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2012 Modularization of Korea's Development Experience:

White Revolution of Agriculture in Korea: The Achievement of Year-round Production and Distribution of Horticultural Crops by the Expansion of Greenhouse Cultivation

2013

RURAL DEVELOPMENT ADMINISTRATION

Korea Fruit Growers Association

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Title	White Revolution of Agriculture in Korea: The Achievement of Year-round Production and Distribution of Horticultural Crops by the Expansion of Greenhouse Cultivation
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Research Management	KDI School of Public Policy and Management
Supported by	Ministry of Strategy and Finance (MOSF), Republic of Korea

Government Publications Registration Number 11-7003625-000060-01

ISBN 979-11-5545-052-9 94320

ISBN 979-11-5545-032-1 [SET 42]

Knowledge Sharing Program

Government Publications Registration Number
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Preface

The study of Korea's economic and social transformation offers a unique opportunity to better understand the factors that drive development. Within one generation, Korea has transformed itself from a poor agrarian society to a modern industrial nation, a feat never seen before. What makes Korea's experience so unique is that its rapid economic development was relatively broad-based, meaning that the fruits of Korea's rapid growth were shared by many. The challenge of course is unlocking the secrets behind Korea's rapid and broad-based development, which can offer invaluable insights and lessons and knowledge that can be shared with the rest of the international community.

Recognizing this, the Korean Ministry of Strategy and Finance (MOSF) and the Korea Development Institute (KDI) launched the Knowledge Sharing Program (KSP) in 2004 to share Korea's development experience and to assist its developing country partners. The body of work presented in this volume is part of a greater initiative launched in 2010 to systematically research and document Korea's development experience and to deliver standardized content as case studies. The goal of this undertaking is to offer a deeper and wider understanding of Korea's development experience with the hope that Korea's past can offer lessons for developing countries in search of sustainable and broad-based development. This is a continuation of a multi-year undertaking to study and document Korea's development experience, and it builds on the 40 case studies completed in 2011. Here, we present 41 new studies that explore various development-oriented themes such as industrialization, energy, human resource development, government administration, Information and Communication Technology (ICT), agricultural development, land development, and environment.

In presenting these new studies, I would like to take this opportunity to express my gratitude to all those involved in this great undertaking. It was through their hard work and commitment that made this possible. Foremost, I would like to thank the Ministry of Strategy and Finance for their encouragement and full support of this project. I especially would like to thank the KSP Executive Committee, composed of related ministries/departments, and the various Korean research institutes, for their involvement and the invaluable role they played in bringing this project together. I would also like to thank all the former public officials and senior practitioners for lending their time, keen insights and expertise in preparation of the case studies.

Indeed, the successful completion of the case studies was made possible by the dedication of the researchers from the public sector and academia involved in conducting the studies, which I believe will go a long way in advancing knowledge on not only Korea's own development but also development in general. Lastly, I would like to express my gratitude to Professor Joon-Kyung Kim and Professor Dong-Young Kim for his stewardship of this enterprise, and to the Development Research Team for their hard work and dedication in successfully managing and completing this project.

As always, the views and opinions expressed by the authors in the body of work presented here do not necessary represent those of the KDI School of Public Policy and Management.

May 2013

Joohoon Kim

Acting President

KDI School of Public Policy and Management

Prologue

Korea is known for achieving rapid economic growth in a relatively short period of time. Especially in 21st century, many developing countries consider Korea as proper model for their economic growth and want to learn the process of economic development and adopt it to their economic development plan.

Korea was annexed by Japan in 1910 and under Japanese rule until the end of World War II. Due to the Japanese unconditional surrender in August 15, 1945, the United States (U.S) and Soviet Union (U.S.S.R.) occupied South and North Korea, respectively along the 38th parallel to disarm the Japanese army. South and North Korea were placed under a U.S. and U.S.S.R. trusteeship and two different governments were set up at southern and northern parts of Korea. The Korean War began in Jun 25, 1950, lasted for 3 years and ended in 1953 with an armistice agreement. Korea remains the only divided nation in the world for now. After the Korean War, South Korea was one of the world's poorest countries in 1950s and depended heavily on international aid to meet daily necessities including food. However, South Korea has now become a donor country due to economic growth which is the result of the success of economy development plan since 1960s. South Korea is the only country which has emerged from a recipient to a donor country.

This rapid economic growth of South Korea came from agricultural development. Under Japanese colonial ruling, Korea suffered from food shortage since most of grains were exploited by the Japanese for the purpose of military supply. The food shortage continued even after unconditional surrender of Japan as many Korean citizens who returned from abroad and the Korean War that ruined the agricultural base. This made economic growth of Korea more difficult.

Korean government set out the first five-year National Economic Development Plan (NEDP) in the early 1960s and recognized that self-sufficiency in food production was the biggest challenge. Thus, the government promoted breeding of new cultivars, expansion and readjustment of arable land, and development of irrigation systems. The South Korean government launchedthe Rural Development Administration (RDA) in 1962 for the rapid progress of agricultural industry in order to increase food production via promoting the development and distribution of new technologies simultaneously. Finally in mid 1970s, 100% self-sufficiency in rice production was accomplished, which is called 'Green Revolution'. The success of the 'Green Revolution' in Korea enhanced national confidence and led President Jung Hee Park to erect a monument written in 'the Achievement of Green Revolution' in the campus of the RDA that had led this success. Rice self-sufficiency was linked to the increase of meat and vegetable consumption. Consumers' demand for fresh vegetables in the cold seasons promoted vegetable production under protected cultivation.

Korea has a temperate climate and distinct four seasons and most of the rain falls in summer, which is favorable for the growth of rice plants. However, its spring and autumn are relatively dry and it is impossible to produce crops in winter due to the cold weather. To adjust to the unique climate, Korea has developed a unique diet in winter including rice, the staple food of Korean, and the traditional fermented food, Kimchi. Rice is grown in summer and Chinese cabbage and radish, the main ingredients of Kimchi, are harvested in late autumn. Owing to the rapid economic growth, South Korea's per capita GNP increased from $100 in 1965 to $1,000 in 10 years. As with the increased GNP per capita, vegetable consumption also increased from 50kg in 1965 to 90kg in 1975. Until 1960, only a few vegetables were consumed in the processed form, Kimchi, but there has been a rapid increase in the consumption of other vegetables since 1970s when protected vegetable cultivation using greenhouse became popular.

According to the World Health Organization (WHO) in the United Nations system, recommended daily allowance of vegetables is 200g/day per capita (73kg/year), which is sufficient to meet the requirement for human health, but poor countries do not meet this requirement. Per capita vegetable consumption in South Korea was 50kg/year in 1965, 60kg/year in 1970, 90kg/year in 1975 and 120kg/year in 1980. It was not until late 1970s that Korea met this requirement when per capita GNP exceeded $4,000 and protected cultivation area for winter vegetable production was expanded rapidly.

The consumption of greenhouse vegetables is positively correlated with per capita GNP. In South Korea, per capita GNP increased from 1,000 USD in 1976 to 10,000 USD in 1995 and proportional increase in protected cultivation area was observed during the same period. As national income grows, South Korea has become one of largest vegetable consumers, showing increase in vegetable consumption per capita from 90kg/year to 150kg/year. The protected cultivation area also rose from about 6,600ha in 1975 to 81,600ha in 1995. After 1995, there was increase in the number of large-sized and multi-span greenhouses and year-round production of vegetables was established. Nowadays in South Korea, acreage under protected cultivation per capita is the largest in the world.

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Summary

The term, Green Revolution, has long been used for describing increase in food production through the improvement of breeding systems and agricultural infrastructure in developing countries. However, 'White Revolution' has only been used in South Korea, the name derived from the extensive use of plastic films (polyethylene film) for greenhouse, mulching and tunnel in field, which turns the color of the landscape into white due to the large acreage under protected cultivation. This report defines 'White Revolution' as the period of modernization of structure, material and technology for greenhouse to achieve the rapid expansion of protected cultivation area and stable supply of vegetables, from 1970s to 1990s.

Economic growth as well as the government plans and policies enabled the rapid expansion of protected cultivation using greenhouses in a very short period of time, the drastic changes called 'White Revolution'. Due to the success of the series of five-year NEDPs since 1962, economic growth leaded to the expansion of consumer markets for fresh vegetablesproduced in greenhouse over the winter season.

The first five-year National Economic Development Plan (NEDP) aimed at establishing independent national economy and increasing energy and food production. Thus, the construction of fertilizer plants and petroleum refineries began. During the first 5-year, the economic growth rate was 7.8% per year from 1962 to 1966.

The second five-year NEDP (1967-1971) aimed at developing agricultural and manufacturing industries and, thus, establishing an export-oriented economic structure. The construction of petrochemical complexes was completed and plastic films, fertilizers and agricultural chemicals were successfully produced and distributed. As a result, the number of prototype greenhouse made of bamboo frame increased rapidly. In this period (1967-1971), the economic growth rate was 9.9% per year and the new community movement(called Saemaeul movement in Korea) was started.

The goal of the third five-year NEDP (1972-1976) was to lay the cornerstone of the national economy. From newly constructed steelworks (POSCO), steel coil that can be used for greenhouse frame was distributed and, thus, the bamboo frames began to be replaced by steel. During this period, economic growth rate was a record-breaking 10.1% per year and South Korea achieved 100% self-sufficiency in rice production. The rice self-sufficiency induced the growing consumers' demand for fresh vegetable in the offseasons. The rapid economic growth in South Korea was continued thereafter, recording 5.8%, 8.6% and 10.0% of economic growth rate in the period of the fourth, fifth and sixth five-year NEDPs, respectively.

Protected cultivation begun in earnest, with 'Income increase program for farmers and fishers' (IIPFF) during the second five-year NEDP. The program was initiated by Agricultural Ministry and a special committee of six ministries was formed in 1968. IIPFF and special committee supported 'Economic crop production complex' and invested in various projects until 1971. Among many projects in the first IIPFF, 'Greenhouse vegetable production project' had good results. Therefore, the Korean Agricultural Ministry initiated the 'Greenhouse standardization plan' in order to modernize greenhouses and the plan was expanded in the second IIPFF which was launched in 1972. In 1974, the IIPFF was merged with the new community movement, which was later proven to be successful. Due to this continuous effort by government, protected cultivation area increasedexplosively in the late 1970s.

The rapid expansion and success of protected cultivation, called 'White Revolution', in South Korea was due to the success of the new community movement and the development of oil and steel industries. South Korea is not an oil producing country and all plastic films were imported until 1960s. Greenhouse vegetable production in winter became popular in 1970 only after the petrochemical industry had begun to produce and distribute plastic films at a low price. The production of steel coil from POSCO, established in 1973, made it possible to replace bamboo withsteel frame ingreenhouses, which increased the durability of greenhouse structure.

There were also significant changes to vegetable industry in South Korea during the period of 'White Revolution'. Vegetable production in greenhouse increased rapidly from 1.5% in 1970 to 33.3% in 1995 and protected cultivation area also from 1% to 20% during the same period. In the early years of protected cultivation, most vegetables grown in greenhouses were the vegetables that grow well in low temperature such as Chinese cabbage, lettuce, and cucumber. With the improvement of greenhouse cultivation technologies, however, it became possible to growvegetables that grow well in high temperature, such as watermelon and oriental melon in greenhouses. Therefore, the expansion of protected cultivation facilitateda year-round production and distribution of most vegetables in demand. In these days, many vegetables are produced mostly in the greenhouse; for example, only 2% of strawberrieswereproduced in greenhouse in 1970s but 98% of it was done in 1995.

In the early stages of 'White Revolution', most crops produced under protected cultivation were vegetables, but fruits and ornamentals also became cultivated in greenhouses later. Protected cultivation of citrus and grape in greenhouses or under rain shelters became popular and field production of rose, chrysanthemum, lily, and other pot flowers were replaced by greenhouse production. Protected cultivation of fruits contributed to the development of large-sized and multi-span greenhouses, and cultivationof flowers ledto the introduction of the glasshouse and hydroponic system, which are desirable for automated greenhouse management system.

Technology improvement and its distribution were important for expanding protected cultivation. Scientists and researchers in National Institute for Horticultural and Herbal Sciences (NIHHS) and universities collaborated to improve and standardize greenhouse structure. The cooperative works resulted in replacing bamboo frames with steel and reducing the design and construction costs of greenhouse. It was also imperative to develop new cultivars adapted to greenhouse cultivation. Seed companies in Korea have developed new cultivars of major horticultural crops for protected cultivation and distributed them to farmers. New cultivars for other crops including strawberry, tomato, and melon have been developed in NIHHS.

Various technologies are needed for protected cultivation. Aside from greenhouse structure, technologies are needed for covering materials, heating, optimum fertilization rate, irrigation, fertigation, reducing successive cropping hazard, supplying CO_2, raising seedlings and controlling combined environmental factors. The Vegetable Research Division in Suwon and the Protected Horticultural Research Station in Busan have been playing pivotal roles in developing and distributing technologies required by farmers.

Since rice self-sufficiency was the supreme priority, Green Revolution in Korea was a government-led development and farmers were forced to keep in line with the government's policy. Therefore, they could not choose their crops in some cases during the period of Green revolution. However, no compulsory policy was taken for 'White Revolution.' Thus, farmers could determine their crops and earn their own profit, as expected in a free- market economy.

During the 'White Revolution' period, it was proven that privately-led technology improvement is more efficient than a state-led improvement. Although many government policies were employed and farmer education programs were sponsored by the government for expanding protected cultivation, farmers learned techniques voluntarily from research institutes through extension systems and even from developed countries. This contributed greatly to the rapid spread of protected cultivation in South Korea.

'White Revolution' in Korea represented by the spread of protected cultivation could not have been achieved without the distribution of low-cost plastic films produced from petrochemical industry supported by government. Also, low-cost steel frame from the steel industry, which was also supported by government, make modernization of protected cultivation possible. The improvement of infrastructure as well as the new community movement also led the rapid expansion of protected cultivation, which increases the farmer's income. The increase in national income that expanded the consumption of greenhouse crops was also important for the success of 'White Revolution'. It posed South Korea as one of the top technological power in the field of protected cultivation technology.

Chapter 1

Introduction

1. Correlation between Increase in Protected Cultivation Area and That in the National Income
2. Change in Eating Habit and Increase in Vegetable Consumption
3. The Conversion from Open Field to Greenhouse Cultivation
4. The Structure and Material Improvement of Greenhouses

Introduction

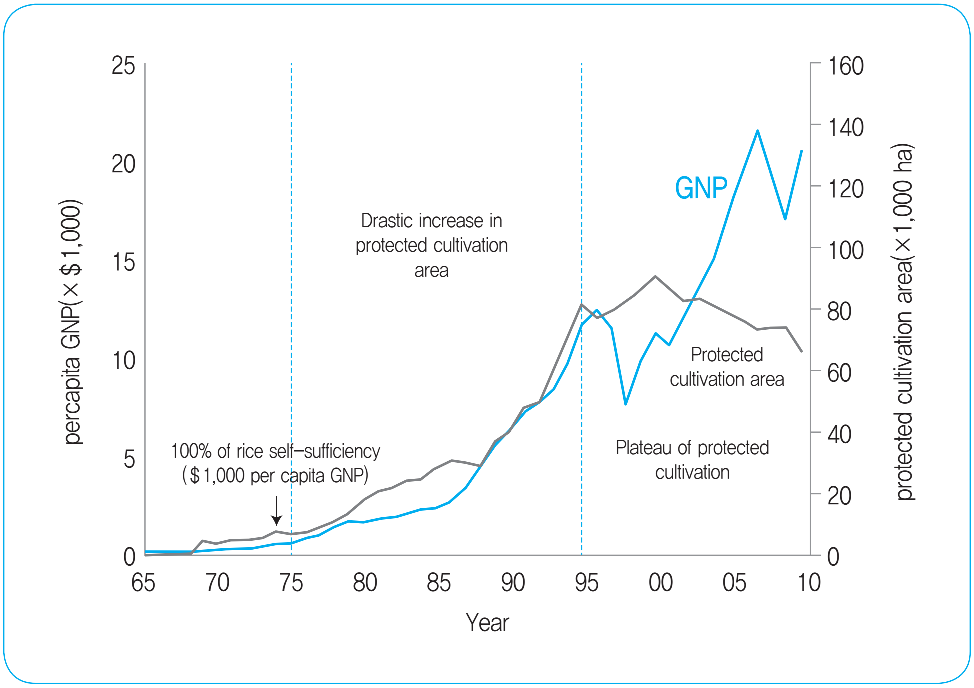
‘Green revolution’ has long been used in agriculture. The term, coined by international organizations such as United Nations or developed countries that aid underdeveloped countries, refers to research, development and technology transfer to increased agriculture production, in order to address the problem of hunger in those countries with a lack of food and a large population. It is still a national goal in those countries where the problem of hunger is very serious. In contrast, the term, ‘White Revolution,’ has only been used in Korea. This report defines ‘White Revolution’ as the period of modernization of structure, material and technology for greenhouse to achieve the rapid expansion of protected cultivation area and stable supply of vegetables, from 1970s to 1990s. Although there has been an abundance of discussion to define (or issues related to the achievement in the process of) ‘White Revolution’ in Korean agriculture, we would like to define it as below:

First, year-round production of agricultural products was achieved through ‘White Revolution’ with the increase in protected cultivation area that are positively correlated with increase in the national income, which make possible for consumers to buy agricultural products regardless of the growing season. Second, due to seamless supply chain of vegetables, Korea is now one of the biggest consumers of vegetables per capita. Third, most vegetable fruits such as watermelon, strawberry, oriental melon, and tomato, which were cultivated in open field before, are now cultivated in greenhouses. Last, but not least, greenhouses framed with bamboo were replaced by those with steel pipe and this made it possible to build multi-span greenhouses; as a result, Korea ownsone of the best technology in protected cultivation.

