THE USE OF PLUG TRANSPLANTS IN KOREA

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ABSTRACT

Plug technology was developed for the efficient production of high-quality seedlings for transplanting. The technology was introduced into Korea in 1992, and has become an important industry. At first, the technology was important mainly for the mass production of vegetable seedlings, which were transplanted into greenhouses or the open field. Recently, there has been more interest in the plug production of flower seedlings. In this Bulletin, the plug industry in Korea is discussed in relation to the demand for the technology, its current status, and the facilities used in plug systems in Korea.

INTRODUCTION

In the past, horticultural seedlings for transplanting in Korea were produced in cold frames or hot beds by individual growers. The main aim was to extend the growing season in Korea's highly seasonal climate. In recent years, high-quality seedlings of various crops have been produced by groups of growers, working together. The aim of raising transplants has been widened to provide a stable supply of high-quality seedlings and improved transplanting efficiency. Plug production has been an important development. The need for year-round production of a diverse range of horticultural crops, a labor shortage on farms and high labor costs have all promoted an intensive technology suited for mass production. Furthermore, growers began to mechanize transplanting operations, and there was a growing market demand for tray plants, both of which needed the mass production of uniform transplants. Although plug technology was developed mainly for flower crops in Western countries, it is currently being applied in Korea to the production of vegetable seedlings.

THE CONCEPT OF PLUG TRANSPLANTS

Benefits of the Plug System

Plug or cell transplants are seedlings or small vegetatively propagated plants which are raised in individual small cells, called plugs. The plugs are filled with a cohesive medium, and are eventually transplanted into other growing systems. In a plug system, seeds are usually sown by an automated seeder into plug trays. These may have from several dozen to hundreds of cells. With a few exceptions, only one plant is raised per cell. Plug transplants have both advantages and disadvantages compared to traditional transplants (see Table 1).

Changes in Transplant Production Technology

All over the world, there have been gradual changes in the way vegetable and flower transplants are produced (see Table 2). At an early stage of development, transplants were raised in late winter in cold frames or in hotbeds, to avoid damage from late frost and to give the plants a head start. The growth and development of the transplants were far in advance of those sown out in the field after the

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danger of frost had finally disappeared. In this way, the growing period was extended, early harvesting was possible, and farmland was more efficiently utilized. The protection of young plants from frost and cold was the prime objective.

However, as crop cultivation under protected structures increased, changes in the social environment brought new objectives. There was an increased need for a stable year-round supply of uniform, high-quality transplants. At the same time, the farm labor force became smaller and the average age of farm workers increased, which made it necessary to increase the efficiency of labor.

Currently, transplant production technology is developing into commercial mass production systems which are not affected by the seasons. With the plug system, in particular, operations are systematized, integrated and mechanized, producing highly uniform transplants throughout the year according to a planned production schedule. Currently, transplant production is a separate activity from crop cultivation, and is managed by specialized producers called plug growers. Crop growers simply buy the transplants of their choice from the plug growers, and devote their efforts to growing their crop.

Table 1. Advantages and disadvantages of using a plug transplant system

Advantages	Disadvantages
Faster and more accurate sowing by mechanical seeder - saves time, labor and seeds	Special equipment required, which is costly
Little or no transplanting shock to young plants	Small soil volume and greater chance of error
Transplanting is done later, with little or no damage to plants	Need for more precise control of environment
Less spread of disease	More space required in the germination area, which should be heated to a higher temperature than other growing areas
Easier to handle plants, which reduces the transplanting time	
Saves overall greenhouse space and allows for extra crops in the same unit area	Operators must be competent and well-informed
Uniform transplants, and transplanting can be mechanized	

Table 2. Changes in the objectives of horticultural transplant production

	Major objectives		
	Stage 1	Stage 2	Stage 3
Cropping system	Extending the growing period	Extending the growing period	Year-round production
Transplant quality	High quality	High quality, diverse range of crops	Uniformity
Operation efficiency	Handling efficiency	Labor saving, mechanization	Mass production
Production type	Individual	Joint or group	Group, commercial

Source: S.G. Park 1994

Why was the Plug System Introduced into Korea?

