Automatization, Labor-Saving and Employment in a Plant Factory

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Recently, plant factory related businesses are increasing because of abnormal climate and natural disasters. Various industries have entered the plant factory business with new cultivating techniques. Various attempts are being made to produce high value crops with research and development of various cultivating techniques. Additionally in the plant factory business, large-scale production, automation and labor-saving are also important for establishing a sustainable industry. Therefore, several techniques have been utilized to improve the use of space, application of automation, and productivity in the plant factory.

Keywords : automatization, employment, job creation, plant factory

INTRODUCTION

The impact of climate change has become a threat for stable agricultural production of vegetables from greenhouse and open culture systems. Moreover, radiation contamination caused by the Great East Japan Earthquake has aggravated stable crop production. We are faced with a problem of how to produce and supply agricultural products. Who could have ever predicted that the media would be taking an interest in the plant factory? The consensus in the plant factory is that industry growth has been caused by the entrance of many companies from a variety of businesses which produce vegetables and supply the system in the plant factory. On the basis of previous companies and research achievements, the plant factory is focused on adding value using multi-staging and LED lighting. Although this focus is important, large scale production, automation and labor-saving will also need to be considered in the future in order to become a sustainable industry. We would like to examine the effects of automation and labor-saving on labor’s work and employment is of particular interest.

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Case introduction of the Netherlands

In the Netherlands, stabilized management is achieved through hiring of low-wage foreign workers and labor-saving by automation in large scale protected horticulture facilities. However in Japan, plant factories have received a lot of attention due to expectations of new industry and job creation in rural areas. Therefore, job creation should take precedence over the introduction of a costly automated system in plant factories. To increase cost competitiveness, production costs must be reduced in ways such as large scale production, automation and labor-saving, although job creation is also important. It is expected that development of the plant factory facilities should keep a balance between job security, automation and labor-saving.

Automation and enhancement of productivity: Development of flattened spacing system

In a container type plant factory that uses maritime containers (Fig. 1), we developed an automated spacing system (Fig. 2). This system increases the space between columns depending on the size of vegetables, which improves productivity through effective use of flat space (Fig. 2). It was substantiated that it is possible to improve the productivity by about two times as compared with an average deep flow technique (DFT) hydroponic system. Following this, we developed an automated spacing system which automates the process from planting to harvest by developing a large scale spacing system in a sunlight type plant factory (Fig. 3). In this system we designed a process in which the laborer manually plants the seedling into planting holes along a column. We think that manual planting is more suitable than machine planting, because this is important for controlling the growth of vegetables. During development, we achieved two dimension spacing by designing an automated process that not only increases the space of the column but also increases space between vegetables in the columns. In this way we could further enhance productivity and yield (Fig. 4).

Development of automated spacing system

The flat type automated spacing system mentioned above focuses on improving vegetable growth productivity and labor-saving through effective use of flattened space. Recently, sterically-multistaged cultivation has used fluorescent light and LED as a main artificial light source. However, most examples are multi-tiered traditional DFT and NFT systems. There are few examples based on auto-
A tri-dimensional automated transportation system was made by ESPEC MIC Corp. and Tsubakimoto Chain Co. in the plant factory R & D center in Osaka Prefecture University. This system effectively utilizes small space. The number of cultivation levels, the cultivation period and the height spacing are all determined by the growth of the vegetable (Figs. 5, 6).

While creating this system, NFT type cultivation trays and planting panels using vacuum plastic molding technology were developed. Twenty-one heads of lettuce can be planted on each of these planting panels.

In this process, established plants that are grown in the nursery room are planted on trays which are raised to the fifteenth level by the automated transportation system in the morning. Vegetables at the bottom level are harvested in the afternoon. Trays and panels on the second to fifteenth levels are lowered a level every day after the bottom level is harvested. Except for harvesting related processes (Cleaning bed and panel, packaging), other growing and production tasks are performed by one person (Table 1).

**Review of productivity enhancement by automated transporting systems**

Production efficiency of an adapted automated transporting system was compared with a non-adapted automated transportation system in a plant factory (Table 2).