1. Correlation between Increase in Protected Cultivation Area and That in the National Income

There have been lots of discussions in defining 'White Revolution' in Korean agriculture. However, most people agree that the term refers to the phenomenon that increase in protected cultivation area were positively related to increase in the national income from mid 1970s to mid 1990s [Figure 1-1]. It was very rare to grow horticultural crops in greenhouses before 1970s [Figure 1-1] but vegetable cultivation in the field started to be replaced by that in greenhouse due to mass production of polyethylene film (PE) in Korea after the Ulsan Petrochemical Complex was constructed in 1970, in the second five-year NEDP (NEDP).

Figure 1-1 | Relationship between per Capita GNP and Protected Cultivation Area in Korea



It was an excellent national development strategy to plan the domestic production of plastic films for use in agriculture in 1966 when per capita GNP was only $125 in Korea where no crude oil is produced. Korea's per capita GNP was only $105 in 1965; however, due to rapid economic growth, it was $602 in 1975, six-fold increase for ten years. In this period, annual economic growth rates were 7.8%, 9.7% and 10.1% during the first, second and third NEDP, respectively.

Protected cultivation of vegetables was rapidly expanded after domestic production of plastic films in 1970. The cultivated area of vegetables under protected cultivation was 6,600ha in 1975 when per capita GNP was $602 and this increased up to 81,600ha in 1995 when per capita GNP was $11,432. As shown in [Figure 1-1], the increase in protected cultivation area was directly proportional to the increase in per capita GNP.

Interestingly, such direct proportion was not observed after 1995. Even after the Asian financial crisis in 1997 when national income was largely reduced, protected cultivation area did not fluctuate. In the first half of 1990s, both per capita GNP ($11,432) and protected cultivation area (81,600ha) were the highest in 1995 but the correlation did not contine after 1995. Per capita GNP was highest in 1996 and rapidly reduced by $7,355 in 1997 due to the Asian financial crisis that made Korea draw financial support from International Monetary Fund (IMF) and then increased continuously until 2007 by $20, 045; however, protected cultivation area did not increase since 1995. Rather, protected cultivation area slightly decreased and small, single span greenhouses were replaced by bigger, multi span greenhouses (capital and technology intensive).

Considering the process of economic growth of Korea, the relatively slow growth of protected cultivation area from 1970 to 1975, even though plastic film were produced and distributed to farmers at a low price, could be due to two important reasons. First, consumers had little or no purchasing power until 1975 when per capita GNP was $602 and, therefore, could not purchase vegetables produced from greenhouses. Second, farmers lacked skills for the stable production of horticultural crops in greenhouses and, thus, could not guarantee the stable production of vegetables in winter season.

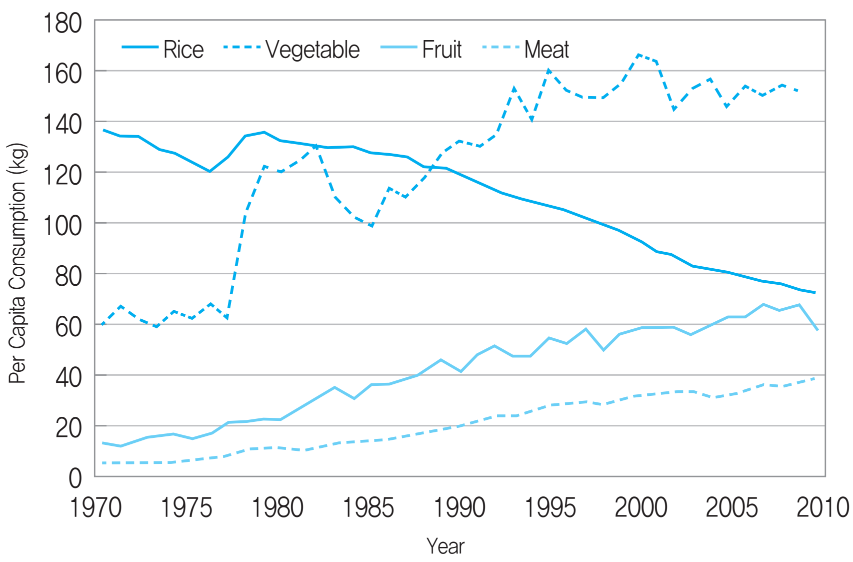
The fact that self-sufficiency in rice production was first accomplished in 1975 and continued thereafter led policy makers to change agricultural policies; redirection from producing a staple food, rice, to improving standard of living via production and consumption of vegetables. Various regulations in Korea had been created and applied to guarantee stable rice production before achieving 100% rice self-sufficiency. A representative regulation would be the regarding “absolute agricultural land” where rice should be planted; rice paddy could be used for greenhouse vegetable production in late autumn and winter, after harvesting rice, but the greenhouse should be removed before transplanting rice seedlings. These regulations have been gradually softened and finally, greenhouses framed with steel could be constructed in all seasons in absolute agricultural land. The easing of regulations, therefore, paved the way to expand the protected cultivation area.

To summarize ‘White Revolution’ in relation with economic growth, Korea emerged from food shortage in 1975 when per capita GNP was $602 and this led farmers to look at diverse ways to increase their income. Consumers also demanded fresh vegetables in winter or off crop season. In mid 1980s, the propensity to consume agricultural products changed from quantity to quality and there was no further increase in protected cultivation area even after per capita GNP was over $10,000 because of the change in the propensity to consume agricultural products. Since1995, Korea has been known for its largest protected cultivation area per capita (about 10m^2).

2. Change in Eating Habit and Increase in Vegetable Consumption

Increased winter vegetable production was due to increased protected cultivation area; as a result, remarkable increase in per capita vegetable consumption was observed as shown in [Figure 1-2]. Rice consumption per capita was over 120kg per year in 1980s and peaked of 135kg in 1980 but decreased rapidly as 120kg in 1990. Decrease in rice consumption was continued as 100kg in 2000, 80kg in 2005 and 70kg in 2010 [Figure 1-2]. The consumption of other foods such as vegetable, meat and fruit increased in contrast to decrease in rice consumption; among them, increase in vegetable consumption was prominent [Figure 1-2]. Per capita vegetable consumption was 60kg per year in 1970s but 120kg per year in 1980s, two-fold increase in 10 years.

Figure 1-2 | Chronological Changes in Consumption of Rice, Vegetable, Fruit and Meat in Korea

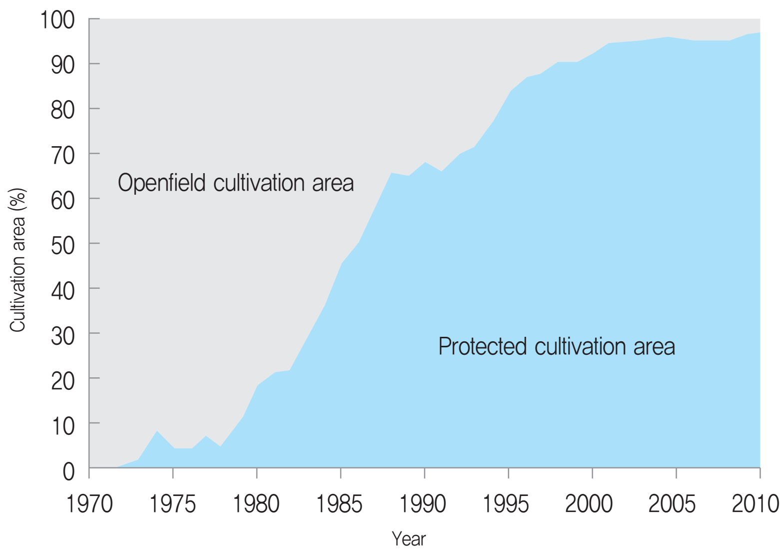


The rapid increase in vegetable consumption for ten years, which started from late 1970s,was possibly due to expending protected cultivation area resulting from 'White Revolution'. The average life expectancy of a Korean was 60 in 1960s but increased up to 80 in 1990s, which is partly due to a balanced diet; decreased rice consumption and increased vegetable and meat consumption. Benefiting from economic development, Koreans could take protein and fat from meat, carbohydrate from cereals, and vitamin and mineral from vegetables. Although improved hygiene and health care were also major factors, improved condition of people's health due to balanced diet also contributed to the increased average life expectancy.

3. The Conversion from Open Field to Greenhouse Cultivation

One of the major changes in the process of 'White Revolution' was that many crops grown in the field before were now grown under protected cultivation after 'White Revolution.' [Figure 1-3] shows the conversion of open field to greenhouse cultivation,for example, of strawberry after 1970. Most strawberries were produced in open field in 1970 but shifted to growth in greenhouses after 1990s. This was due to the fact that the yield of strawberries were unstable in the open field and that it was difficult in the open field to obtain stable income due to excessive supply in the market caused by a simultaneous harvest.

Figure 1-3 | Chronological Changes in Field and Protected Cultivation Area in Strawberry



Strawberry is native to Northern temperate region and flower buds are differentiated in low temperatures and short days. Breaking of dormancy of differentiated flower buds occurs in low temperature of winter, the growth of plants is resumed in spring of the following year, and fruits are harvested in early summer. Due to the continuous breeding program to improve strawberries, the limitation of the dormancy breaking, and requirement of low temperature and short day have been overcome and this make possible protected cultivation of strawberry in off-seasons, winter and spring. Farmers can obtain stable income and consumers can have more choices through greenhouse cultivation of strawberries.

In protected cultivation of Korean agriculture, this irreversible change [Box 1-1] has been in progress in various vegetables. Main characteristics of such major vegetables as watermelon, oriental melon, peppers (including paprika), tomato, cucumber, squash, and eggplant have been modified to adapt to a greenhouse environment and the field cultivation of them is no longer feasible.

Box 1-1 | Changes in Strawberry Cultivation

Particularly noteworthy is that strawberry varieties in these days cannot be grown in field any more. The current major strawberry varieties have been bred for greenhouse cultivation and, thus, field cultivation of these varieties is difficult and cannot guarantee stable production. Furthermore, this change is irreversible since many landraces adapted to field cultivation have disappeared.

A greenhouse with bamboo frame (early 1970s); 5% of strawberries are grown in greenhouses.

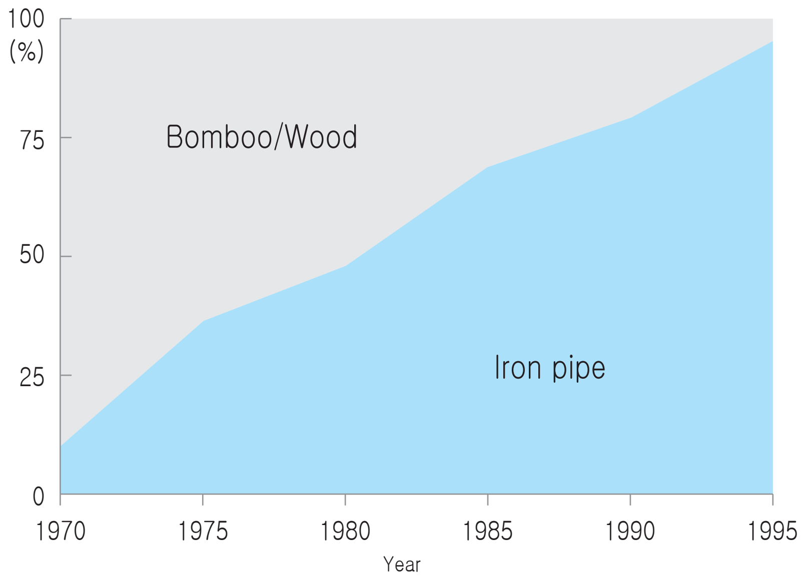
Double-layered polyethylene roof for heat conservation (1980s); 50% of strawberries are grown in greenhouses.

A multi-span greenhouse A greenhouse with steel frame (1990s); 95% of strawberries are grown in greenhouses.

4. The Structure and Material Improvement of Greenhouses

One of the technological changes in the process of 'White Revolution' was the modernization of greenhouse facilities. [Figure 1-4] shows the chronological changes in structural materials of greenhouse from wood or bamboo to iron frame. Concentrated protected cultivation for commercial purpose in Korea began in the southern coastal provinces and a case in point was Gimhae, Gyeongsangnam-do. A high solar irradiance and little snowfall in winter in southeastern Korea were favorable to the establishment of protected cultivation in the early stage. Rapid establishment of greenhouse was also possible as black bamboo is native to this province (*Phyllostachys nigra var. honosis*).

Figure 1-4 | Chronological Change in Greenhouse Frame Materials (Bamboo/Steel pipe) in Korea



The black bamboo is suitable for greenhouses frames since it is 5-7m tall and the diameter of its lower stem is about 5cm. The frames of early greenhouses were mostly made of bamboo by planting the bamboo in the ground in two rows and bending and tying them together to make an upside down U-shape. Bamboos were popular for the frame of early greenhouses since they were cheap and easy to get. They had long been used due to the limited supply of iron frame in the early stage of protected cultivation. Bamboos are appropriate for building single-span greenhouses but not for multi-span greenhouses;

besides, greenhouses with bamboos needs more workers in construction than that of iron frames and they needed to be dismantled and reconstructed every cropping season.

Small-sized, single-span greenhouses made of bamboo frames are generally 5-6m in width, less than 1.8m in height. When bamboo greenhouses are set up in rice paddy, they are built after harvesting rice, vegetables are cultivated in winter and then the greenhouses are disassembled before transplanting rice seedlings. This process is repeated. Giant timber bamboo (*Phyllostachys bambusoides*), which is much higher than the black bamboo, is native to Jeollanam-do and thus farmers in this region have used it for greenhouse frames. Giant Timber Bamboo is 15-20m in height and the diameter of its lower stem is about 10cm. Due to its thick lower stem, it cannot be bent and, therefore, is used as greenhouse frames without bending; as a result, large-sized greenhouses were developed [Figure 1-5]. The width of this greenhouse is about 20m when built in the form of lean-to greenhouse or three-quarter greenhouse and 30-40m for an even-span greenhouse. These forms have been maintained even after replacing bamboo with iron frames.

Figure 1-5 | Green Pepper Cultivation in a Large-sized Greenhouse Made of Bamboo and Wood in 1970s

In 1973, Pohang Steelworks was completed producing 100,000 ton of crude steel and took the lead in the economic growth of Korea. As production of crude steel increased, a shift from bamboo to steel frame of greenhouse was carried out simultaneously. As shown in [Figure 1-4], bamboo frames were rapidly replaced by iron frames. This paved the way to a leap forward in horticultural industry. At that time, Korea was experiencinga shortage of iron ore and they were imported from other countries.Beside, most of the crude steel from Pohang Steelworks has alternative uses in other industries. However, farmers and agricultural organizations demanded the production of steel coil and small manufacturers produced greenhouse pipes using steel coil and then bamboo greenhouse was replaced by steel.

The Korean Agricultural Ministry established 'Greenhouse standardization plan' in 1971 in order to replace bamboo withsteel frame and a research consortium led by the NIHHS, Universities, and companies performed various researches to improve greenhouse structure. As a result, galvanized pipes were adopted for greenhouse structure material and most greenhouses have been constructed adopting standard greenhouse design provided by the NIHHS. Construction cost was reduced and, therefore, farmer's income increased by using the standard greenhouse design that contributed the modernization of greenhouse later. The first 'Increasing income program for farmers and fishers'(IIPFF) were started in 1968 and Pohang Steelworks was constructed in 1970 through investment by the government to foster steel industry.

Protected horticultural industry in Korea achieved much technological improvement which narrowed the greenhouse technology gap between Korea and advanced countries such as Japan. Since 1990s, Korea has acquired independent greenhouse technologies and actively exported greenhouse facilitiesby adopting these technologies.

Chapter 2

Policies for Nurturing Greenhouse Horticulture and Related Industries

1. Increase in National Income by Successful Five-year National Economic Development Plan
2. Integration of Increasing Income Program for Farmers and Fishers and the New Community Movement
3. Nurturing of Greenhouse-related Industries and Expansion of Cultivation under Structure
4. Development of New Varieties for Greenhouse Cultivation

Policies for Nurturing Greenhouse Horticulture and Related Industries

In Korean agriculture, the term 'White Revolution' was derived from the extensive use of plastic films in agriculture, which turns the color of land into white due to the large acreage under protected cultivation. To produce crops in greenhouses covered by glasses or plastic films, there are many things needed other than crop cultivation technology. Consumer markets and purchase power to buy agricultural products are necessary to industrialize protected cultivation. The major driving force for the success of protected cultivation in Korea was to purchase greenhouse vegetables in winter in high prices, in parallel with increased national income. The increase in national income came from economic growth as a result of the success of a series of five-year National Economic Development Plan (NEDP). The domestic supplies of necessary greenhouse materials, frames that build greenhouse structure and plastic films that cover the structure, were possible at the early stage of protected cultivation in Korea.