Problems of the Traditional Technology

Traditional transplant production technology has several limitations and problems. Raising the seedlings takes a relatively long time (Table 3). A large amount of medium is used, and since the components, of the medium are neither uniform nor sterile, the result may be disease and/or seedlings of different quality and size. A relatively large area of land is needed, and management costs are high. The result is poor transplant quality and high production costs (Table 4).

Secondly, big growing containers containing a large volume of medium are heavy. Transportation and mechanization are difficult. Roots are severely damaged in the process of transplanting, so that plants take longer to establish their roots after transplanting.

Thirdly, production by individual growers of their own transplants has limitations. The low level of technology used, the small scale of production, and the lack of standardized materials or a standardized production environment, are not favorable for the production of high-quality transplants. Even though the labor input is high, the transplants are poor.

Finally, it is difficult for growers who depend on their own seedlings to maintain year-round production of a variety of crops in diverse cropping systems. All these problems made specialized plug production desirable (Table 4).

Need to Reduce Production Costs

The demand for high-quality horticultural produce is steadily increasing in Korea, and is constant throughout the year, regardless of the season. This has led to a steady increase in greenhouse cultivation. The farm labor shortage means that greenhouse operations need to be mechanized and automated. In addition, Korea's domestic produce must be competitive in terms of price and quality with imported commodities from other countries.

Table 3. Time (days) required for the production of transplants for major vegetable crops, relative to cultivation period

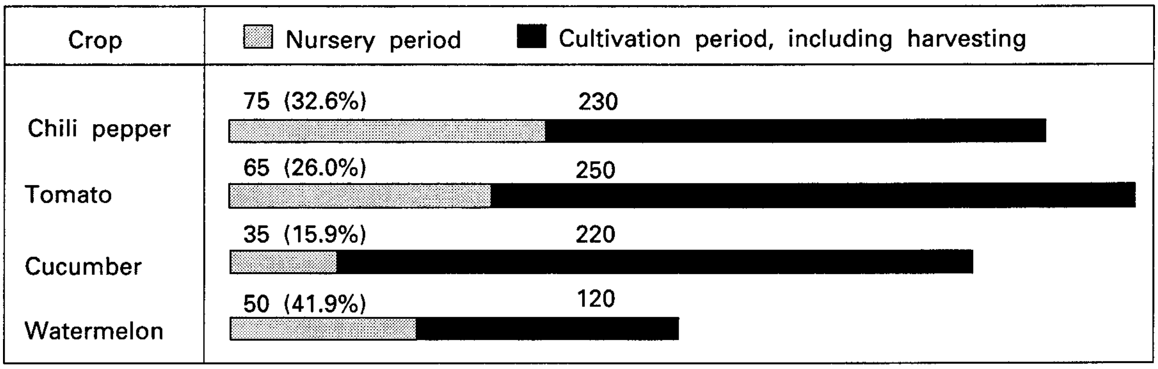

Table 4. Comparison of traditional vs. plug transplant production efficiency

	Traditional	Plug	Plug advantage
Labor (hours per ha)	2,010	460	76% saving
Cost (US$ per plant)	0.175 (cucumber)	0.083 - 0.100	48% saving
	0.083 (hot pepper)	0.050 - 0.058	35% saving
Medium (mL per plant)	300 - 500	15 - 32	94% saving
Seed consumption (arbitrary)	100	70	30% saving
Production efficiency (plants per m^2)	1,000	10,000	10 times increase

Source: Kim 1998

Plug transplants are high in quality as well as uniform. This makes possible mechanized transplanting, thus reducing production costs (Table 5).

Benefits to Growers

Plugs give growers the mental and physical freedom from the pressure imposed by the difficult and complex process of transplant production. Growers can give more time and effort to growing crops and improving their production efficiency.

Secondly, the supply of professionally-produced high-quality transplants is plentiful, stable, and timed so as to meet growers' needs.

Thirdly, handling and transplanting are easy, saving time and costs. In addition, the utilization of greenhouse space is more efficient, and there is a more flexible response to market demand.

