DEVELOPMENT OF GRAFTING ROBOT

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ABSTRACT

This study was carried out to develop an automatic grafting system suitable for fruit-vegetable seedlings. The study consisted of two research sections: 1) development of a medium-sized, low-cost automatic grafting system for cooperative farms and commercial seedlings production company, and 2) commercializing research for prototype development based on the above concepts. The grafting robot developed in this research can be described as follows,

a. Developed grafting robot can cover the whole operations for grafting scion and rootstock, only if operator provides scion and rootstock tray.

b. Five seedlings can be grafted at one time, and about 1,200 seedlings can be grafted in one hour.

c. The success ratio of mechanical grafting scion and rootstock with ceramic pin bonding provided by the holder is more than 95% when the conditions of seedlings are satisfied.

d. The grafting efficiency has improved over 10 times compared with manual work, and the grafting cost generated 44% savings.

Key Word: Robot, Grafting, Tomato, Ceramic-pin

INTRODUCTION

In Korea, grafting of seedlings is very popular in fruit-vegetable production. At present, seedlings grafting is done manually. In 1999, the number of seedlings grafted was over 500million. There are sold to farmers who tend to buy the high quality grafted seedlings. This necessitates mechanization of the work to increase production of higher quality grafted seedlings.

MATERIALS AND METHODS

A labor-saving grafting system was designed considering price and operating days. The inarching graftage was selected for graft-taking rate, target crops of grafting, etc. The system was developed in a scale appropriate to cooperative farms and moderate-size plant factory. The Pin-method employed in this system as inarching graftage is shown in Figure 1.

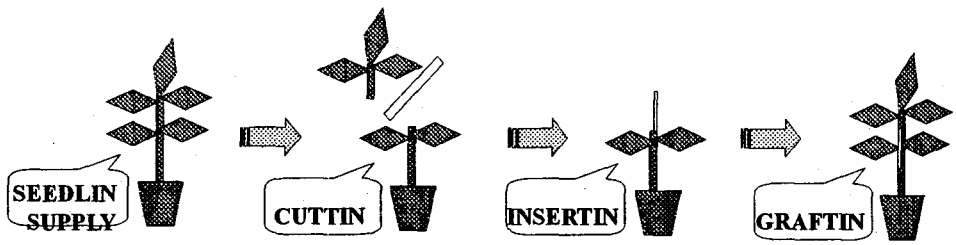

Figure 1. Process in pin-method grafting for tomato.

RESULTS AND DISCUSSIONS

The grafting robot was designed as shown in Figure 2. The robot could accomplish four functions in grafting ; supplying scions and rootstocks on the two conveyor belts, cutting the two stalks, inserting a pin to a rootstock, and grafting the two stalks.

On the two different conveyor belts, scions and rootstocks move to the grafting position, and then the rootstock's leaves are removed before approaching the photo sensors. Then, the sensors recognize the stalks, and the conveyor belts stop. Grippers hold the two stalks and two ceramic knives cut the two stalks in horizontal direction. A pin, provided by the pin holder, is inserted to the rootstock, and the scion moves toward the pin in the rootstock. Finally, the rootstock is combined with the scion by the pin. After the grafting process is completed, the grafted plant is discharged. One-chip microprocessor-based controller, including I/O interface and driver board was built to control the actuating sequence of the system.

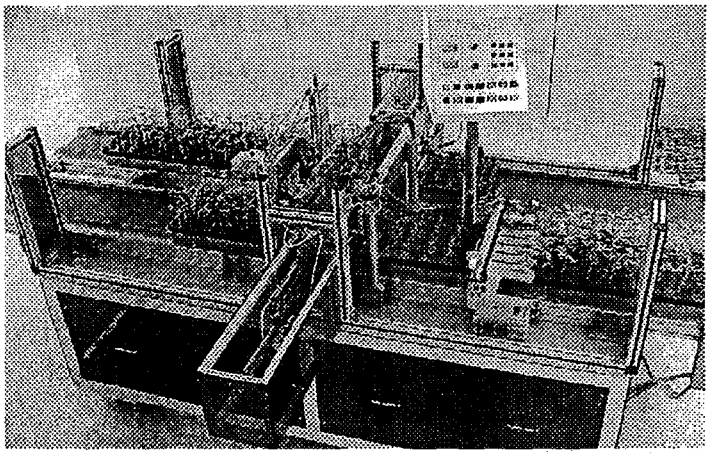

Figure 2. Photo of the prototype grafting robot

Table 1 shows the specification of the grafting robot system completed by adding an air compressure and cell trays.

Table 1. Specification of prototype system.

Size(mm)			Compressure (kg_f/cm^2)	Ceramic pin	No. of cell per tray	
L	W	H			Scion	Rootstock
3,000	2,200	1,500	5	L:15mm Dia:Ø0.5mm Pentagon shape	5× 16 (24× 24 in cell)	5× 8 (52× 52 in cell)

The properties of the scions and rootstocks used by prototype system in grafting operation are shown in Table 2. As this robot could perceive the missing plant, supplemental plating should be done manually before grafting. If the seed is sown at the corner of the cell, the robot hand can not grasp the hypocotyl accurately. Therefore, the seed must be sowed within a center circle of diameter 12mm.

Table 2. The properties of the scions and rootstocks used in this study.

	Rootstock	Scion
Seedling in cell (mm)	Dia. 12	Dia. 12
Cotyledon height(mm)	26~	20~
Cutting height(mm)	25	10
Hypocotyl diometer (mm)	1.5~5.0	1.2~
Plant length (mm)	33~	~100
Hypocotyl degree(°)	30° less than	
Plant width(mm)	< 130	< 80

Two workers are needed to operate the grafting robot. One is main operator, the other is assistant who delivers seedling trays and plants. This robot can graft five seedlings at one time, and the maximum grafting performance is about 1,200 seedlings per hour(Table 3).

The success rate of grafting increased to over 95% after trials and errors. Failure of grafting was mainly caused by the irregular size of seedlings. The errors in positioning of the sliding cutter and grafting tool resulted from the variation of the hypocotyl thickness (Table 4).

A nursery room for grafting plants was designed to control temperature, humidity, and daylength. The room temperature and relative humidity were set at 25℃and 90%, respectively. The grafted plants are kept in the nursery room for 4 days. Under there conditions, survival rate of grafted plants increased to over 95%. The sources of errors are shown in Table 5.

The grafting efficiency was over 10 times better than manual work, and the grafting cost was reduced by 44%.

Table 3. Grafting performance of the prototype

No of seedling	Grafting time(sec)	Grafting result		Grafting performance (Seedling/hr)
		Well	Missed	
1,015	3,045	965	50	1,200

Table 4. Grafting ratio of the seedling

Grafting ratio	Remark
95 % (965/1,015)	Plant length of scion over 100㎜ : 1% Grafting tool error : 3% Less than Ø1.2㎜ of scion dia. : 0.7% Less than Ø1.5㎜ of rootstock dia. : 0.3%

Table 5. Survival percentage of the seedling

Survival percentage	Remark
95 % (917/965)	Scion cutting stem greater than rootstock : 3% Cutting error of scion : 1% Cutting error of rootstock : 1%

CONCLUSIONS

This study was carried out to develop an automatic grafting system suitable for fruit vegetable seedlings. The study consisted of two research sections: 1) development of a medium-sized, low-cost automatic grafting system for cooperative farms and commercial seedlings production company, and 2) commercializing research for prototype development based on the above concepts. The grafting robot developed in this research can be described as follows,

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