Although Korea is not an oil producing country, the petrochemical industry was nurtured as the construction of the Ulsan Petrochemical Complex began in 1962 and completed in 1970. Plastics for agriculture that were previously imported from other countries was localized in 1970 and distributed in a lower price. Also, rapid replacement of bamboo with steel greenhouse frames made possible the modernization of greenhouse horticultural industry, which was due to the fact that the construction of Pohang Steelworks started in 1970 and completed in 1973. It was through developing and distributing fertilizers, agrochemicals and other agricultural materials that promote labor-saving, mechanized farming.

All industrial bases in Korea were devastated by the Korean War from 1950 to 1953. However, vegetable breeding rapidly became competitive globally thanks to the effort of Dr. Jang-Chun U. He contributed largely to 'White Revolution' by training vegetable breeders who develop various varieties appropriate for protected cultivation in private companies.

This chapter analyzes policies and related industries contributing to the rapid growth of greenhouse horticultural industry.

1. Increase in National Income by Successful Five-year National Economic Development Plan

Most important factor of the rapid progress in Korea's protected cultivation called 'White Revolution' was the formation and expansion of consumer markets for winter vegetables accompanied by increased national income. It was possible due to the virtuous cycless that farmers made more money by selling greenhouse vegetables in high prices, they expanded, with increased income, their greenhouses and produced more greenhouse vegetables, and consumers had purchasing power to buy more greenhouse vegetables from 1970s. The expansion of the consumer markets was due to increase in national income which was the result of a series of five-year NEDP. The summery of purposes and results of five-year NEDP is described below.

1.1. The First Five-year National Economic Development Plan (1962-1966)

The purpose of the first NEDP was to recover the damages of industrial facilities from the Korean War by acquiring energy sources, constructing industrial bases and establishing social infrastructure and, thus, to achieve economic independence. The main export items in agriculture were raw silk and mushroom during this period, which were the results of efforts to expand agricultural production and its export. The Government's plan in agriculture during this period was 'increased agricultural production'.

Jung-Hee Park, who seized power through a military coup, invalidated farmer's usurious credit and started 'the national reconstruction movement.' The government conducted 1) deep plowing, soil amendmentm and green area increase as well as free distribution of calcium and silicate fertilizers to increase soil fertility: 2) redevelopment of arable land and construction of multi-purpose dams to acquire agricultural water: 3) the finding of new income sources in agricultural off-season to increase farmers' income. During this period, the number of agricultural officials rapidly increased from 1,192 in 1962 to 3,173 and 6,684 in 1965, for efficient distribution of agricultural technologies. The expansion and reorganization of agricultural system were largely contributed to 'Green revolution' for rice self-sufficiency and, later, 'White Revolution' for farmers' income increases.

Economic growth rate in this period was 7.8%, exceeding its initial goal and the GNP increased from $87 to $125; nonetheless, Korea was still one of the world's poorest countries. No production and purchasing power of greenhouse vegetables was found in this period. There was also lack of power to produce agricultural plastic films even though the construction of Ulsan Petrochemical Complex was started in 1962 and completed in 1964. Official statistics indicated no greenhouses in 1965 except for the 764ha of model greenhouses mostly in research institutes and agricultural schools. Very few farmers run greenhouses with very limited vegetable production for rich consumers who are few in number.

1.2. The Second Five-year National Economy Development Plan (1967-1971)

The goal of the second five-year NEDP was to establish an export base through constructing sophisticated industry by fostering petrochemical, steel and machine industries and by increasing food production and forestation. In this period, the Ulsan Petrochemical Complex was completed in 1970 and made possible domestic production of agricultural plastics. Whole processes of petrochemicals production was completed domestically in this period. The first IIPFF begun in 1968 and Pohang Steelworks was completed in 1970, which was invested by the government to foster steel industry. In 1970, the new community movement (called Saemaŭl movement in Korea) began, which affected greatly not only to rural but also urban areas, and the Seoul-Pusan expressway was completed that in turn later paved the way to national economic growth.

President Jung-Hee Park emphasized eight priorities for agricultural development in a joint meeting on December 5, 1968, which were the very foundations of nation's agricultural policy and affected the process of 'White Revolution.' The priorities were 1) increasing food production, 2) increasing citizen's income, 3) developing agricultural and manufacturing industries, 4) expanding financial support for increasing farmers and fishers' income, 5) developing agricultural water source and establishing measures for drought-control, 6) encouraging side job in agricultural off-seasons, 7) fostering agricultural guidance project and, 8) fostering small agriculture enterprises.

The first IIPFF including various projects was started in 1968 and ended in 1971. One of the projects, the greenhouse vegetable production project,was considered the best among programs in the first IIPFF. Along with this project, growing silkworm, mushroom, fruit tree, tobacco, and beef cattle were considered as good projects and were continued in the second IIPFF. Other projects such as Angola rabbit and trout culture, and growing asparagus, hops plant and scallion were excluded in the second IIPFF because of technical problems or wrong consumer's demand forecast. The operation and evaluation of IIPFF turned out to be efficient because the production of crops in successful projects in the first IIPFF has been expanded but those in excluded projects has not established with very few exceptions.

Economic growth rate per year in the second five-year NEDP was 9.7% and per capita GNP increased from $142 in 1967 to $290 in 1971. Although domestic production of agricultural plastic films was achieved in 1970, greenhouse vegetable production was in its infancy and less than $300 per capita GNP was not enough to promote consumer market of winter greenhouse vegetables. Therefore, protected horticulture was still in a beginning stage in 1970 where per capita GNP was $254 and greenhouse cultivation area was only 3,700ha.

1.3. The Third Five-year National Economy Development Plan (1972-1976)

The goal of the third five-year NEDP was to foster the heavy-chemical industry to be balanced with other industries. The resources of a nation were concentrated to achieve economic independence in the first five-year NEDP, export base establishment in the second and economic leap in the third. The Korean government concluded that achieving economic independence was possible because of the expansion of social infrastructure, construction of agricultural base and expansion of export, which were the result of the first and second NEDPs. Although Korea achieved, through the first and second five-year NEDP, rapid economic growth by industrialization and export expansion, this largely relied on foreign investment that would be a potential risk factor. The other risk factors for Korea's economic development were the gap between urban and rural area, imbalance among industries,and low foreign exchange reserve. Therefore, the third five-year NEDP aimed at stable and balanced growth of national economy, establishment of independent economy and balanced development among regions and industries.

Rice self-sufficiency was the most important achievement in agriculture in this period. Related to 'White Revolution,' the most important change was that bamboo frames of greenhouseswere replaced by steel due tothe mass production of steel from Pohang Steelworks and protected cultivation area rapidly increased. It was also notable that Korea suffered from the first oil crisis in 1973 but overcame this with strong export-oriented policy. The initial goal of the third five-year NEDP was 8.6% of economic growth rate but 10.1% of growth was achieved; as a result, per capita GNP increased from $320 in 1972 to $818 in 1976. This economic growth led the public to purchase winter greenhouse vegetables more than before and allowed rapid expansion of consumer market. Greenhouse vegetables made a lot of money and reinvested this money in expanding their greenhouses. They produced more greenhouse vegetables and all of them were purchased by consumers with increased purchasing power due to increased income, showing virtuous circles.

The first IIPFF (1968-1971) concluded that many projects including greenhouse vegetable production were effective in increasing farmer's income. Based on this conclusion, projects of 21 crops were expanded in the second IIPFF started in 1972 and 570,000 farms from 137 regions participated in the program. The second IIPFF was merged with the new community movement in 1974 and the name was changed to 'The new community (Saemaeul) increase income special-program' (SIISP). Both IIPFF and SIISP was most important program that led to the progress of greenhouse horticultural industry and the success of 'White Revolution.' Greenhouse area in 1975 was 6,600ha, about two-fold increase from 3,700ha from the start of the third five-year NEDP. During this period, vegetable cultivation under greenhouse began to expand rapidly.

1.4. The Fourth Five-year National Economy Development Plan (1977-1981)

The fourth five-year NEDP aimed at rationalizing economy structure by establishing self-development economy structure, promoting economic equity through social development and increasing efficiency through technical advancement. However, there was no great achievement in long-term economic growth because of the second oil crisis in 1979 and, therefore, the initial goals were could not be achieved. As a result, the economic growth rate per year was only 5.8% in this period. Structural vulnerability of the Korean economy was exposed with slowdown of quantitative growth as changing international situation and government policy of industrialization was faced with the limit.

In Korean agriculture, however, 'Green Revolution' was achieved officially in 1977, two years after accomplishing 101% of self-sufficiency in rice production in 1975. The Korean government focused more on the increase in farmer's income thereafter. Per capita GNP was $1,034 in 1977 and $1,800 in 1981. Koreans started to seek high quality food sources because of their increased income. Various agricultural plastic products needed for greenhouses were developed and bamboo frames of greenhouses were rapidly replaced by steel frames. About 70% of greenhouse structure was made of bamboo in 1977, while steel structure formed 50% of greenhouse in 1981.Greenhouses were rapidly modernized as galvanized steel pipes that are antirust were distributed. 'White Revolution' was started in earnest in this period. Acreage under protected cultivation surged 271% (17,900ha) in 1980 from 6,000ha of five-years earlier, showing the highest increase.

1.5. The Result of Later Five-year National Economy Development Plan

NEDP continued after 1981 but the portion of agriculture in the Korean economy was rapidly reduced and there were no great changes related to 'White Revolution.' The fifth NEDP (1982-1986) aimed at social stabilization. Year-round production and distribution of fresh agricultural products was top priority during this period. Per capita GNP was $1,893 in 1982 and $2,643 in 1986, showing economic growth rate of 8.6% per year. Consumer's purchasing power for agricultural products increased steadily and acreage under protected cultivation increased by 160% (28,600ha) in 1985 compared to that in 1980. There was much progress in 'Greenhouse standardization plan' in this period and 70% of greenhouse structure was made of steel and the rest was bamboo or wood. Many vegetables that were grown in field beforewere now produced in greenhouses. The goal of the sixth NEDP (1987-1991) was the advancement of economy and policies in agriculture were focused on stable farm income through quality improvement of agricultural products. Per capita GNP was $3,323 in 1987 and $7,105 in 1991, showing high economic growth rate of 10.0% per year. Acreage under protected cultivation was 40,000ha showing 140% increase compared to that in 1985 and 80% of greenhouse structure was made of steel. Bigger and multi-span greenhouses became popular and farming was rapidly mechanized as various greenhouse cultivation techniques were developed.

'White Revolution' in Korean agriculture was completed in the seventh NEDP (1992-1996). Per capita GNP was $7,527 in 1992 and $11,432 in 1995, exceeding $10,000 for the first time, and Korea saw the possibility of joining the ranks of advanced countries. In 1996, the last year of the seventh NEDP, per capita GNP was 12,197, which was the record high at the time, but Korea experienced a financial crisis due to the subsequent Asian financial crisis in 1997, which made Korea draw financial support from IMF and to experience negative growth. Acreage under protected cultivation in 1995 was 81,600ha which was an increased by 204% compared to that in 1990, and greenhouses made of steel fame covered 95% of greenhouse cultivation area. The growth of protected cultivation area slowed after 1995 as it was 90,000ha in 2000 and then it started to decrease thereafter as 78,500ha in 2005 and 66,400ha in 2010.

It was through increased winter vegetable consumption due to rapid economic growth by a series of NEDP since 1960s to achieve 'White Revolution.' Greenhouse cultivation began in late 1960s for the purpose of vegetable production in off-season; however, consumer market for off-season vegetable was not formed until 1970 when per capita GNP was $254 and most of plastic films had to be imported. It was not until 1975 when per capita GNP exceeded $600 that both vegetable consumption and greenhouse cultivation area started to increase thanksto the growing demand for fresh winter vegetables.

Consumers demanded high quality vegetables from 1980 when per capita GNP was $1,645 and quality and quantity of greenhouse vegetables increased, positively correlated with increase in greenhouse cultivation area. The situation of rural community in Korea was aggravated due to population reduction, urbanization, and an increase in aging population and labor costsin the rural areas. These changes in the agricultural environment demanded farmers to consider labor cost reduction. Mechanization of farming and greenhouse facility improvement were embodied to meet the demand of farmers. In the duration from 1985 to 1990 when per capita GNP was $2,309 and $5,147, respectively, technology development was going smoothly, making compromises between the needs of high quality vegetables requested by consumers and production cost reduction by farmers. Increased national incomes increased purchasing power of fresh vegetables and this led to quantity increase and quality improvement of agricultural products.

Korea's per capita GNP was $7,105 in 1991 and 11,432 in 1995 and more than a two-fold increase in acreage under protected cultivation was observed for the same period. However, the correlation between national income and protected cultivation area was not continued after 1995 and increase in the cultivation acreage was slowed. This was possibly due to the fact that year-round production of greenhouse horticultural crops met the demand from consumers and that there was no more increase in new demands.

2. Integration of Increasing Income Program for Farmers and Fishers and the New Community Movement

A three-year plan to increase agricultural production was initiated in 1949 just after the establishment of the Korean government but this plan gained no achievement due to the Korean War breaking out in 1950. After the Korean War ended in 1953, the first five-year increasing agricultural production plan (1953-1957) was initiated but this plan was for cereal crops, not for horticultural crop production. Besides, the first plan fell short of the expectations due to limited budgets and political instability and, thus, did not successfully recover the devastated agricultural bases by the Korean War. Nonetheless, the Korean government reorganized the Agriculture Ministry by establishing two new divisions for agricultural materials and instructions in 1955 in order to increase food production and established the institute for agriculture by enacting an agricultural extension law in 1957. In 1962, not long after the Korean Republican Party was launched in 1961 through a military coup, the institute for agriculture changed its name to the Rural Development Administration (RDA) and later, the RDA, with agricultural research and extension ability, played very important role to achieve Green Revolution and 'White Revolution' in Korea.

In 1950's, when no plastic film was produced in Korea, a few farms near Gimhae, Gyeongsangnam-do imported agricultural plastic films from Japan and constructed greenhouses using bamboo and the imported plastic film in order to cultivate vegetables in winter. The price of imported plastic film was very expensive and greenhouse vegetables could not besold in high prices and, thus, greenhouses did not become common. Very few farmers produced greenhouse vegetables for a limited number of consumers and greenhouses were constructed for educational purposes in agricultural institutes and schools.

Besides, plastic films could not be imported legally and thus had to be imported through other channels from Japan since it was before the establishment of diplomatic relations with Japan.

The goal of the second five-year increasing agricultural production plan (1958-1962) was not very different from the previous goal, to increase agricultural production and to achieve self-sufficiency in cereal production. The differences were to expand cultivation area of such cash crops as vegetables and fruits, to increase the production of horticultural crops by fertilization and management and fruit drop control, and to improve quality and quantity of agricultural products through high quality seeds, and disease and insect pest control. However, the increasing agricultural production plan were established independently by the Agricultural Ministry and, thus, not closely connected with other national development plans. The second five-year increasing agricultural production plan did not achieve its goals due to political instability. The third five-year increasing agricultural production plan was conducted (1962-1966) at the same period of the first NEDP.

Box 2-1 | President Park Visited the Farm Growing Vegetables in Greenhouses

Plastic film production was accelerated by president Jung-Hee Park after he visited a farm where crops were cultivated in greenhouses located in Gimhae, Gyeongsangnam-do in 1965. The farm grew cucumber, lettuce, and tomato in greenhouses that was constructed using imported plastic film from Japan and sold them to luxurious restaurants in high prices in winter. President Park, who sought for new sources of farmer's income in off-season (winter), decided to promote greenhouse vegetable production. Domestic production of agricultural plastics was needed for greenhouse vegetable cultivation and he decided to establish a Petrochemical Division in the Ministry of Trade and Industry to set up a plant to produce 100,000 tons of naphtha in December, 1966. In July, 1968, the Korean government entered into partnership with Dow Chemical by establishing a joint-stock company 'Hanyang Chemical' to prepare the production of agricultural plastics and finally in 1970, it was possible to produce various petrochemical products as the Ulsan Petrochemical Complex was completed.

Korean government also established the RDA in 1962 and enacted laws to reinforce research and training functions of RDA to increase food production. After the success of Green revolution in late 1970s, however, there were no changes in established agricultural system but special instruction from President Park was announced to increase farmer's income. After the instruction was announced, the IIPFF started as a result of a Joint Meeting organized by President Park who emphasized agriculture in the meeting.