DEMAND FOR PLUG TRANSPLANTS IN KOREA

Demand for Vegetable and Flower Transplants

The areas cultivated in different types of vegetables in Korea in 1996 were as follows: Root vegetables (radish, carrot, etc.), 45,038 ha; Leaf vegetables (Chinese cabbage, lettuce, spinach, cabbage, water dropwort, edible chrysanthemum) 70,882 ha; Fruit vegetables (watermelon, melon, cucumber, squash, tomato, strawberry, eggplant, green pepper, and muskmelon), 81,485 ha; Condiment vegetables (chili pepper, garlic, onion, green onion, and ginger) and others, 24,773 ha. Flower production occupied a total of 5,342 ha, including 3,274 ha of greenhouses. If we estimate that around 16 million vegetable and flower plants were grown, half of which began as transplants, about 8 million horticultural transplants were needed in 1996. If we assume that 50% of these transplants were supplied as plugs, then the demand is about 4 million each year. The potential for the plug industry in Korea is therefore quite large.

The maximum number of plug transplants that can be produced in a 4,860 m^2 plug greenhouse in one year varies according to the crop species (Table 6). Currently, it is estimated that about 60 4,860 m^2 plug greenhouses, including a number of 14.3 ha greenhouses subsidized by the government, are in production in various parts of Korea. Assuming that each greenhouse produces 20 million plugs a year, then to meet the demand for 4000 million plug transplants a minimum of about 200 greenhouses are required. Demand can be expected to increase as more growers start to use plugs and the number of greenhouses expands.

Table 5. Price and production time of major plug transplants sold in Korea in 1993

Crop	Tray size (no. cells)	Price per plant* (US$)	Production time (weeks)
Chili pepper	128 - 200	0.05 - 0.10	8 - 9
Cucumber	128 - 162	0.04 - 0.06	2 →
Chinese cabbage	128 - 288	0.02 - 0.03	4 - 5
Tomato	128 - 188	0.06 - 0.08	8 - 9
Lettuce	128 - 288	0.02 - 0.03	3 - 4
Cauliflower	128 - 288	0.03 - 0.04	4 - 5
Chrysanthemum	128 - 288	0.05 →	5 - 7
Marigold	288 →	0.03 →	4 →
Cyclamen	128 - 288	0.10 - 0.13	16 - 18
Carnation	128 - 288	0.06 - 0.08	6 - 8
Primula	128 - 288	0.06 - 0.17	12 - 15

* 1US$ = 1,200 Korea Won
Source: S.G. Park 1994

Current Status of Plug Technology in Korea

Table 7 shows the current status of plug technology in Korea, compared to that found overseas in other industrialized countries. The production of a diverse range of crops, each grown in relatively small quantities, presents numerous problems in Korea. The variety of crops demands a number of diverse greenhouse environments for optimum plant quality. This is difficult to achieve on a single holding. Also, the demand for different species and varieties changes with the season, and varies in different parts of the country.

Secondly, because of the small volume of medium used for each seedling, precise control of heating, irrigation and fertilization is critical. Failure to achieve control of the environment causes various disorders. Some plug growers fail, and resume the use of larger cell trays.

Thirdly, for uniform growth, high-quality seeds must be used. If germination is not uniform, there will not be uniform growth.

The development of proper technology suited to Korean conditions, as well as materials and equipment related to plug production, is necessary. This has to be supported by appropriate cropping systems and cultural management. Because plug transplants are grown in a small volume of rooting medium, there is a very narrow window of opportunity with regard to transplanting time. Small plants have a relatively weak tolerance to cold or heat. All,

Table 6. Numbers of plug transplants that can be produced in a 4,860 m^2 plug greenhouse each year

Crop	Time required per crop (days)	Tray size (No. cells)	No. of crops per year	Yearly transplant production (millions)
Chili pepper	60	128	5	13.4
Cucumber	30	72	8	12.1
Watermelon	35	72	7	10.6
Tomato	30	128	8	21.5

Source: Jeong 1998

Table 7. Comparison of current status of plug production technology in Korea and overseas

	Korea	Advanced countries
Transplant production	Large specialized system	Large specialized system
Production method	Mechanized plug system	Mechanized plug system
Medium	Individual mix, not standardized, various materials	Standardized media, simple and standardized materials
Seedling raising period	Long, 60 days for tomato, 75 days for chili pepper	Short. 35 days for tomato, 40 days for bell pepper
% germination	Low, 80% for chili pepper	High, > 90% for tomato
Seed treatment	In development	Commercialized (coating, pretreatment)
Transplant method	Manual, transplanted at a fairly advanced growing stage, mechanized transplanters being developed	Mechanized, transplanted at an early stage, includes flowers

Source: S.K. Park 1994

these factors have to be considered in crop breeding and marketing.