In the adapted automated transportation device plant factory, 252 heads of lettuces were harvested every day, with the potential to harvest 90,720 heads of lettuces per year (360 harvests). In a non-adapted automated transportation device plant factory, the maximum level of cultivation shelves is four due to efficiency and worker safety constraints. In this system, the daily lettuce production was
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about 132 heads and potential annual production (360 harvests) was 47,520 heads.

The cultivation room of the adapted automated transporting system has a larger total growing area and higher planting density than the non-adapted automated transporting system. The total growing area on 35 m$^2$ of floor area is 129.6 m$^2$ in an adapted automated transporting system cultivation room and 59.4 m$^2$ in a normal non-adapted cultivation room. Planting densities are 108 heads m$^{-2}$ in an adapted automated transporting system and 75.4 heads m$^{-2}$ in a normal cultivation room with a non-adapted system.

Each production cost was calculated during the trial using the following conditions. Running cost and production amount of the non-adapted system were both set at one third of those in the adapted system. Number of workers in both systems were set at 1.5. The results show production cost in the automated cultivation system is about 21% lower than the non-automated system (Fig. 7).

It is to be considered that production efficiency was increased through the use of an automated transporting system and that the workload for the same worker was also increased. It was also observed that the employment cost rate in the automated cultivation system was lower than the non-automated cultivation system (Fig. 7).

In addition to increasing the size of the plant factory, ongoing automation (such as cleaning, transporting, packing and managing) productivity will be increased and workload decreased.

DISCUSSION

Unlike a sunlight type plant factory, an artificial light

### Table 1 Growing and production task flow and number of workers per day.

| Area                  | Nursery room (Manual system) | Cultivation room (automated transportation system) | Workroom |
|-----------------------|------------------------------|-----------------------------------------------|----------|
| Growing task          | Seedling and transplanting   | Planting                                      | Harvesting |
| Number of workers per task | One (1 h)                  | One (2 h)                                     | Two (2.5 h / worker) |
| Production task       | Cleaning (room) and maintaining | Cleaning (room) and maintaining | Cleaning (bed and panel) and packaging |
| Number of workers per task | One (0.5 h)                | One (0.5 h)                                   | Two (1.5 h / worker) |

### Table 2 Growing area and production amount between adapted and non-adapted automated transportation system.

| Area of cultivation room | Adapted automated transportation system | Non-adapted automated transportation system |
|--------------------------|----------------------------------------|---------------------------------------------|
| Area of cultivation room | 35 m$^2$                                | 35 m$^2$                                    |
| Growing area             | 129.6 m$^2$                             | 59.4 m$^2$                                  |
| Growing area index       | (0.72 m$^2$/panel × 15 levels × 12 columns) | (2.97 m$^2$/level × 4 levels × 5 columns) |
| Planting density         | 108 heads m$^{-2}$                      | 75.4 heads m$^{-2}$                         |
| Amount of production per day | 252 heads                          | 132 heads                                   |

Fig. 7 Production cost rate of lettuce between adapted (left) and non-adapted (right) automated transportation systems (Depreciation is not included. Monthly electricity charges, water charges and expendable items of the non-adapted automated transportation system is about half of those of the adapted automated transportation system).
type plant factory can make efficient use of space because of multistage cultivation. Efficient use of space affects the amount of production and cost. Results show that increasing the number of levels increases production amount and decreases production cost. However, it is certain that there are limitations related to worker safety and the efficiency of work at heights.

In a plant factory with high-rise and multi-level shelves, worker safety, efficiency and increased production will be secured by using an automated transporting system. This is especially important in an artificial light type plant factory, where an increase of production and a decrease of electricity charges and employment pay are important for reducing production costs. Automation of cultivation systems can decrease the workload for production amount and also increase the production amount without increasing the number of workers. Therefore, it can reduce employment costs.

This provides an opportunity for job creation, social contribution and economic support from the government. Automation and increasing the size in plant production systems are underway for reducing production and running cost. Automation and increasing size can create opportunities for employment and social contribution.

As mentioned above, results suggest that automation in an artificial light type plant factory decreases running costs and increases productivity. In addition, it also creates new job opportunities and social contribution. However, because of the high initial cost, it is recommended that preparations are made for automation that consider production scale, product and sale destinations before designing the plant factory.