Since special instruction from Park overrode laws or administrative actions at that time when Korea was under the authoritarian administration, the IIPFF had a strong driving force at the beginning. 'White Revolution' and its policy ground were started from the first IIPFF (1968-1971). Among projects in the first IIPFF, the greenhouse vegetable production project was effective in increasing farmer's income and the project was continued in the second IIPFF that started from 1972. The second IIPFF was merged with the new community movement in 1974 and the name was changed to the SIISP.

2.1. The First Increasing Income Program for Farmers and Fishers (1968-1971)

The third five-year increasing agricultural production plan that started at the same time with the first NEDP (1962-1966) was to avoid growing rice only and, thus, to focus instead on increasing the production of cash crops by establishing 'five-year plan for increasing horticultural crop production', in order to reduce the import of cash crops and to increase farmer's income. Although their effects were limited, the government measures were established to increase agricultural products, to stabilize their prices, to promote the production of clean, fresh vegetables and fruits for the United States Armed Forces in Korea. Since the goal of the first NEDP was to 'prepare migration from agrarian to industrial country,' investment in agriculture was lower than that in industry, which was reduced by 50% compared to its initial plan. In the process of industrialization due to the first NEDP, incomes of farmers and fishers began to become lower than that of city workers from 1965 <Table 2-1>. During this period (1968-1971), the economic growth in agriculture, forestry and fishery industry was only 5.5% but that in mining and manufacturing and that in infrastructure and service was 15.1% and 8.9%, respectively, showing severe imbalance among industries. The IIPFF was established to resolve this imbalance.

Table 2-1 | Incomes of Farmer and Urban Workers in 1960s

(Unit: Thousand Won)

Year	1963	1964	1965	1966	1967
Urban Worker (A)	80,160	97,200	112,560	161,520	248,640
Farmer (B)	93,179	125,692	112,201	130,176	149,470
Ratio (B/A)	116.2	129.3	99.7	80.6	60.1

Source: Farm household economy survey, Ministry of Agriculture and Forestry

Comprehensive and coordinated government measures were prepared to improve farmers' and fishers' income by replacing food production increase policy with stabilizing the cost of agricultural products and constructing major producing districts for cash crops, which started in 1966. A trigger accelerating the IIPFF was an address from President Park given during the Agriculture Encouragement Day, which was Jun 10, 1968. Initially, Agriculture Encouragement Day was 10th of June but it was moved up to first of June since it was the day for rice transplanting of the variety 'Tong-il'. The Agriculture Encouragement Day was further moved up to fourth Tuesday of May and disappeared after fixing the Farmer's Day on the 11th of November.

President Park emphasized increasing farmer's income through growing cash crops and livestock although Korean agriculture needed to continue focusing on increasing the food production. He also instructed to expand 13 chief crop-producing districts that were included in the 'greenhouse vegetable production plan.' President Park expanded 13 districts to 90 districts with 43 crops, including 410,000 farms which accounted for 17% of total farms and funneled a 45.2 billion won budget into the plan. He also instructed to organize a 'special committee' that six Ministries including Agriculture, Interior, Commerce, Construction, Finance and Economic Planning Ministries were involved in. Each Minister had to focus on the plan because Park checked the progresses of each districts regularly. Park's strong will become a catalyst for expansion of greenhouse vegetable production to increase farmer's income.

By analyzing the result of chief crop producing district construction program that was conducted for two years (1966-1967), the Korean government estimated that they could not achieve the goal by small scale chief producing districts. Therefore, they established a development plan of 13 large scale agricultural producing districts to produce multi-purpose agricultural products. In the process that this program was reported to the President, the IIPFF was expanded according to President Park's special instruction to make additional projects in pressing needs for increasing farmers' and fishers' income by mobilizing all available budgets and hands. The government measures were focused on 1) constructing chief crop-producing complexes for cash crops that are adapted to core agricultural regions, 2) concentrating funds, techniques and administrative works by pooling various funding sources, 3) promoting commercial farming through group farming and productivity increasing and 4) developing rural area by supporting production, processing and distribution and narrowing the gap between urban and rural area by increasing farmers and fishers' income.

This plan started on 11th of May, 1968 and was conducted for four years between 1968 and 1971 during the first IIPFF. The major results of this plan was 1) the production portion other than grains increased from 34.6% in 1965 to 42.2% in 1970 as rapid increase in sericulture, livestock, cash crops productivity; 2) supply increase in livestock, fruit and vegetable met consumer's demand and also increased their consumption; 3) new fields such as greenhouse vegetable cultivation, sericulture and livestock raising were developed to enhance small farmers' competitiveness; 4) local economic development and localization of agricultural development were achieved; 5) export of agricultural and marine products increased by five hundred fifty three-fold from 129 million in 1967 to 71,328 million USD in 1971 by rapidly increased production of raw silk, mushroom and raising marine products. This increased the income of rural area dramatically and narrowed the gap between farmers or fishers and city workers. This trend was continued and finally in 1974, the income of farmers exceeded that of city workers. In particular, for the vegetables, tomato, cucumber, red pepper, garlic, strawberry, ginger, and lettuce were chosen as promising horticultural crops in the IIPFF and they were nicknamed 'Higher vegetables.' To produce these 'Higher vegetables,' the Korean government provided vegetable farms with 70% financing of 662 million won to construct 115ha of greenhouses in total, in order to promote greenhouse vegetable production.

The Agricultural Ministry unveiled a 'comprehensive plan to promote side jobs for farming and fishing villages' in November, 1968, allocating 3.4 billion won from the government budget. However, it was estimated that side jobs alone werenot sufficient to increase farmers' and fishers' income and, therefore, IFFIP also started instead of 'comprehensive plan to promote side jobs for farming and fishing villages.' In December 1968, the first comprehensive supporting plan for increasing farmers' and fishers' income was started by Park's special instruction with 178 billion won budget.

Table 2-2 | Chief Producing Districts of Horticultural Crops in the First Increasing Farmer's and Fisher's Income Program (1968)

Chief producing districts	Cities	Horticultural crops
Vegetable complex near Seoul	Incheon, Goyang, Siheung, Yangju	vegetables
Pyeonggwang vegetable complex	Pyeongtaek, Gwangju	Vegetables for pickling (scallion, sprig, burdock)
Pyeongchang highland vegetable complex	Pyeongchang, Daegwanryeong	vegetables
Jinsa horticulture complex	Jinju, Jinyang, Sacheon	vegetables, raspberry, vegetables for pickle
Gimhae-Changwon horticulture complex	Gimhae, Changwon, Milyang	Vegetables, grape

Chief producing districts	Cities	Horticultural crops
Jeongun horticulture complex	Jeonju, Iri, Gunsan	Vegetable, scallion, grape, oriental pear, flowers
Gwangna fruit tree complex	Gwangsan, Naju, Gwangju	Oriental pear, peach, asparagus, scallion, sprig
Daedeok grape producing complex	Daedeok	Grape
Gayasan fruit tree complex	Seosan, Dangjin, Yesan, Hongseong	Grape, apple
Geochang apple complex	Geochang	apple
Sourthern coast mandarin producing complex	Geoje Tongyeong, Namhae	mandarin
Jeju mandarin producing complex	Jeju	mandarin

<Table 2-2> shows twelve chief producing districts of horticultural crops. Such vegetables as scallion (*Allium chinense*) asparagus (*Asparagus officinalis*), burdock (*Arctium lappa*) and eggplant (*Solanum melongena*) were excluded from the second IIPFF because of their poor performances in the first IIPFF. The success of the IIPFF was proven by the fact that crops selected in the second IIPFF based on the result of the first IIPFF, which included 'Higher vegetables' and other crops such as apple, oriental pear, peach, and tangerine massively increased in production.

Box 2-2 | The Start of New Community Movement (called Saemaeul movement in Korea)

The new community movement was proposed by the President Park during the process of the first IIPFF (1968-1971). He proposed the movement in a gubernatorial conference, saying 'Heaven helps those who help themselves.' We need to encourage farmers to overcome poverty for 4,000 years by themselves. First of all, "we can start the new community movement to improve the poor living conditions in rural area." As the movement, which was voluntary, spread across the country, 'greenhouse vegetable production program' that its initial goal was limited to increase farmer's income by side job was rapidly expanded beyond its limit. In 1970, the third year of the first IFFIP, the Agricultural Ministry established 74 projects to increase farmers' and fishers' income providing 12.0 billion won and later in October 1971, announced 'Greenhouse standardization plan' that was the first policy to foster greenhouse horticulture.

2.2. The Second Increasing Income Program for Farmers and Fishers (1972-1976)

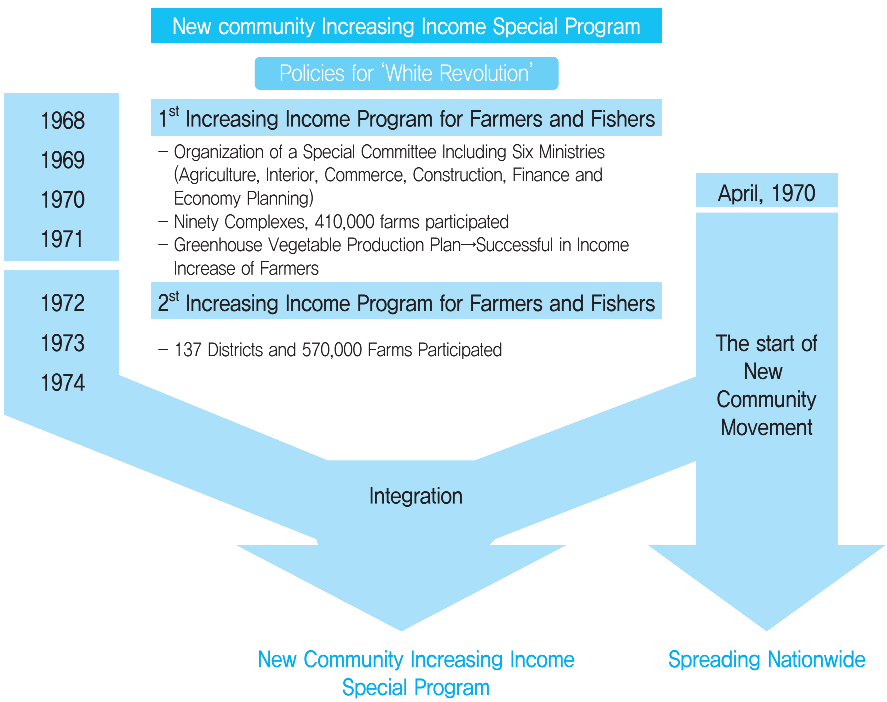
The Second IIPFF begun in 1972. Addressing problems in the first IIPFF, its goals were to 1) increase production of crops in rising demand as increased national income, 2) develop strategic export items considering comparative advantages, 3) develop local agriculture by constructing chief producing districts and 4) increase farmers' and fishers' income by improving productivity and supporting distribution of agricultural products.

750,000 farmers and fishers in 137 regions participated in this program that contain 21 items including sericulture, livestock raising, cash crop growing and fish-raising by providing 71.6 billion Won. The difference between the first and the second IIPFF was that each chief producing district included not only horticultural crops but also other crops; in the first IIPFF, individual chief producing district included only horticultural crops. This change was due to the fact that the goal of the second IIPFF was to increase farmer's income and that important decision in the process of the program was made by farmers, not by the government. Free of governmental intervention, it turned out to be the key for the success of this program. The government support for greenhouse construction in this period was 50 ha per year and farmers, by themselves, chose their crops, learned cultivation techniques to grow them and took responsibility for their own decision. The name was changed to the SIISP after it was merged with the new community movement in 1974, the third year of the second IFFIP.

2.3. The New Community Increasing Income Increase Special-Program

The government encouraged farmers and fishers to improve poor condition of rural area by themselves at the beginning of the new community movement. The movement was to make a comfortable living by diligence, self-reliance, and cooperation and to pave the way for increasing national income by improving environment and establishing self-supporting villages. Initially, various policies in the movement were more focused on the improvement of environment that were not related to increasing national income and, thus, those policies were replaced with increasing income policies. In an effort to replace policies, the IIPFF was changed to the SIISP.The program was started to make up for the weak points in the IIPFF by increasing government support to increase production of agricultural and marine products and to generate capital in the rural sector by expanding side businesses of farmers and constructing the new community factories. As shown in [Figure 2-1], the effect of integrating the IIPFF and the SIISP was very significant.

Box 2-3 | Background Information of the New Community Increasing Income Special Program



The government budget for supporting greenhouse farmers was small in the first (1968-1971) and second IIPFF (1972-1976) and even after initiating the SIISP. Among the investment of 662 million won for greenhouse industry in the first IIPFF, the government loan was 70% (423 million won) and greenhouse farmers bore 30%, and the scale of investment and percentage of the government loan was similar in the second IIPFF. However, the IIPFF was the first program that farmer bore the expense in agricultural industry in contrast to previous programs. This is due to the fact that the goal of the IIPFF was to increase farmer's income and the goal was consistent with farmers' goal: to increase their own income. It was appropriate and timely actions for maximizing the autonomy of the program that the Korean government tried to encourage farmers' investment by reducing government support.

The changes in the acreage of greenhouse vegetable cultivation during the IIPFF are shown in <Table 2-3>. Although there was no increase in government support for the program, the greenhouse cultivation area steadily increased from 1969 to 1975. This represents the fact that farmers increased greenhouse vegetable cultivation area regardless of government support, greenhouse vegetables were in great demand by themarket, and the smooth operation of greenhouse horticultural industry.

Table 2-3 | Greenhouse Vegetable Production Acreage during IFFIP and SIISP

(Unit: ha)

	1969	1970	1972	1974	1975
Total	4,358	3,727	4,664	7,639	6,611
Leaf vegetables	593	981	1,016	2,689	2,013
Root vegetables	13	32	199	669	484
Fruit vegetables	3,443	2,444	3,267	4,195	3.988
Condiment vegetables	-	7	-	-	-
Others	309	263	182	86	-

Korea's per capita GNP was $169 in 1968 when the first IIPFF was started, $254 in 1970 when the new community movement was started, and $290 in 1971 at the end of the first IIPFF. Per capita GNP was $320 in 1972 when the second IIPFF was started, $401 in 1973, and $554 in 1974 when the IIPFF was merged with the SIISP. During this period, the greenhouse cultivation area slightly increased although the Korean economy rapidly improved with a high economic growth rate. However, greenhouse cultivation area rapidly increased after integration of the IIPFF and the SIISP.

2.4. Revamping Agricultural Land Act and Legal System

2.4.1. Farmland Preservation and Utilization Act

There was a nationwide trend toward industrialization and urbanization due to the success of the first and second NEDP, resulting in a decrease of agricultural land. Redeveloped paddy field near cities was appropriate for industrial land and converted into factory site. Agricultural land inKorea was 2,320,000 ha in 1968 but 2,240,000 ha in 1973, a decrease of 16,000 ha per year. Considering newly developed agricultural land by land clearing and reclaimed land, more agricultural land disappeared during this period. Therefore, the Farmland Preservation and Utilization Act was enacted in December 18, 1972 and enforced in 1973.

The Act was revised in December 31, 1975 to achieve constant food self-sufficiency by tightening regulations to conserve agricultural land. Major revisions included the following:1) designation of absolute agricultural land was legislated, 2) conversion of agricultural land was restricted, and 3) the substitution and classification of absolute agricultural land was also restricted. Therefore, farmers should grow food crops in absolute agricultural land, and both substitute farming in fallow land and growing perennial crops in absolute agricultural land were also prohibited. It was a landmark policy to designate absolute agricultural land. This law defined the absolute agricultural land as the land that is developed by government investment and agricultural base was improved and collectivized. The Minister of Agriculture and Fisheries designated and announced the absolute agricultural land to regulate its conversion and use for other purposes.

2.4.2. Restrictions in Greenhouse Industry by Strengthening Agricultural Land Use Policy

There was no restrictions to construct greenhouses in agricultural land in the 'Agricultural land conservation and utilization law' enforced in 1973. However, regulatory provision related to greenhouse cultivation was included in the revision of this law in 1976, which led to confusion. According to the revision, stationary greenhouses should be constructed in a relative agricultural land and should not exceed 3,300m^2. At that time, most greenhouses were constructed in paddy field especially in the southern part of Korea where growing two crops per year was possible. In the early 1970s, most greenhouses would become mobile to growgreenhouse crops in winter and then removed before rice transplanting.

However, when it comes to constructing stationary greenhouses in absolute agricultural land, farmers had to have the permission from authorities. Realistically, it was difficult to construct stationary greenhouses in absolute agricultural land considering the social situation at that time when self-sufficiency of staple food was the highest priority. Also, farmers should follow the regulation that "perennial crops or ornamental plants should not be planted in paddy field and the fields with inclination of less than 15%" and had to have permission from the Minister of Agriculture and Fisheries or mayors of the county if they wanted to grow those plants in absolute agricultural land. Therefore, it was realistically difficult to cultivate perennial plants in agricultural land that have high productivity, except for a few special cases. The policy to conserve high productive agricultural land for self-sufficiency of food was the chief obstacle to the development of greenhouse horticultural industry that requires the expansion of crop production in stationary and modernized greenhouses.