FACILITIES DEVELOPED FOR PLUG PRODUCTION

Plug production requires an environmentally controlled greenhouse, uniform good-quality media and fertilizers, standardized trays, a systematized seeding system, environmentally controlled germination chambers, culture beds equipped with automatic fertigation, a conveyor system for moving plug trays, and transplanting machines. A schematic diagram showing the flow of the system is shown in Fig. 1.

Development of Standard Greenhouses for Plug Production

Standard greenhouse models were developed in Korea, which took into account the factors involved in each step of plug transplant production. Two greenhouse models, an even-span glasshouse with a steel framework and an even-span greenhouse with rigid covers, were chosen as standard models. Both models were designed to be constructed either as a single greenhouse, or as two separate greenhouses connected by a gutter. The latter was designed to give the easy environmental control necessary for raising plug transplants of different crops at the same time. The greenhouse design included an estimate of the maximum number of transplants which can be produced at any one time, and specifications of construction costs, details of the construction, and an analysis of the safety of the structure with regard to snow and wind loads.

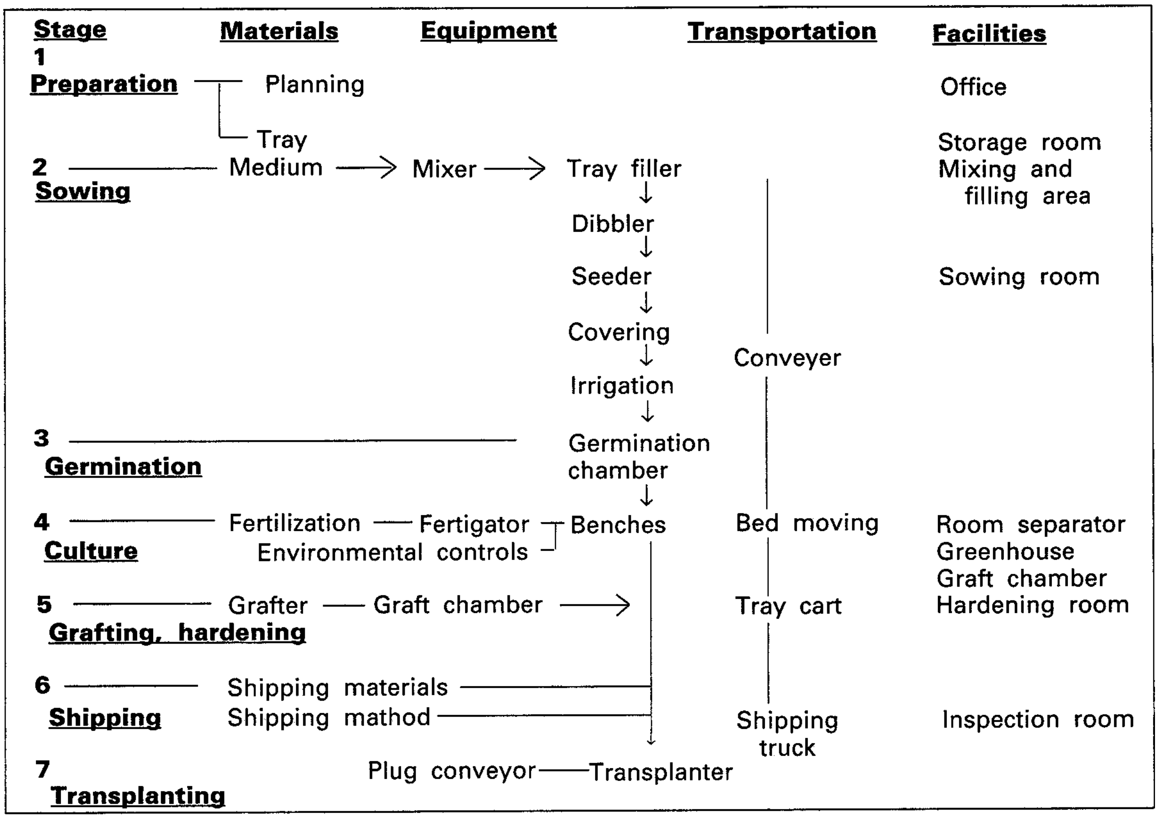

Fig. 1. Flow of materials, in the plug system, and equipment and facilities used
Source: J.C. Park 1994

