greenhouse owned by a strawberry farmer in Saga Prefecture. In a nine-bed system, the center bed is fixed, and eight beds are moved by four gear-motors. In Figure 1, bed Nos. 1 to 4 have gear-motors, while bed Nos. 6 to 9 are uninstalled. Bed No. 1 is connected to a No. 6 by a 5-m pipe (diameter 22.2 mm); bed No. 2 to No. 7, No. 3 to No. 8, and No. 4 to No. 9 similarly. Therefore, the aisle between bed Nos. 6 and 7 is expanded simultaneously with the 1-m enlargement of the aisle between bed Nos. 1 and 2. The operation is controlled by a programmable logic controller (PLC).

Two planting benches are suspended from the two-wheeled frame of the hanging-bed (Figure 3). The volume of the bench is about 0.4 L per plant of strawberry. A nonwoven-fabric planting bag 45 cm long can be planted in the number of three strawberries, the volume of which is about 0.3 L per strawberry plant. The strawberries are nursed only by the planting bag, while the transplanting time could be shortened because of only setting on the planting bench.

## 2. Outline of the platform system for the strawberry harvest robot

A strawberry harvest robot for the hanging-bed cultivation system has been developed by the Bio-oriented Technology Research Advancement Institution. The robot, which has an end-effector comprising two fingers and a cutter for removing the fruit at the peduncle, can harvest one fruit in about 10 seconds. We have to develop a traveling system for the robot to be operated alongside the hanging beds and we developed a platform system, so that the robot could approach a fruit from every aisle in the greenhouse.

The platform for the robot travels on two rails, 30 × 60 mm in size. The left rail has stoppers attached at both

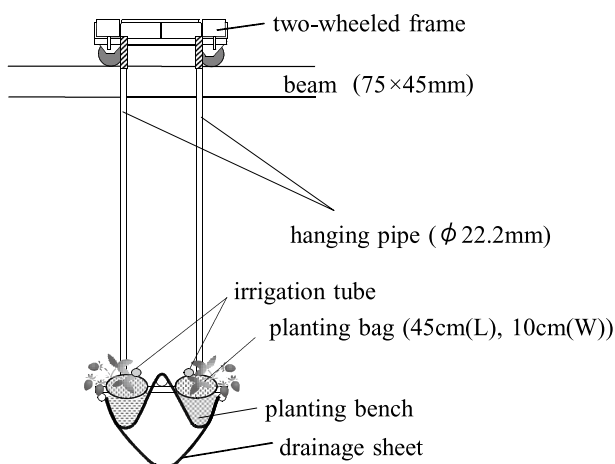


Fig. 3. Two planting benches of hanging bed

ends (Figure 4). One stopper operates to stop the limit switch of the platform, while the other is used to make the platform turn back. The robot is attached to frame B, which moves on the main frame (A) of the platform.

The trial platform is 3.7 m wide and 1.2 m long (frame A) in the Saga greenhouse (Figure 5). Frames A and B are moved by 120 W (100 V AC) motors. Frame A travels 200 mm every time the robot sends a signal after discontinuation of the harvest.

## Results and discussion

### 1. Strawberry yields under high-density cultivation

In case of 6 m width greenhouse cultivation, a conventional table-top system was used to grow 8,300 plants / 10 a. A high-density system grew 1.5 times that number. The strawberry yield of the high-density system was 5.2 t / 10 a (the cultivar Benihoppe), which is estimated as 1.5 times higher than a conventional system (Figure 6). The other case in Figure 1 greenhouse cultivation, namely the cultivar Sagahonoka yield, was about 8.5 t / 10 a.

### 2. Movable hanging-bed system

#### (1) Material cost

Our movable hanging beds were installed in a greenhouse 8 m wide and 39 m long. Their material cost was 1.5 million yen / 3.1 a (= 4.8 million yen / 10 a). The nine beds cost 259 thousand yen; the drive system was 248 thousand yen; the moving frames were 538,000 yen; and the controller was 454 thousand yen. The material cost of conventional table-top systems ranges from 1.5 to 4 million yen / 10 a. The overall cost is not considered high because productivity is 1.5 times that of a conventional system.