2.4.3. Legislation of Agricultural Land Act and Elimination of Agricultural Land Use Restriction

As agricultural land use restriction was relaxed from 1989 to 1994 for the convenience of farmers, more than 10,000ha of agricultural land was used for growing perennial plants or other purposes. The Agricultural Land Act, which was comprehensive and fundamental, was enacted in 1996 by reorganizing the legal system for agricultural land. The Farmland Preservation and Utilization Act was eliminated and its agricultural land use-related provisions were included in the Agricultural Land Act. It was allowed to construct stationary greenhouses and grow perennial crops in agricultural development region (which similar to the previous absolute agricultural land) designated in the Agricultural Land Act and, therefore, all factors limiting the use of agricultural land were eliminated.

3. Nurturing of Greenhouse-related Industries and Expansion of Cultivation under Structure

3.1. The Development of Petrochemical Industry and Agricultural Plastic Production and Distribution

Korea is a not an oil producing country. However, fuel oils such as gasoline are the chief items of export in Korea. Some oil producing countries export crude oil to other countries and import fuel oils such as gasoline and diesel because they have no refineries. In this regard, Korea has a very peculiar industrial structure.

Protected cultivation, that is growing crops in greenhouses, is not possible without agricultural plastics since greenhouses are usually covered by polyethylene films. Petrochemical industry is necessary to produce agricultural plastics and their basic raw material is naphtha that is byproducts during the process of refining oil. The construction of the Ulsan oil refinery was begun in 1962 and completed in 1964. But the refinery could not produce various petrochemicals because it only purified crude oil to produce gasoline, diesel, kerosene and coal tar. Before 1970, no agricultural plastics were produced in Korea but annual consumption of agricultural plastics was presumed to be about 2,000 tons, most of them imported from Japan. At that time, it was realistically difficult to import agricultural plastics asthe Korean government tried to limit imports due to the scarcity of foreign exchange.

There are many processes to produce agricultural plastics from crude oil and they are largely divided into two processes; upper process that produce ethylene, propylene, butadiene,toluene, and xylene from pyrolysis of naphtha or natural gas and lower process that produce, using products from upper process, high-molecular substances such as synthetic resins (LPDPE, HDPE and PP) or its raw materials (Caprolactam, AN and EG) and synthetic rubber (SBR and BR), synthetic detergent, dye and agricultural chemicals. Before 1966, upper and lower processes in petrochemical industry were not closely connected to each other. Although a few chemical products such as lactic acid, caustic soda, ammonite, soap and paints produced in 1950s, the scale was very small. However, after lactic acid production facility was constructed, the process of petrochemical products was intimately connected. It was not until 1970 when the Ulsan Petrochemical Complex was completed that agricultural PE, PVE, artificial silk and acrylic fiber were began to be produced. <Table 2-4>shows summary of the process of the development of the petrochemical industry of Korea.

Table 2-4 | Development of Petrochemical Industry and Supply of Agricultural Plastics

	1970s (Development Stage)	1980s (Growth Stage)	Late 1980s-mid 1990s (Take-off Stage)	After late 1990s (Restructuring Stage)
Led by	← government →		← private companies →	
	Government led promotion of industry (Ulsan petrochemical complex)	Establishment of petrochemical foundation (Yeosu petrochemical complex)	Building large scale complexes(Daesan petrochemical complex)	Industry reorganization through M&A
Ethylene production (No. companies)	155,000ton/year (1)	505,000ton/year (2)	4,330,000ton/year (8)	5,700,000ton/year (7)
Exports and imports	Net import	Import → balance	Balance → export	Net export
Growth industry	Light industry	Light → heavy chemical industry	Heavy chemical industry	High-tech industry (IT,BT,NT)
Major policy	• Enactment of petrochemical industry fostering Act • Designated petrochemical industry as strategic industry • Public enterprise led industry. • Government adjusted the price of raw materials and products	• business support project (Basic rationalization plan) • Privatization of public enterprise → private companies led industry • Abolition of petrochemical industry fostering act/Effectuation of industry development law ('86)	• Liberalization of petrochemical investment (partial liberalization by investment rationalization) • Price liberalization-self-regulating prices by private enterprise	• Full autonomy in industrial policy • Inducing companies to do restructure (to improve competitiveness by financial structure improvement)

The first agricultural plastic industry in Korea was the production of polyvinyl chloride (PVC) in 1966 and four facilities in the Ulsan Petrochemical Factory produced 3,000 tons of polystyrene, 3,600 tons of phthalic anhydride and 10,000 carbon black. However, the production could not meet the demand yet. BTX factory was constructed in Ulsan Petrochemical Complex in 1970 and produced lactic acid which is a main material for petrochemical products. In October 1972, the construction of nine facilities related to naphtha cracking was completed, which could produce 100,000 tons of ethylene. Therefore, mass-flow production system from lactic acid to final products was completed for the first time and the Yeocheon Petrochemical Complex was completed in October 1979, which consisted of five companies and twelve factories, producing 350,000 tons of ethylene. Korean petrochemical industry continued to grow and remains a keystone of Korean economy.

The Korean petrochemical industry had been developed by a government-led project and has achieved economies of scale in production. Agricultural plastics from petrochemical industry and distribution of them in low prices made possible the establishment of protected horticulture industry in Korea.

3.2. The Development of Steel Industry Leading to the Improvement of Greenhouse Structure

South Korea has small iron ore deposits but produces and exports a lot of steelthese days, contributing greatly to the national economy. Recently, the Korean steel industry has become competitive all over the world, constructing steelworks abroad. The first steelwork in Korea was the Kyeomipo Steelworks when Korea was under the Japanese colonial rule, constructed in 1918 by the Mitsubishi Steelwork in Hwanghae-do which now belongs to North Korea. Subsequently, the imperial Japanese government constructed Cheongjin (now Kim Chaek Steelwork) and Heungnam Steelworks, which are also in North Korea, for the expansion of armaments. In South Korea under the Japanese colonial rule, the first steelworks was the Korekawa steelworks which had eight small blast furnaces that produced a total of 20 tons/day of steel in 1943,which is now in Samcheok, Gangwon-do. The reason that most of steelworks were constructed in North Korea was that most of the iron ore was produced in those regions. Also, North Korea was rich in coal deposits and hydroelectric power plants and thus easy to get coal and power that are needed for the production of steel.

After the unconditional surrender of Japan,the United States (U.S) and Soviet Union (U.S.S.R.) occupied South and North Korea, respectively, and two different governments were set up at southern and northern parts of Korea. The Korean War began in Jun 25, 1950, lasted for 3 years and ended in 1953 with an armistice agreement. After the Korean War, the production of steel in South Korea was small, if at all. The name of Korekawa Steelworks, the only steelworks in South Korea at that time, was changed to Samhwa Steelworks in 1945 and it remained as the only steelworks in Korea until 1973 when Pohang Steekworks was completed.

The Korean government in 1948 tried to produce steel by establishing the Korea Heavy Industry Corporation but it failed due to the political chaos and the Korean War that destroyed most industrial bases. After the Korean War, the government staged a full-court press for the recovery and reactivation of steelworks but little achievements could be seen.

The Korean government disbursed subsidy two times in 1952 and 1954 to repair three out of eight blast furnaces in Samhwa Steelworks and it produced 627 tons of pig iron. Privatized in 1959, the steelworks shut down frequently and produced a total 4,172 tons of pig iron until it closed down, which was still not enough to meet the domestic demand. The steelworks produced agricultural steel pipes albeit in a small scale. In 1963, many private companies entered in steel industry such as Busan Still Mill (now Dongkuk Still Mill) who introduced electric furnace for the first time. Dong Kuk Steel Mill took over seven blast furnaces from Samhwa, improved their structure and used them until 1990. The company also produced and supplied agricultural pipes in a small scale.

During this period, the production facilities of steelworks was mostly a downstream process rather than upstream and the government continuously made efforts to construct an integrated steel industry by expanding upstream facilities to acquire molten metal. Private companies focused on establishing infrastructure for steel industry by developing technologies to produce various steel products. Rolling facilities in downstream process are necessary for the production of various steel pipes,which are essential for replacing bamboo frame in greenhouses.

The government invested the construction of the first blast furnaces of Pohang Steelworks (now POSCO) by enacting the Nurturing Steel Industry Act in 1970 and steel production system was greatly improved. By constructing the two to four blast furnaces, structural imbalances in steel manufacturing were improved and small and deteriorated facilities were renovated. Self-sufficiency of upstream process, that is, the productivity of molten metal, was greatly increased and this led to a rapid growth of steel industry of Korea. Italso provided a foundation for rapid development of greenhouse horticultural industry, which is now internationally competitive.

Box 2-4 | The Construction of Pohang Steelworks (now POSCO) and Changes in Greenhouse Frames

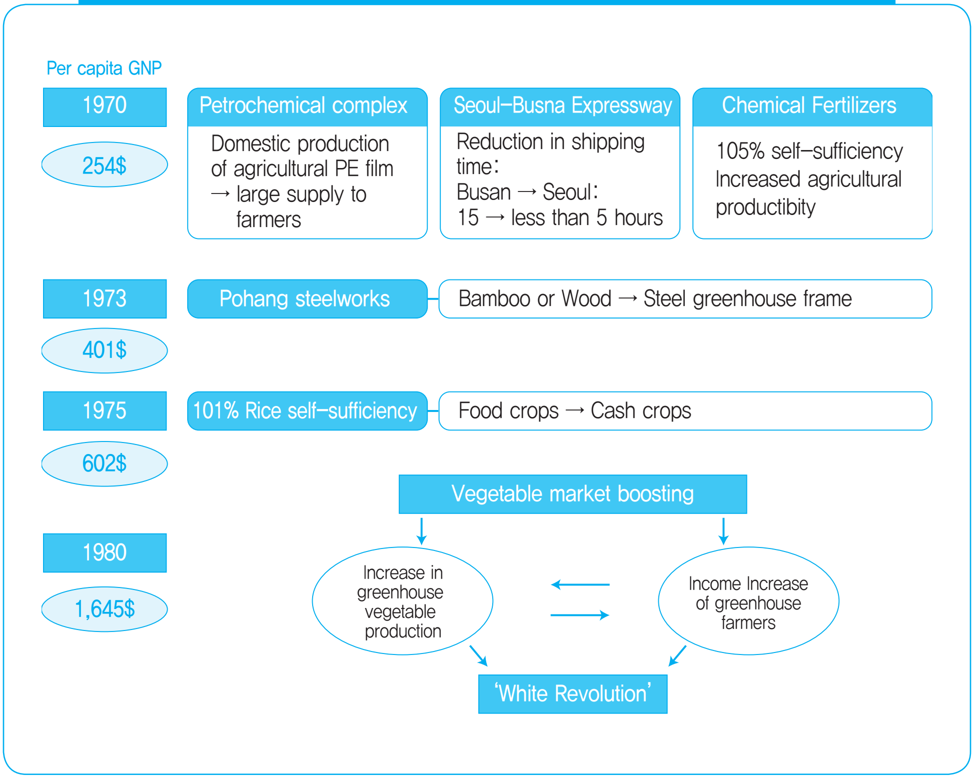
It was not until the production of steel in Pohang Steelworks began in earnest that the supply of steel frame of greenhouse was going smoothly. Korean steel and iron industries grew rapidly after the completion of Pohang Steel works construction as this made it possible for rolling companies and steel pipe manufacturers to expand their business and facilities. Pipes for greenhouses until 1970s were mainly electric wielded pipes produced from steel mills and they were zinc-galvanized from 1980s. Steel pipes generally last longer than bamboo but become rusty easily; however, zinc galvanized steel pipes are rustproof and, thus, became popular.

Conventional steel pipes should be wielded together to be connected and rust usually starts to occur on the surface of its underground and wielded parts. Using zinc galvanized steel pipes, it can be connected by a steel loop (called one-touch band) without wielding and, thus, it is easy to assemble and disassemble greenhouses and no rusts occur in connected parts. The zinc galvanized steel pipes, with a trade name of 'Pentite' was in great demand since its quality was proven as a greenhouse frame material. The pipes were distributed in various diameter and length and contributed to the improvement of the greenhouse industry.

The NIHHS at the RDA proposed a series of greenhouse design standards appropriate for various regions and cropping types through joint researches with Universities, companies and national institutes. 'Greenhouse standardization plan' reduced design cost and integrated many different sorts of greenhouses into few standard greenhouse forms. The plan also affected the development of materials, machines, facilities for mechanization and labor saving cultivation. We will describe the effect in detail in the fifthchapter.

The Korean steel and iron industry has grown rapidly and contributed greatly to the development of construction, shipbuilding, automobile, machinery, electronics and home appliance industries. POSCO expanded their facilities by constructing four plants in Gwangyang and built the world's first FINEX in 2007. This was possible through the construction of two blast furnaces in Hyundai Steel Company in 2010 and providing crude steel to extend automobile business abroad. Steel and iron companies have constructed steelworks throughout the world and they have served as a growth engine for the Korean economy.

Box 2-5 | Relationship between Key Industry Development and 'White Revolution'



3.3. The Development of Fertilizer and Agrochemical Industry Related to Horticultural Crop Production in Greenhouses

3.3.1. Rapid Growth of Fertilizer Industry

Production and distribution of fertilizers that are necessary for growing crops are one of important factors for the rapid increase in greenhouse cultivation area. Fertilizers were applied to provide crops with nitrogen, phosphoric acid and potassium, which are usually deficient in arable land. Korean government fostered the fertilizer industry since processes of fertilizer production are similar to those of explosive and, thus, closely related to defense industry. In the first NEDP (1962-1966), fertilizer industry policy was initiated for the purpose of increasing food production by constructing urea fertilizer plants in Naju and Chungju. Private companies such as Gyeonggi Chemicals and Daewoo also constructed fused phosphate plants in 1966 and 1967, respectively. Self-sufficiency of nitrogenous fertilizers was more than 90% at that time. Fertilizer production capacity of Korea was far above domestic consumption due to increased fertilizer production from various national and private enterprises since 1968. Eighty thousand tons of nitrogenous fertilizers were exported due to overproduction in 1968 and phosphatic and potassic fertilizers were also produced at a rate of extra 50% more than their domestic demand.

The Korean government distributed chemical fertilizers to increase food production from 1950s to 1960s and farmers preferred to use those fertilizers since they act faster and are easier to use than organic fertilizers such as compost and manure. However, overuse of chemical fertilizer caused soil acidification and, therefore, the Korean government also curbed the overuse of nitrogenous fertilizers and distributed lime to neutralize acidified soil, injecting 193 million won to provide farmers with 500,000 tons of lime.

Before 1960s, domestic production of chemical fertilizers was insufficient and farmers had to pay for chemical fertilizers, which accounted for 35% of total production cost. The Korean government fostered the production and use of organic fertilizers to reduce farmer's expense to purchase chemical fertilizers. After self-sufficiency of chemical fertilizers <Table 2-5>, in parallel with overproduction of chemical fertilizers, the overuse of chemical fertilizers in late 1960s decreased productivity of farmland and caused salination of greenhouse soil in 1970s.

Table 2-5 | Changes in Production and Consumption of Chemical Fertilizer in Korea

(Unit: 1,000ton)

Year	Production	Consumption	Self-sufficiency ratio (%)
1960	0	215	0
1962	78	250	36
1965	88	393	20
1970	590	563	105
1975	860	886	97
1980	1,345	828	162

In 1965, 41% (161,000 tons) of total chemical fertilizer supply was used for rice production, 31% for wheat and barley, 4% for miscellaneous grains, 4% for potato and sweet potato, 4% for herbal crops, 4% for vegetables, 2% for mulberry, 2% for fruit trees and 1% for pulse crops. Self-sufficiency of chemical fertilizers in 1965 was just 33% in nitrogenous fertilizer and 13% in phosphatic fertilizer and, thus, most of them were imported. Only after five years in 1970, self-sufficiency of nitrogenous fertilizer was 110% and that of phosphatic fertilizes was 112; however, that of potassic fertilizers was 60% but it also increased to 97% in 1975.

Before 1975 when greenhouse cultivation acreage greatly increased, Korea had enough production capacity to meet demand for chemical fertilizers but the overuse of them deteriorated physicochemical property of soil under greenhouses. Composite fertilizers were supplied to farmers after mid 1970s and application of single fertilizer was replaced by that of composite fertilizer to reduce labor cost for application.

3.3.2. The Growth of Agrochemical Industry and Greenhouse Horticulture

The most prominent change in microenvironment under greenhouses is the higher temperature and relatively higher humidity than the conditions in the field. Plants in greenhouses usually overgrow compared to those in field and are susceptible to various diseases. Besides, farmers usually plant crops denser in greenhouses than open field, which make diseases more likely to occur in greenhouses than in the field. Therefore, more agrochemicals are applied to plants in greenhouses than of those in field. The development of agrochemical industry was necessary for preventing diseases in greenhouse cultivation since farmers depended heavily on agrochemicals for disease control in greenhouses to ensure high profits.