Standardization of Facilities, Equipment and Materials for Plug Production

Equipment and facilities such as growing beds, thermal curtains which can be opened and closed, an overhead fertigation system, a fertilizer injector, an automated chemical fogger, an integrated environment control system, a germination chamber, a graft union chamber, and an automatic seeder, have all been developed for use in Korea.

Development of Automated Systems

Automated Seeding System

An automated seeding system recently developed in Korea can mix the medium, put it in trays of cells, sow seeds and cover them with medium, water the trays, and move them into a germination chamber. Only two persons are needed for this work, which can produce 150 trays of 200 cells per hour.

Automated seeders of both drum and nozzle types have been designed. The nozzle seeder is slower (180 trays per hour) than the drum seeder (up to 300 trays per hour). However, the nozzle seeder has 98% sowing efficiency, compared to 90% for the drum seeder. The nozzle seeder is also more efficient at handling seeds of different shapes and sizes. For this reason, only the nozzle seeder is being produced commercially in Korea.

Plug Conveyors to Move Trays in the Greenhouse

Movable greenhouse beds were developed, 1.9 m wide and less than 40 m long so that four lines of beds fitted into each 9 m wide greenhouse. Seven rows of standard 560 mm x 280 mm trays fitted longitudinally into each bed. This arrangement gave an effective culture area of 76 - 79%.

Two conveyor systems for moving trays, one consisting of moving beds on rails and the other of movable tray racks, were developed. Movable beds were five times more efficient than the tray racks, but cost ten times more to manufacture. Because of cost considerations, only the tray rack system was introduced to growers.

Standard Specifications for the Germination Chamber

Pressed styrofoam panels 200 mm thick, which have a high thermal insulation efficiency, were used on the walls. The germination chamber was estimated to need a cooling load of 36 $kcal \cdot h^{-1} \cdot m^2$, and a cooling and heating capacity of 166.4 $kcal \cdot h^{-1} \cdot m^2$. Floor heating with 25 mm XL pipes laid out at 15 cm intervals as radiators gave sufficient heat.

A fogging system was designed, based on the maximum removal of 0.8 $g \cdot min^{-1} \cdot m^2$ of water during cooling. With a fog particle size of 15 μm and a fogging capacity of 5 $g \cdot min^{-1} \cdot m^2$, 95% relative humidity is achieved in 10 minutes.

Greenhouse Management System

Greenhouses producing plugs need many different types of facilities and equipment. Prototype models were developed for a traveling fertigation system, a fertilizer injector, a cooling system, an ultra-fine fogging system, and a vertical curtain which can separate a greenhouse area into sections.

Integrated Environmental Control System

Hardware and software were developed which gave good environmental control. Hardware emphasizing the precision of different sensors, the reliability of the interface cards and controllers, optimizing the circuit composition of the local control panel, and prevention of surge or noise, was developed. Software development focused on grower-friendly menus and control programs. For the control of environmental set points, P, PID and fuzzy technologies were introduced. Factors such as temperature, humidity, air circulation, CO_2 supply, insulation, water curtains, protection of the growing environment under abnormal climatic conditions, and the fertilizer supply, are all automatically controlled.

Grafting Devices and Graft Union Chamber

The use of grafted transplants to prevent physiological disorders in fruiting vegetables is increasing. The major objectives of grafting transplants are to suppress soil-born diseases, increase resistance to adverse environmental conditions such as high or low temperatures, and avoid physiological disorders caused by continuous cultivation.

Grafting techniques are currently applied to cucumber, watermelon, and melon. However, they will be further extended in the near future to other crops such as tomato and chili pepper. The root stocks commonly used are pumpkin, gourd and melon.

Grafting methods commonly used include

inarching (cucumber), insertion grafting (watermelon), grafting of cuttings (many cucurbit transplants), inarching with only one cotyledon, and pin grafting (tomato).