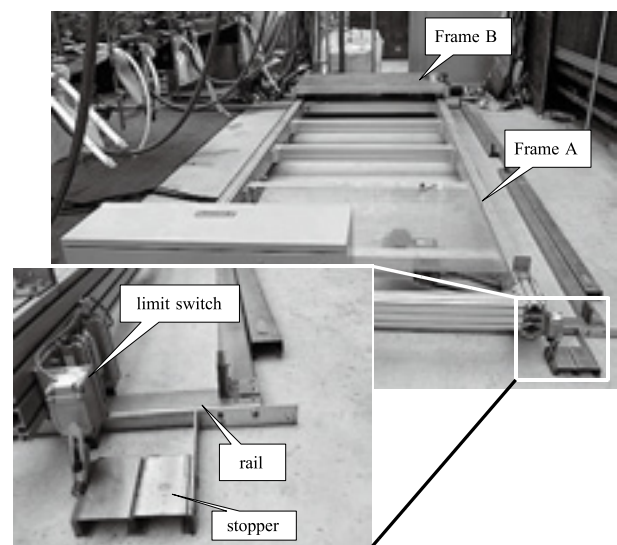


Fig. 4. Stopper and limit switch of platform

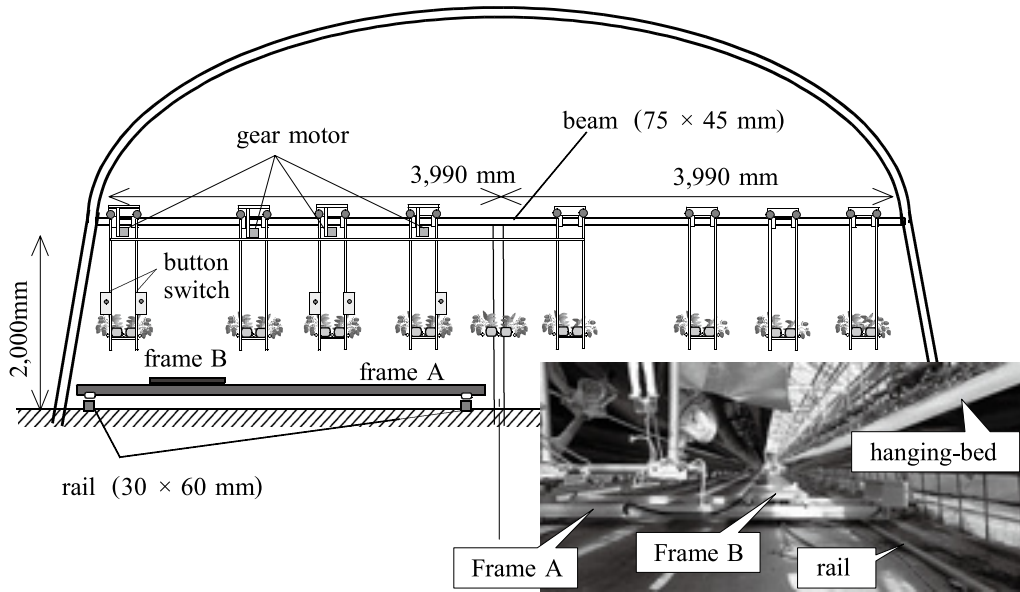


Fig. 5. Trial platform setting in Saga greenhouse

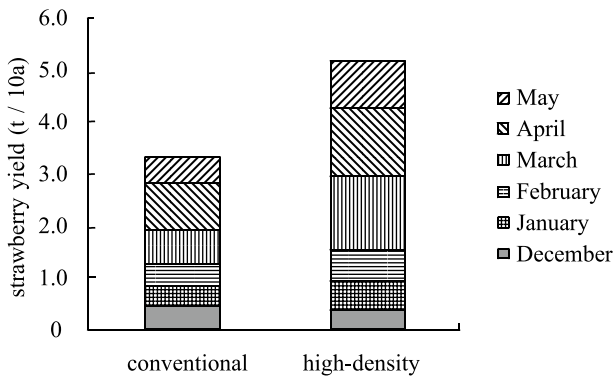


Fig. 6. Strawberry yield increase of high-density cultivation  
Cultivar: Benihoppe

(2) Performance and improvement

The weight of a hanging bed (length: 35 m, including soil and plants) is estimated to be 550 kg. The beams attached at intervals of about 3 m and a height of about 2 m are confirmed as having adequate strength.

A gear-motor can drive two hanging beds comfortably. An aisle of movable hanging beds opens in about 30 seconds via a switch at the aisle entrance. The opening operation is stopped by pressing the button again. Eighty-second intervals are set to prevent accidents after the opening operation.

3. Platform system for the strawberry harvest robot

The trial platform approximately 30 cm high travels on the rails at a 20 cm pitch. Frame B can be automatically moved to a predetermined aisle for harvesting. The aisle opens synchronously before the mainframe moves

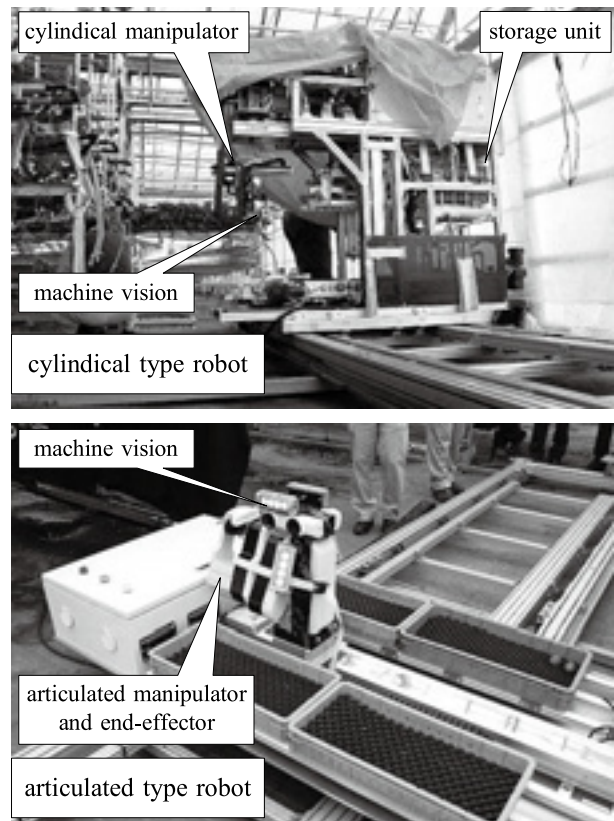


Fig. 7. Two-type strawberry harvest robots

under the hanging beds.

Two types of strawberry harvest robots have been able to attach the trial platform (Figure 7), namely cylindrical and articulated types<sup>3</sup>. The mass of the robots is about 100 – 150 kg, but frame A can travel at the setting speed of 0.08 m/s.

The platform can also be used for chemical spraying with a boom-nozzle attachment. In this case, frame A travels at 0.2 m/s.

## Conclusion

Our movable hanging-bed system was effective for increasing the strawberry yield and ease of operation. The overall cost was about 4.8 million yen / 10 a, which is considered low because productivity is 1.5 times that of a conventional system.

Our trial platform system accommodates the adaptation of strawberry harvest robots to greenhouses.

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