Before 1950s, limited number of agrochemicals such as Bordeaux mixture, lime sulfur, pyrethrum and arsenate were used in agriculture of Korea. Since they were expensive, farmers applied these agrochemicals mostly to cash crops that guarantee high profits, not to grain crops whose diseases were only controlled by disinfection of seeds. Agrochemical application greatly increased from 1950s when Korea received agrochemical aid from the U.S after the Korean War. There was a discernible trend of increased agrochemical application in rice cultivation from 1955. Especially in 1963, there were many agrochemical companies that produced or imported agrochemicals and various agrochemicals were in market due to rapid increase in agrochemical demands. Expansion of agrochemical market was centered on rice cultivation and three-fold increase was observed from 1970 to 1975. During the same period, greenhouse cultivation of horticultural crops was expanded rapidly and more farmers started to apply agrochemicals before diseases/insects occurred.

Most pest control researches in Korea were focused on increasing rice production before 1970s. The effects of agrochemicals on different diseases were tested in horticultural crops from 1970s. Especially in 1970s, various researches were conducted on agrochemicals via an intensification program of crop protection training (1972-1977) and the Korea-Japan agricultural research cooperation program (1974-1992). In this period, various agrochemicals were in market and farmers bought and applied them easily.

Early pesticides were lead arsenate, contact agents such as parisgreen, and lime compounds and botanical insecticide such as lactic acid nicotine. Pyrethrum insecticide and lime-sulphur mixture were used from 1930s for control of aphid and coccid. In 1960s, organo-hydrochloric, organophosphorus and carbamate insecticides were introduced and pest control methods for vegetables were established and distributed, which increased the productivity of vegetables. From 1965, the type and density of nematodes were classified and investigated, respectively, on a national scale, funded by the Ministry of Agriculture, Forestry and Fisheries. In late 1970s when self-sufficiency of rice was achieved, type and distribution of pests for cash crops and their life cycle were investigated. Based on these investigations, disease forecastingformajor pests were available. These researches made it possible to develop pesticides to specific pests such as beet armyworm, broad mite, and pumpkin fruit fly.

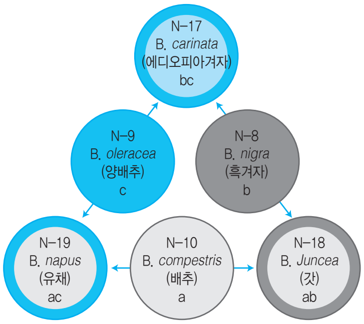
In 1990s when greenhouse horticulture was settled, an illustrated guide for life cycle and control methods of vegetable pests was published and applied in vegetable production. There are approximately 320 species of pests that affect vegetables, and most of them are included in the families of Lepidoptera and Coleoptera. Myzus persicae, cabbage moth and snails, which previously caused no problems in vegetable production, became major pests. These insects developed pesticide resistance rapidly and, thus, were difficult to control. Various researches have been conducted to develop methods to control these insects such as colored sticky traps and pest attracting traps. Environment-friendly control techniques by soil disinfection such as soil fumigant and solar heat have been developed and disseminated to control downy mildew, powdery mildew, gray mold rot, phytophthora blight and fusarium wilt which occur frequently in successive cropping. In addition, various pollen vector insects such as honeybees were selected and disseminated for pollination of fruit vegetables in this period.

4. Development of New Varieties for Greenhouse Cultivation

Korea was the world's poorest country in 1950s and in particular, the Korean War for three years from June 1950 to July 1953 devastated the national infrastructure and agricultural production base. However, vegetable breeding technologies were world-class, thanks to the efforts of Dr. Jang Chun Woo (Jang Chun U). Dr. Woo served as the director general at the Korean Institute for Agricultural Technology, the Central Institute for Horticultural Technology, and the Horticultural Research Institute (now National Institute for Horticultural and Herbal Science, NIHHS) in National Institute of Agriculture and contributed largely to the development of vegetable breeding in Korea [Box 2-3]. After his death, the National Institute of Agriculture was reorganized to the RDA in 1962 and the RDA has develop and disseminate agricultural technologies, which paved the way to achieving both increased food production and increasing farmer's income through greenhouse cultivation. The RDA, agovernmental institution, contributed largely not only to Green revolution in Korea via increase in rice production in mid 1970s but also to "White Revolution" that expand off-season vegetable production. That Korea achieved these 'revolutions' in a relatively short period was due to the breeders and technicians who were trained by Dr. Woo for ten years and to the government-led research and development.

In the initial stages of vegetable breeding in Korea, the RDA or its affiliated organization, the Horticultural Experiment Station, led the development of new horticultural varieties by selecting introduced varieties or breeding elite lines and then distributing them to seed companies. As breeding technologies of seed companies improved, companies took the lead in developing commercial varieties and RDA supported them by introducing and distributing genetic resources and providing them with disease resistant or stress tolerant varieties. As a result, Korea is one of advanced countries in breeding of such vegetables as Chinese cabbage, pepper and radish and this advanced vegetable breeding technologies contributed largely to the achievement of 'White Revolution.' Major results in vegetable breeding are described below.

Box 2-6 | A World-class Breeding Scientist Dr. Jang-Chun Woo (Jang-Chun U)



(U's Triangle : 우박사의 삼각형)

Dr. Jang-Chun Woo was born in Tokyo, Japan in 1896 to a Korean father and a Japanese mother and conducted researches in an agricultural experiment station in Japan after receiving a doctoral degree from Department of agriculture, Imperial University of Tokyo in 1936. He had acquired international prestige by breeding double flower petunia and introduced theory known as Triangle of U by studying the evolution and relationships between chromosomes of three Brassica species. Dr. Woo did not change his Korean name to Japanese, not following a policy aimed at assimilating Koreans into the Japanese culture. He abdicated from his position in 1937 and was hired into the Takii research farm, where he laid the groundwork for present-day Takii seed company. After unconditional surrender of Imperial Japan on August 15, 1945, he resigned from his position in Takii research farm and prepared to leave Japan to Korea. However, Japanese government did not allow him to leave Japan by a policy to prevent outflow of brain. He returned to Korea in March 1950 and joined with the team organized to allow him to work as soon as he came to Korea. The team established the Korean Agricultural Science Research Institute near the city of Busan and conducted various researches on vegetable breeding and worked to train the upcoming generation. However, researches were not going well due to the Korean War that was begun in June 1950. After the Korean War, he served as the director general of the National Institute of Horticultural Technology in 1953 and then the Horticultural Experimental Station in the National Institute of Agriculture in 1957. He passed away in August 1959. In the ten years he worked in Korea, crop breeding technologies were improved rapidly and reached a world-class level. He contributed greatly to the progress in the Korean agriculture by training an upcoming generation of experts who were active in crop breeding, academia, and administration.

4.1. Chinese Cabbage and Radish

4.1.1. Chinese Cabbage (Brassica Compestris)

Chinese cabbage, a major ingredient of Kimchi, isa very important leaf vegetable in Korea. It is self incompatible and, thus, most breeding efforts have been focused on producing inbred lines to make F_1 hybrids. They grow well in high temperature at early growth stage but in low temperature durng the latter stages. Chinese cabbage initiates flower bud differentiation when it is exposed to low temperature at the early growth stage due to their seed or green plant vernalization. Therefore, it is easy to cultivate in fall but difficult in early spring due to low temperature that promote bolting which reduce eatable parts.

Chinese cabbage had been mostly grown in fall before 1960s. Year round production of it was achieved in 1960s through progresses in breeding and cultivation techniques. The first hybrid heading the Chinese cabbage varieties were ‘Horticulture No. 1’ and ‘Horticulture No. 2’ using self incompatibility in 1960 in the Central Institute of Horticultural Technology (now NIHHS). These were the first cultivated hybrid Chinese cabbage cultivars in Korea. Before these hybrid varieties, most of cultivated Chinese cabbages were open-pollinated, native varieties without head,such as ‘Gaeseong’ and ‘Seoul,’ and introduced varieties with head. After the first hybrid varieties, many new varieties in Chinese cabbage have been developed and nowadays, Korea produces sufficient seeds for domestic demand and export. However, Chinese cabbage is grown usually in field and rarely in greenhouses <Table 2-6>.

Table 2-6 | Changes in Protected Cultivation Area in Chinese Cabbage of Korea

(Unit: ha)

	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	72,137	40,478	51,599	44,908	47,495	46,483	51,801	37,203	28,270
Field cultivation	71,331	39,199	47,820	41,266	43,822	39,977	45,527	34,147	24,570
Protected cultivation(B)	806	1,279	3,779	3,642	3,628	6,506	6,274	3,056	3,700
B/A (%)	1.1	3.2	7.3	8.1	7.6	14.0	12.1	8.2	13.1

Source: Production area of greenhouse and field vegetables, 2011 (Ministry for Food, Agriculture, Forestry and Fisheries)

4.1.2. Radish (Raphanus Sativus)

Radish is also a major ingredient of Kimchi has been cultivated for diverse purposes and thus shows varietal differentiation. Radish varieties can be classified based on planting seasons of spring, summer, fall and winter and based on root forms and their uses. Before 1960, most radishes were native open-pollinated varieties and later, F_1 hybrid varieties were grown. In 1953, radish breeding was started atthe Central Horticultural Technology Institute by line separation of introduced varieties from other countries and native varieties from different regions in Korea. Afterwards, crosses among separated lines were conducted and selected lines were distributed to seed companies. F_1 hybrids were started to be developed from 1960s and the most popular F_1 hybrid variety was 'Bulamdaehyoungbommu.' The variety made it possible for a year-round radish production since it can be planted not only in spring at the field of sea level but also in summer at high land. Most radishes are produced in the field and are used for making Kimchi. Therefore, the acreage of radish greenhouse production is small as shown in <Table 2-7>.

Table 2-7 | Changes in Protected Cultivation Area in Radish of Korea

(Unit: ha)

Year	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	66,453	36,973	50,305	40,009	37,127	35,518	40,238	27,130	21,891
Field cultivation	66,427	36,489	48,541	37,521	34,642	31,052	33,541	22,757	20,890
Protected cultivation (B)	26	484	1,764	2,448	2,485	4,466	6,697	4,373	1,001
B/A%	0.0	1.3	3.5	6.1	6.7	12.6	16.6	16.1	4.6

Source: Production area of greenhouse and field vegetables, 2011 (Ministry for Food, Agriculture, Forestry and Fisheries)

4.2. Chili Pepper (*Capsicum Annuum*)

Manychili pepper varieties have been developed in private seed companies since chili pepper is one of the more important crops for farming household economy. Eight hundreds forty nine varieties were registered by 2004 and chili pepper breeding technologies of Korea is now world-class. Among them, a variety for greenhouse cultivation 'Bulam house green chili pepper' was developed in 1969, which is the first F_1 hybrid variety in Korea and is the first variety developed using male sterility in the world. Subsequently, 'Nokkwang' and 'Cheongyang' chili peppers were bred for greenhouse cultivation. The variety 'Cheongyang' was bred using cytoplasmic-genic male sterility (CGMS) in 1983 and has been one of popular varieties since then, due to its unique spicy and sweet taste.

However, the acreage of chili pepper cultivation in greenhouse was also small <Table 2-8> because most chilipeppers were grown for chili pepper powder production in field.

Table 2-8 | Changes in Protected Cultivation Area in Chili Pepper of Korea

(Unit: ha)

Year	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	37,106	99,618	134,314	120,289	64,855	92,198	80,130	67,023	49,976
Field cultivation	36,983	99,113	132,703	117,877	62,759	87,469	74,471	61,299	44,584
Protected cultivation (B)	123	505	1,611	2,412	2,096	4,729	5,659	5,724	5,392
B/A (%)	0.3	0.5	1.2	2.0	3.2	5.1	7.1	8.5	10.8

Source: Production area of greenhouse and field vegetables, 2011 (Ministry for Food, Agriculture, Forestry and Fisheries)

4.3. Watermelon (*Citrullus Vulgaris*)

Korea has a strong preference for watermelon and per capita consumption in a year is about 20kg, making Korea one of highest watermelon consumption countries in the world. Greenhouse cultivation of watermelon was marginal and limited to the southern parts of Korea until 1970s. However, greenhouse cultivation of watermelon has been expanded steadily since then and up to 86% of watermelon was produced in greenhouse in 2010. The percentage is forecasted to rise.The first F_1 hybrid watermelon variety was ‘Suwon’ bred in 1967. Various varieties that were bred in Korea were distributed to farmers by the 1970s. Greenhouse production of watermelon begun in earnest from 1990s and 42% in 1995, 69% in 2000 and 86% in 2010 of watermelon were produced in greenhouses <Table 2-9>.

Table 2-9 | Changes in Protected Cultivation Area in Watermelon of Korea

(Unit: ha)

Year	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	4,904	8,060	7,150	16,714	24,500	25,681	45,207	30,451	23,179	16,396
Field cultivation	4,904	7,349	6,892	15,687	21,208	20,277	26,230	9,499	4,055	2,293
Protected cultivation (B)	0	711	258	1,027	3,292	5,404	18,977	20,952	19,124	14,103
B/A (%)	0.0	8.8	3.6	6.1	13.4	21.0	42.0	68.8	82.5	86.0

Source: Production area of greenhouse and field vegetables, 2011 (Ministry for Food, Agriculture, Forestry and Fisheries)

4.4. Cucumber (*Cucumis Sativus*)

Most cucumbers had been cultivated during the summer in Korea before F_1 hybrids were developed and polyethylene film was distributed. Cucumber is the first vegetable produced year-round in Korea. Cultivation area of cucumber was 3,200ha in 1960 and highest in 1974 of 10,200ha and then decreased to 4,400ha in these days <Table 2-10>.

Cultivated varieties in 1950s were landraces and the first F_1 hybrid variety was 'Jin-ju hybrid No.1' that was the first F_1 variety among fruit vegetables in Korea. In chief producing district in the southern part of Korea, cucumber varieties with growth ability at low temperature have been popular. Cucumber varieties with small leaves have been used for high density planting and those with high growth ability at low temperature have been bred and grown in greenhouse since 1980s.

Table 2-10 | Changes in Protected Cultivation Area in Cucumber of Korea

(Unit: ha)

Year	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	4,640	8,771	5,173	6,332	6,418	6,951	8,548	7,269	5,853	4,396
Field cultivation	4,640	8,264	4,142	4,940	3,992	3,022	2,600	1,426	1,356	807
Protected cultivation (B)	0	507	1,031	1,392	2,426	3,929	5,948	5,843	4,497	3,589
B/A (%)	0.0	5.8	19.9	22.0	37.8	56.5	69.6	80.4	76.8	81.6

Source: Production area of greenhouse and field vegetables, 2011 (Ministry for Food, Agriculture, Forestry and Fisheries)

4.5. Oriental Melon and Melon

4.5.1. Oriental Melon (*Cucumis Melo var. Makuwa*)

Oriental melon is a popular summer fruit vegetable in Northeast Asia and Korea is the highest in oriental melon consumption among them. Landraces were cultivated until 1950s but a true bred variety 'Euncheon' became dominant from 1957, whose fruit shape and yield are superior. A variety 'Chunhyang' with high productivity in greenhouse was introduced in late 1950s and was popular in some regions.

A variety 'New Euncheon' bred in 1974 was an epoch-making variety since it grows well at low temperature and produces 30% more fruits although it has lower sugar content. Since then, most of oriental melon varieties in Korea have changed to 'New Euncheon' type. 'New Euncheon' also triggered the expansion of greenhouse cultivation of oriental melon and contributed to increase in farmer's income. A new variety in 1984 'Geumssaragi Euncheon'

(Gold dust Euncheon) is characterized by its unisexual flowers while other varieties are all bisexual flowers. In the early stages of its distribution, fermented fruits were a major problem of the variety but the problem was solved by research and cultivation efforts.

The quality of oriental melons, similar to watermelon, was determined by sugar contents. Although most oriental melons were produced in the field until 1980s, they have been produced in greenhouse thereafter <Table 2-11> assugar contents of oriental melon from the field were sometimes not consistent.

Table 2-11 | Changes in Protected Cultivation Area in Oriental Melon of Korea

(Unit: ha)

Year	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	6,042	9,141	11,878	12,977	11,193	8,160	11,999	10,253	7,077	6,215
Field cultivation	6,042	8,934	11,295	10,139	6,872	3,951	2,254	754	422	118
Protected cultivation (B)	0	207	583	2,838	4,321	4,209	9,745	9,449	6,655	6,097
B/A (%)	0.0	2.3	4.9	21.9	38.6	51.6	81.2	92.2	94.0	98.1

Source: Production area of greenhouse and field vegetables, 2011 (Ministry for Food, Agriculture, Forestry and Fisheries)

4.5.2. Melon (*Cucumis Melo*)

Melon was the latest crop introduced among fruit vegetables except for paprika. Dr. Woo grew melons for the first time in 1954 at the Central Institute for Horticultural Technology and small scale cultivation was continued until 1960s. The first hybrid variety was 'Pungmi' in 1981. 'VIP' and 'Super VIP' were bred in late 1980s and late 1990s. 'Earls Elite' has been the most typical melon variety since 2000s, which is easy to grow and accounts for two-third of melon cultivation area. 'Picnic' was bred in 2000. Melon is a typical greenhouse crop in Korea due to its disease susceptibility and unstable sugar content in the open field.