Graft union chambers (or graft healing chambers) were developed and put into commercial production. The air temperature, relative humidity, and air movement of the chambers can be adjusted. A cabinet type with shelves on which trays can be stacked, and a tunnel type, were both developed.

Other Facilities

A soil mixer, tray filler, medium compactor or auto dibbler, a device to cover newly sown seed with medium, irrigation systems, fertilizer injectors, grafting devices, and transplanting machines were also developed and put into commercial production. Table 8 shows how automation has reduced the time required to produce lettuce seedlings for transplanting.

DEVELOPMENT OF PLUG CULTURE TECHNIQUES

Korean farmers have access to extension information on cultural management and control techniques which covers such areas as environmental needs at different stages of seedling growth, medium management, irrigation and fertilization techniques, water quality and preparation of nutrient solutions, CO_2 fertilization, control of growth, the production of grafted seedlings, hardening off of perennial plug seedlings, and postharvest handling of the plug seedlings.

Growing Media and Nutrient Solutions

Several different media and nutrient solutions have been developed and put into local commercial production, while several other media are imported. Most media are mixtures of peat moss, coir, perlite, vermiculite, and other materials such as ground or carbonized rice hulls. Some brands contain basal fertilizers, while others have no added fertilizers. However, most media currently blended and sold in Korea contain imported raw materials. Current research is working to develop growing media using local resources.

The irrigation system most commonly used in plug greenhouses is a traveling boom sprayer. Fertilizers are injected into the irrigation system. Not many growers are using CO_2 fertilization as yet.

Trays

Diverse sizes of plug trays, ranging from 32 to 288 cells, are currently on sale in Korea. The most widely used plug trays measure 56 cm x 28 cm x 5 cm, and contain square cells. Trays are made of rigid or soft plastic materials.

Seed Treatment and Germination

Seed treatment techniques are currently in development. Priming and coating techniques have been studied for several years, and seed companies are very interested.

In the first stage of plug seedling production, germination chambers with a high relative humidity supplied by fog nozzles, and an optimum gemination temperature, are used by most plug producers to ensure a high germination rate. Seeds are usually covered with coarse vermiculite, to meet

Table 8. Comparison of time required to produce traditional seedlings and plugs of lettuce seedlings, and transplant them

Method of seedling production and transplanting	Time required (hours per ha)		
	Transplant production	Transplanting	Total
Traditional transplants + manual transplanting	228	283	511
Plug transplants + mechanical transplanting	40	30	70

Source: G.Y. Kim 1998

the oxygen demand of the germinating seeds.

Regulating the Growth of Plug Transplants

Growers need to be able to control the growth of plug transplants. A number of growth control methods are used overseas, including manipulation of the water supply and nutrition, growth retardants, mechanical stimulation, day and night temperature differential (DIF), and light manipulation, to elongated growth in the plants. However, only very basic methods are used in Korea. Many producers have the problem that their plug plants are too elongated, especially when growers demand vegetable transplants at a more advanced growth stage. A few plug producers are interested in the use of DIF to prevent elongation of seedling stems.

Most plug growers sell their transplants as soon as they are ready. They do not usually hold them until prices improve. Precooling of transplants due to be shipped to growers is not widely practiced yet. Plug transplants are boxed, and shipped in trucks.

Production of Rooted Cutting and Hardened-off Transplants

Plug technology is usually applied to seedlings in Korea. However, the same technology can be applied to rooted cuttings of flowers such as chrysanthemum, rose and carnation. Rose and chrysanthemum are propagated asexually, and many growers use plug trays and clean medium. Cuttings treated with rooting hormones and planted in clean medium are put under a mist or fogger for rapid rooting.

Perennial crops such as strawberries and some flower species need low-temperature treatment for a certain time period to induce their reproductive phase. Plants are propagated first in plug trays, and then the young transplants are put into a cold chamber for a specified period of time to induce flowering.

CONCLUSION

Plug production technology was first introduced into Korea in 1992. It is now well established as an important industry, and represents a dramatic change in horticultural production methods. Most of the equipment, machinery and facilities related to plug transplant production and use are already developed, and produced commercially in Korea. However, some techniques of production and marketing, such as growth control and planned production to meet market demand, still need some improvement.

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