4.6. Pumpkin and Squash (*Cucurbita Moschata*)

Landraces of pumpkin and squash were grown until 1940s and squash was grown for greens or herbs and pumpkin was for ripe fruit. In 1954, the Central Horticultural Technology Institute started improvement program of pumpkin and squash varieties by differentiating lines from 'Seoul Madi' and 'Jinachosang.' Around this time, zucchini was grown in greenhouses, earlier in the spring than other pumpkins.

Most pumpkins were grown in the field but varieties of zucchini for greenhouse cultivation were bred in 1969 and cultivated in greenhouses in winter. Zucchinis and green pumpkins have been grown in greenhouse and pumpkins which are grown as full ripe fruitare grown in fields. Since 1990s, greenhouse production account for 40% of total production of varieties of *Cucurbita moschata* <Table 2-12>. The first squash bred in Korea was the autumn squash variety 'Bamhobaek' in 1977. Most autumn squash seeds were exported since it was not popular in Korea at the time. By the 1990s, autumn squash became popular and squash production also increased since people became more concerned about their health.

Table 2-12 | Changes in Protected Cultivation Area in Pumpkin and Squash of Korea

(Unit: ha)

year	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	7,739	8,910	1,687	2,775	3,223	4,091	7,080	8,434	9,327	8,970
Field cultivation	7,739	8,796	1,432	2,407	2,528	2,444	4,124	4,516	5,743	5,724
Protected cultivation (B)	0	114	255	368	695	1,647	2,956	3,918	3,584	3,246
B/A (%)	0.0	1.3	15.1	13.3	21.6	40.3	41.8	46.5	38.4	36.2

Source: Production area of greenhouse and field vegetables, 2011 (Ministry for Food, Agriculture, Forestry and Fisheries)

4.7. Strawberry (*Fragaria Ananassa*)

Many varieties of strawberries have been introduced to Korea since 1910 and cultivated in fields nearby large cities but most field cultivation have now been converted into greenhouse cultivation <Table 2-13>. In 1975, 4% of strawberries were grown in greenhouses and a significant portion was still produced in the fields until early 1980s but 97% of it was in greenhouses in 2010. In 2000s, the varieties that produce strawberry fruits in all season were grown in the highland area.

Since private companies do not breed strawberry varieties, strawberry breeding by crossing was started in 1977 at the Gimhae station of the Horticultural Experimental Station. A forcing strawberry variety 'Chosenghongsim' was bred in 1982 and this was the first strawberry variety bred in Korea. As strawberry cultivation area increased sharply, the Strawberry Experimental Station was established in 1994 at Nonsan, Chungcheongnam-do and breeding of strawberries suitable for Korea's environment was started in earnest. After 2002, there was a loyalty problem from a request to pay for the foreign-bred clones in strawberry production and many governmental research institutes such as the National Institute of Highland Agriculture began to breed new strawberry varieties. As a result, Korean varieties increased sharply from 9% in 2005 to 61% in 2010.

Table 2-13 | Changes in Protected Cultivation Area in Strawberry of Korea

(Unit: ha)

Year	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	0	20	3,935	10,195	7,584	6,857	7,394	7,090	6,969	7,049
Field cultivation	0	20	3,773	8,281	4,135	2,142	1,193	535	260	208
Protected cultivation (B)	0	0	162	1,914	3,449	4,715	6,201	6,555	6,709	6,841
B/A (%)	0.0	0.0	4.1	18.8	45.5	68.8	83.9	92.5	96.3	97.0

Source: Production area of greenhouse and field vegetables, 2011 (Ministry for Food, Agriculture, Forestry and Fisheries)

4.8. Tomato and Eggplant

4.8.1. Tomato (*Lycopersicon Esculentum*)

Private companies were not interested in tomato breeding since demand for domestic tomato seeds consumption was not high in Korea and varieties from Japan were dominant from the early stage. The Horticultural Experimental Station collected and conserved a lot of varieties such as 'Hwangtaehwan' until 1970 and germplasm characterization and line separation were conducted using these varieties. Breeding of hybrid varieties was initiated in 1969, trying to develop new varieties with wilt disease resistance. Varieties 'Dongkwang' resistant to TMV and bacterial leaf spot and 'Kangdong' resistant to wilt disease were developed in 1983 and 1986, respectively. The production of a cherry tomato increased until mid 1990s but production acreage tends to decrease in these days. <Table 2-14> shows histological changes in protected cultivation area of tomato.

Table 2-14 | Changes in Protected Cultivation Area in Tomato of Korea

(Unit: ha)

Year	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	2,326	4,239	2,736	2,630	3,035	2,485	3,927	4,916	6,749	5,270
Field cultivation	2,326	3,643	1,878	1,742	1,387	493	593	170	256	-
Protected cultivation (B)	0	596	858	888	1,648	1,992	3,334	4,746	6,493	5,270
B/A (%)	0.0	14.1	31.4	33.8	54.3	51.6	84.9	96.5	96.0	100.0

Source: Production area of greenhouse and field vegetables, 2011 (Ministry of Agriculture, forestry and fishery)

4.8.2. Eggplant (*Solanum Melongena*)

Landrace 'Jinju-Janggaji' had been popular until 1980s and produced in fields. Breeding of eggplant was started from selection of introduced varieties and 4 lines with black skin and elongated fruit shape were selected in 1958. Ten lines with wilt and insect resistances were selected in 1960. The first hybrid variety 'Heukganggun-Janggaji' was developed in early 1970s and then 'Shinheuksanho-Janggaji' was released in 1979. These varieties were mostly grown in greenhouses. The cultivation acreage of eggplants has decreased since 1980 and no new hybrid variety has been released thereafter. Most eggplant varieties are landraces or introduced varieties. The portion of eggplants under protected cultivation was very small at the initiatory stage but it increased to 35% in 2000s; however, the greenhouse cultivation of eggplants is lower than other dessert fruit vegetables <Table 2-15>.

Table 2-15 | Changes in Protected Cultivation Area in Eggplant of Korea

(Unit: ha)

Year	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	4,217	2,815	2,785	929	520	1,225	966	1,013	889	662
Field cultivation	4,217	2,789	2,720	861	452	1,176	691	623	582	418
Protected cultivation (B)	0	27	66	68	68	49	265	390	307	244
B/A (%)	0.0	1.0	2.4	7.3	13.1	4.0	27.4	38.5	34.5	36.9

Source: Production area of greenhouse and field vegetables, 2011 (Ministry of Agriculture, forestry and fishery)

4.9. Lettuce and Spinach

4.9.1. Lettuce (*Lacuca Sativa*)

Lettuce is a cleistogamy plant and most varieties are inbred lines. It is the second largest leaf vegetable in production acreage after Chinese cabbage and the first vegetable among those consumed raw. Lettuce is divided into two forms, leafy and head lettuces, which account for 84% and 16% of production area, respectively. Most lettuce is produced from greenhouses. The greenhouse production of lettuce steadily increased from 30% in 1974 to more than 80% in 2000s <Table 2-16>. Most cultivated lettuces were landraces and introduced varieties until mid 1990s. Lettuce production sharply increased from early 1990s. Red lettuce became popular in 1995 but this type has yield loss in summer due to bolting.

Most head lettuces are introduced varieties but a variety 'Adam' was released in 2001. In the same year, two varieties 'First' and 'Best' were released and expected to be exported. Superior varieties of head lettuce will be developed in near future.

Table 2-16 | Changes in Protected Cultivation Area in Lettuce of Korea

(Unit: ha)

Year	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	109	1,768	4,482	4,488	4,890	8,307	7,685	5,610	5,248
Field cultivation	0	1,245	3,230	2,613	2,497	2,751	1,767	1,329	709
Protected cultivation (B)	109	523	1,262	1,875	2,393	5,566	5,918	4,281	4,539
B/A (%)	100.0	29.6	28.2	41.8	48.9	67.0	77.0	76.3	86.5

Source: Production area of greenhouse and field vegetables, 2011 (Ministry of Agriculture, forestry and fishery)

4.9.2. Spinach (*Spinacia Oleracea*)

In the southern coastal regions of Korea, spinaches were sown in autumn and harvested in winter or next spring. In central regions, they are planted in early autumn or early spring and harvested in late autumn or early summer, respectively. Cropping pattern that plants spinach in winter and harvests in early spring in all parts of the country became popular due to greenhouse production. Greenhouse production accounts for 45% of total spinach production, contributing to the year-round supply of spinach <Table 2-17>.

There are two types of spinach, 'Oriental' and 'Western' types. Oriental types usually exhibit early bolting while western types do late bolting. The first oriental type spinach was introduced in 1400s and became landraces. Regional landraces were cultivated until 1950s and varietal differentiation of spinach was accomplished in 1960s.

Western types of spinach do not suit the Korean palate and are usually planted in late spring and summer when growing oriental types of spinach is difficult. Most hybrid varieties were imported and sown in January and February. Since importing spinach seeds was difficult in the past, F_2 seeds were used that were gathered from F_1 plants. It is difficult to produce seeds in Korea because spinach seed production is usually in rainy season. Seed production of domestic spinach varieties is usually conducted in other countries or foreign variety seeds are imported. About 7% of spinaches were produced in greenhouses in 1985 but 43% of them were in greenhouse only after five years and the proportion have been maintained after 2000s <Table 2-17>.

Table 2-17 | Changes in Protected Cultivation Area in Spinach of Korea

(Unit: ha)

Year	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total cultivation area (A)	903	3,150	2,936	6,294	6,449	5,237	8,219	7,441	6,693	5,351
Field cultivation	903	3,133	2,885	6,102	5,972	3,103	4,353	4,169	3,715	3,767
Protected cultivation (B)	-	17	51	192	477	2,224	3,866	3,272	2,978	2,400
B/A (%)	-	0.5	1.7	3.1	7.4	42.5	47.0	44.0	44.5	44.9

Source: Production area of greenhouse and field vegetables, 2011 (Ministry of Agriculture, forestry and fishery)

Chapter 3

The Development of New Technologies Leading 'White Revolution'

1. Standardization and Modernization of Greenhouses
2. Setting Criteria of Safety in Greenhouses for Horticulture Crops
3. Development of Energy Saving Greenhouse Technology
4. Development of Subsidiary and Labor-saving Automated Facilities
5. Establishing Year-round Mass Production System of Standard Seedlings
6. Development of Hydroponic System for Year-round, Stable Production
7. Establishing Appropriate Environment for Greenhouse Production
8. Improving Soil Environment within Greenhouses

The Development of New Technologies Leading 'White Revolution'

Modern protected cultivation was started in the Netherlands. The Netherlands is located in latitude 48, northern temperate climate region and its long and cold winter is a major limitation tocrop production. This led the advancement of greenhouse technology in the Netherlands and now they have a great influence in the world's flower market. Japan also has advanced greenhouse technologies and is located in similar latitude with Korea. Japan consists of many islands where there are limitations in production and transportation of agricultural products. The Japanese greenhouse technologies have been developed for winter vegetable production in the East coast of Japan near the Pacific Ocean with much sunshine in winter. The Korean horticulturalists have studied the Japanese greenhouse technology due to its similar environment and food habit with Korea. The other country that has advanced greenhouse technologies is Israel, a relatively new country founded in 1948 and located in dry subtropical region at latitude 32. Since the nation's founding, Israel has made great efforts to develop drip-watering methods for the first time to conserve water. Israel has developed different systems for greenhouse cultivation in dry climate. Greenhouses in the Netherlands are covered with glass with good sunlight penetrability and have facilities of supplemental lighting, heat conservation and heating in order to overcome insufficient light and cold weather. Due to its climate with excess sunlight, high temperature and insufficient water source, however, greenhouses in Israel are covered with plastic films and equipped with ventilation and shading systems.

Neither the Dutchor the Israeli greenhouses are suitable for Korea or Japan due to their unique climates. Winter in Korea is colder than the Netherlands and summer is similar to Israel but with high relative humidity. In the early stage of greenhouse vegetable production in Korea, greenhouses with high heat conservation were installed for vegetable production in winter and then disassembled in early summer for rice production. As fixed greenhouses became popular, multi-functional greenhouses were required for growing plants both in cold and dry winter and in hot and humid summer. Neither greenhouses of the Netherlands for low temperature and insufficient light, nor that of Israel for high temperature and excess light is sufficient for the Korean climate. Greenhouses in Korea typically have both double or triple covering materials for heat conservation in winter and shading and ventilation systems for cooling in summer to make possible growing crops in summer and winter in a same greenhouse. It was impossible in the early greenhouse structure to achieve these two goals but continuous efforts to develop new technologies made it possible to grow plants in a same greenhouse in both winter and summer.

1. Standardization and Modernization of Greenhouses

The production and use of zinc galvanized steel pipes sharply increased by the 1980s since many farmers installed greenhouses using these pipes but the greenhouses varied in size and form. The standardization of greenhouse structure was needed for efficient greenhouse construction and management. Therefore, the National Horticultural Experimental Station developed four standard greenhouse models and distributed standard blueprints <Table 3-1>. These standard greenhouse designs include labor saving facilities of semi-auto curtain, side ventilation and watering systems, representing the first blueprint for greenhouse horticultural crop production in Korea. These new greenhouses were distributed rapidly due to its labor saving production of vegetables. The Korean government supported the construction of these new greenhouses and the Horticultural Experimental Research Station also educated farmers on the improvement of new greenhouse standards compared to old ones. These new greenhouses contributed largely to year- round production of vegetables and expansion of greenhouse industry.

Knowledge on architecture engineering is needed to design and construct greenhouses but farmers usually do not have this knowledge. Therefore, the government provided free standard greenhouse designs, each of them specific to each crop and climate, and farmers could save design costs for constructing greenhouses. The standard greenhouse designs provided by government also helped farmers to decide what crops they grow in different climate and how much money they need to construct greenhouses. Various facilities and machines were needed for labor-saving crop production in greenhouses. Subsidiary facilities were developed in accordance with the standard greenhouse designs and helped to reduce labor costs.

Table 3-1 | Greenhouse Types and Sizes
(National Horticultural Experimental Station, NHES, 1980)

Types and names	Length (m)			Purposes
	Width	Flank height	Height	
Single span greenhouse type1-1 Single span greenhouse type 1-2 Single span greenhouse type 1-3 Single span greenhouse type 1-4	4.5 5.9 7.0 5.4	1.4 1.6 2.0 1.8	2.4 2.9 3.4 3.0	Sericulture and raising seedlings Raising seedlings, leaf and fruit vegetables Crops with tall plant height Leaf and fruit vegetables

2. Setting Criteria of Safety in Greenhouses for Horticulture Crops

Climate condition, distance to a market, geological features, and soil productivity should be considered for rational managements of greenhouse horticulture. First of all, regional climates for 30 years in Korea were analyzed to establish safety standards for greenhouse structures and adaptable crops. This was to help select regionsthat are well adapted to a specific crop. The investigation of regional climates is also important for energy savingsince much energy is needed for year-round crop production due to striking temperature differences between summer and winter in Korea.

Climate conditions including the average temperature, amount of solar radiation, snowfall and wind speed are important factors of consideration for design greenhouses to ensure year-round crop production.Therefore, minimum air temperature, maximum amount of snowfall, and maximum wind speed were investigated for setting up regional safety standards for greenhouse structure.

Heating demand is required amount of heat for sustaining greenhouse temperature appropriate for the growth of crops. This depends on both difference between outside temperature and setting temperature in greenhouse and on heating degree hour (DH). There are large differences among crops in the number of crop cultivation days without heating in greenhouses. The crop cultivation days can be calculated in greenhouses that are able to maintain 10°C using heat reserving system. These greenhouseshave coverings outside and inside the frame and small tunnels inside the coverings. Cold-acclimated vegetables such as lettuce and strawberry can be cultivated in January in the southern part of Korea in greenhouses adopting heat reserving system. Especially in Jeju island, most vegetables, except for red pepper, bell pepper, and melon can be grown in greenhouses without heating.

3. Development of Energy Saving Greenhouse Technology

3.1. Greenhouse Covering Materials

Polyethylene (PE) films were produced only after 1960s in Korea and used for covering materials in greenhouse construction. Ethylene-vinyl acetate (EVA) and polyvinyl chloride (PVC) films begun to be used in early 1970s but more than 90% of covering materials were PE film. The advantage of PE film is its low cost compared to EVA and PVC films although its thermal resistance and durability are little less than EVA and PVC. Due to its low cost, PE film is a very popular covering material for greenhouse and accounts for 70% of greenhouse covering materials till today.

Various plastic films have been produced in Korea since 1970s and, thus, many researches were performed to verify the effect of these plastic films on the growth of plants. Researches revealed that EVA film is more appropriate for semiforcing culture than PE film since it has better heat reserving ability. Also, cashmilon is good substitute for straw mat [Figure 3-1] which was the most popular heat reserving materials before.

Figure 3-1 | Heat Conservation Using Straw Mat on the Roof of a Greenhouse in Late 1970s

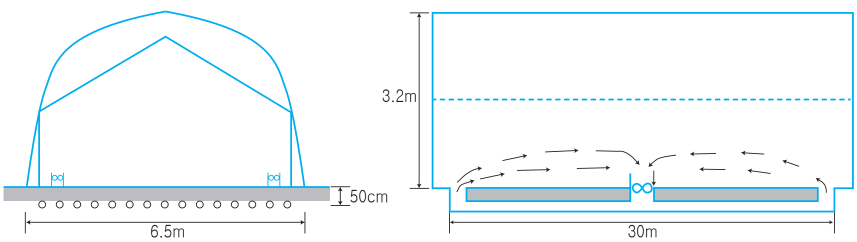
By the 1980s, various fabrics for greenhouse curtain, covering materials for row covers and films for mulching were developed. Covering materials for greenhouses should have good light transmission. However, heat reserving materials should be equipped with both thermo-keeping ability and workability and, therefore, researches were conducted to use aluminum-coated or mixed films for trapping radiant heat from heaters in greenhouses. Both insulation materials such as cashmilon and intumescent PE film and aluminum coated or mixed films were used for greenhouse heat-keeping.

In 1990s, researches were conducted on improving light quality and preventing water drops in greenhouses using surfactants and various functional films were developed, which improve light quality and prevent water drop in greenhouses. These films were distributed and contributed to the improvement of not only working environment in greenhouses but also farmer's income.

3.2. Underground Heat Storage Greenhouses

Only 50% of solar radiation is transmitted in greenhouses and seven to eight percent of the remaining 50% solar radiation is getting into underground. To improve these low thermal efficiency of solar heat, the NHES developed underground heat storage facilities that consist of PVC pipes (100mm in diameter) and earthen ware pipe (90mm in diameter) buried in the ground 50 cm and 80 cm in depth, respectively, with 60cm spacing and air in a greenhouse is circulated by air blowers located in the center of a greenhouse. Using this facility, air temperature in underground heat storage greenhouses increased by 10.2°C when compared to outside temperature (-5.8°C) from December 8 to 9, 1980. Underground heat storage also increased as 57% of solar radiation (220,585Kcal) was transmitted into greenhouse and heat storage was 22.3% (86,365Kcal). Production of tomato, cucumber and lettuce increased by 5 to 28% using this facility and 80-89% of heating energy was reduced in semiforcing culture of lettuce and cucumber.

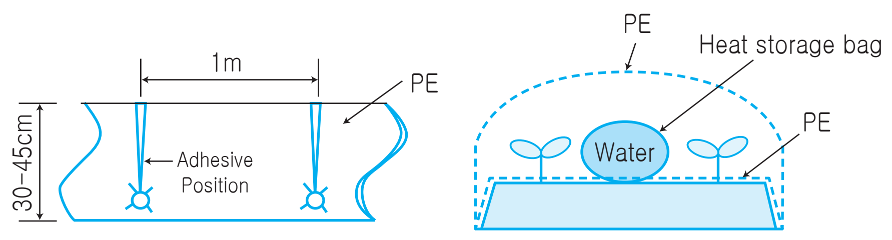
Box 3-1 | The Structure of Underground Heat Storage Greenhouse (NHES, 1982)



3.3. The Development of Heat Storage Bags

Heat storage bags are plastic tubes (15-45cm in width) containing water located on the ground in greenhouses. The plastic tubes are made of PE film and their colors are transparent, black and partial transparent. Average air and ground temperatures increased 2.4°C and 3.4°C, respectively, using 30cm PE tubes (in width) in greenhouses covered with EVA film (0.07mm) with one layer internal curtain. 4,131Kcal per 10m^2 of heat radiation was absorbed in both soil and heat storage bags in contrast to 1,987Kcal (4.4% of heat radiation) absorbed in soil alone, showing a two-fold increase in efficiency of solar energy utilization when using heat storage bags. Heat energy in heat storage bags was 2,437Kcal and that of soil was 1,694 Kcal. Heat storage bags are useful in the region where receives large amount of solar radiation in winter since greenhouses in this region usually have no heating systems and, therefore, depend entirely on solar energy. Heat storage bags are more effective in the region where average amount of solar radiation is more than 200 cal/cm^2/day.

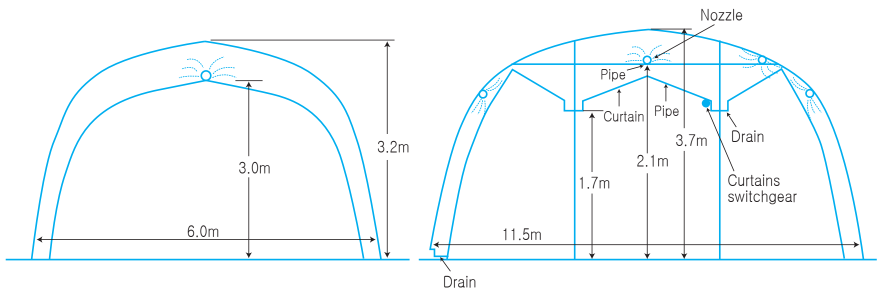
Box 3-2 | Sizes and Installation Site of Heat Storage Bags (NHES, 1981)



3.4. Water Curtain Greenhouse

Water curtain greenhouse utilizes latent heat in underground water. Curtains are set up in a greenhouse and underground water (14-16°C) is applied on curtains using nozzles to maintain air temperature in a greenhouse. A drainage system is necessary for water curtain greenhouse. A series of experiments conducted by the Busan Horticultural Research Station revealed that the water curtain greenhouses are efficient heat reserving system. Air temperature in greenhouses was 9.4°C when outside temperature was -9.2°C and average underground temperature was 16.7°C, showing 18.6°C difference between outside and inside greenhouse temperatures. Heating cost was reduced by more than 76% when underground water was applied at 264L/min/10a.

Box 3-3 | Schematic Diagrams of a Water Curtain Greenhouse (HRES, 1981)



4. Development of Subsidiary and Labor-saving Automated Facilities

In 1960s, most greenhouse frames were made of wood and bamboo, and no labor-saving facilities were equipped in greenhouses. Therefore, farmers had to do everything manually to grow horticultural crops. By the 1970s, however, labor saving cultivation became an emerging issue due to 1) rapid expansion of greenhouse cultivation, 2) decrease in the rural population, 3) population aging in rural society and 4) increase in labor cost. Some farmers began to introduce heaters and irrigation facilities in their greenhouses.

It was not until 1980s that standard greenhouse designs included side wall windows, curtains and irrigation facilities. These facilities were distributed rapidly due to a labor shortage in rural area although these facilities were not automated since electric power was not supplied in greenhouses. At the time, irrigation was the most labor-intensive work and, therefore, furrow irrigation system was substituted by dripper or nozzle irritation systems. Manual chemical spray system was replaced by fog applicationor fumigation [Figure 3-2]. By the 1990s, there were many achievements in labor-saving greenhouse cultivation by greenhouse facility modernization. Ventilation and heat reserving curtain systems were automated and irrigation system was changed to a fertigation system to water and fertilize greenhouse plants at the same time. Fan heaters with an automatic temperature regulator were developed and distributed rapidly. These automated facilities were adopted in greenhouses accounted for 5,000 ha by 2002.

Figure 3-2 | Moving Spryer in a Greenhouse

The Korean government supported for developing these labor-saving facilities by funding and policy making. The National Horticultural Research Institute (the NHRI, now the NIHHS) conducted many researches in this period on improving subsidiary and ventilation facilities in greenhouses, standardizing aluminum structures in glasshouses, labor-saving harvests and improving hot water heating systems. These efforts contributed greatly to the improvement of greenhouse cultivation technologies.

5. Establishing Year-round Mass Production System of Standard Seedlings

5.1. Systematization of Plug Seedling Production Technologies

Plug seedling production refers to the seedling production technology with automated equipments for bed soil filling, germination, irrigation, transportation, and management in dedicated facilities, in order to produce high quality plug seedlings in large quantities similar to producing goods at a factory. As greenhouse cultivation acreagerapidly increased after the 1980s, the need for year-round vegetable production without seasonal constraints increased. Seedlings were produced in small scale by individual farmers in the beginning.

However, chiefhorticultural crop producing districts became large and there were increased demand for seedlings regardless of seasons. Some groups of farmers started cooperative seedling production in order to lower the management costs and improve the environment for raising seedlings.

Technologies for plug seedling production have been developed since 1992 as there was aneed for seedling specialization. Afterthe development of plug seedling production technologies, the next step was automation for a cost-effective plug seedling production. Various automatedfacilities have been developed thereafter including the seedling production-dedicated greenhouses, nursery bed conveyer for seedling trays and environment management models depending on seedling stages. Nursery bed soils for automatic seedingand automated devices for filling bed soil were also developed. Other automation equipments for seeding, and irrigation, germination and seedling management were also developed to systematize plug seedling production. Based on these facilities,automated, uniform seedling production system was established to ensurelabor-saving greenhouse cultivation.

5.2. Development of Bed Soils Dedicated to Seedling Production

With the establishment of plug seedling production technologies during the 1990s, new nursery bed soils were needed for large-scale production of plug seedlings. Peatmoss and Coierhave been used since they are organic bed-soil materials with homogeneous compositions and good physio-chemical properties, high work efficiencies, and light weight. Peatmoss is made of sphaerocarpus grown at high-latitude regions such as Canada, the U.K., Russia and New Zealand, while Coier is made of coconut by products from tropical regions such as Indonesia and Sri Lanka. Light-weight mixed bed- soils dedicated for seedling production using Peatmoss and Coier were developed and distributed to nurseries. Manufacturing technologies for these bed soils allowed rapid development of nursery bed-soil industry. Since the 2000s, most seedlings have been produced from specialized nurseries and farmers just order seedlings from nurseries and transplant them into greenhouses. Thus, seedling business has been specialized, separate from crop production. A distribution system for planned production and sales of plug seedlings has been established as well. This improved quality and reduced in production costs of greenhouse vegetables, leading to increased income forfarmers.

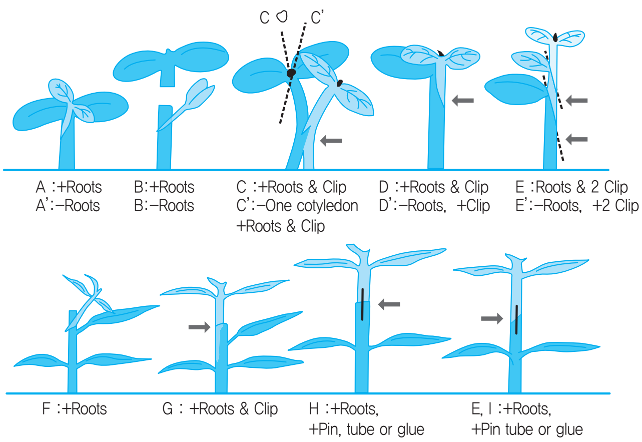
5.3. Development of Production Technologies for Grafts

Grafts have been frequently used for various purposes such as preventing damages from soil-born diseasesdue tosuccessive cropping, improving plant growth at low temperature in greenhouses, reducing salt injury, and improving qualitiesof vegetables. In accordance with the introduction of plug seedling production technologies in early 1990s, the proportion of producing grafted seedlings at nurseries for various purposes has rapidly increased with increasing demand for grafted seedlings. As the demand for grafts is expected to further increase, manyresearchers have been studied to develop grafting methods, grafting machines, environment management technologies and devices to improve graft compatibility.

Blight resistant rootstocks have been commercialized for peppers and more than 10 tomato rootstocks that are resistant to various diseases and insects including brown root rots, root blue stems, fusarium wilt, verticillium wilt and nematodes have been distributed. For eggplants, four rootstocks resistant to drying disease, verticillium wilt and blue stems have been distributed, and various rootstockshave been developed with various resistances.

Grafting technologies were first developed for *Cucurbitaceae* vegetables and various grafting technologies are being utilized. Pumpkins and gourds are often used for watermelon as the rootstocks to prevent fusarium wilt. For oriental melons, pumpkins that have high growth ability at low temperature, hot tolerance, and resistance against fusarium wilt are often used as rootstocks. Rootstocks for cucumbers are pumpkins and in case of white-spine cucumbers, Bloomless rootstocks are utilized.

Box 3-4 | Grafting Methods in Fruit Vegetables (*Cucurbitaceae and Solanaceae*)



Several grafting methods have been developed for vegetables;cleft grafting, inarching, insertion grafting, root pruning insertion grafting and pin grafting.Nurseries often used a pin grafting method for *Solanaceae* vegetables. Academic-industry collaborative research groups have developed grafting robots for labor-saving grafting technologies and made practicalmass production of grafted seedlings, which significantly contributed to the establishment of year-round seedling production system. Such technologies have been exported with grafting robots, providing the opportunity for Korea's seedling production technologies to spread all across the world. These technologies have been applied and are common in Korean nurseries [Figure 3-3].

Figure 3-3 | Mass-scale Plug Seedling Production

6. Development of Hydroponic System for Year-round, Stable Production

In Korea, multi-purpose standard nutrient solution was first developed for hydroponics in the late 1980s. Appropriate Electric Conductivity (EC) and nitrogen types and proportions for different growth stageswere suggested for cucumbers and lettuces and thisbecame the motive for putting hydroponic technology into practical use. Hydroponic systemhas been distributed since 1994 by including the system in the government-led greenhouse facility modernization program that began in 1992. Hydroponics expanded rapidly thereafter. Acreage for hydroponics increased from 168ha in 1995 to more than 700ha just 5 years later, and further expanded to 1,100ha in 2010, contributing to a year-round stable production and supply of greenhouse horticultural crops.

6.1. Development of Hydroponic System and Culture Media

Hydroponic system can be broadly classified as non-solid and solid medium cultures. Most leafy vegetables with short growing periods are grown in non-solid medium while many fruit vegetables with relatively long growing periods are grown in solid medium. Rockwool medium developed in the Netherlands was often used for solid medium. While the Rockwool medium has excellent physio-chemical properties and high work efficiency due to its easy forming and shaping, it causes environmental issues upon disposal after the harvesting of crops.

Perlite was chosen for an alternative solid medium for Rockwool. Perlite has good physio-chemical properties comparable to Rockwool, its price is also low and its disposal is easy and environmental-friendly. Therefore, 70% of hydroponics has adopted the perlite medium. Perlite medium was particularly good for strawberry production using elevated bed system [Figure 3-4]. Elevated bed system was developed for work conveniences and labor saving as the farmers would not need to bend down as they work.

Figure 3-4 | Hydroponics for Strawberry Production Using Elevated Bed System

6.2. Development Nutrition Solutions and Fertilizers Specialized for Each Crop

In late 1980s, NHRI standard nutrient solutions that could be used for various purposes (T-N:P:K:Ca:Mg:S= 15:3:6:8:4:4 me/L) have been developed and distributed to farmers. Then, through sustained tests for appropriate nutrient solution in different crops, specialized solutions for 12 crops, including dedicated nutrient solution for green pepper perlite medium, have been developed and distributed to farmers. This technology has been transferred to private companies, and the companieshave modified and sold them in the forms of complex fertilizers, which are convenient for farmers to use.These fertilizers are still widely being used.

7. Establishing Appropriate Environment for Greenhouse Production

7.1. Technologies for Temperature Control

Underground heat storage greenhouses and heating storage bags were developed to improve heat conservation in greenhouses and distributed in 1982. When the outside temperature was –5°C, temperature of greenhouses with curtains was higher than that of greenhouses without curtains by roughly 2.5°C but the heat conservation efficiency decreased as the outside temperature increased. As for heating materials, flaps had higher heat conservation capacity than foam PEs. During the 1990s, the area of heating greenhouses rapidly increased with facilities modernization. While the proportion of heater-supplied greenhouses was around 10% in 1990s, the proportion doubled to 20% in 2001.

Fan heaters were mainly used inplastic film-covered greenhouses while hot water heating system was supplied at glasshouses. Centered on farms growing ornamentals in greenhouses, hot water heating system, which allowed more precise temperature control, came to be gradually expanded. During this period, geothermal water-heating boiler werealso developed and distributed. Also, after the 1997 foreign currency crisis in Korea, electrical automatic nighttime temperature-control system with sensors to detect the amount of solar radiation was developed and implemented to save energy and improve productivity, resulting in 10-15% reduction in heating costs.

7.2. Technologies for Light Control

During 1980s, the types of cover materials used in greenhouses became diversified and films with high light-penetration capacity were distributed. Meanwhile, the development of shading materials to lower temperature and control sunlight became popular as well. These shading materials have been used in growing ornamentals as well as other crops requiring with low light saturation point such as lettuces, crown daisies and chives in the summer seasons.Technologies for flower inhibiting through light control and shading have become systematized. Light control technologies have been applied to lettuces, crown daisies and spinaches, and shading technologies to strawberries, which significantly contributed to establishing stable year-round production system.

During 1990s, many researchers studied theoptical characteristics of glass greenhouses. By suppressing the penetration of high frequency waves but maintaining high penetration rates, temperature of glasshouses rose more than anhour earlier than PE greenhouses. This can improvethe quality and productivity of tomatoes, melons, and peppers, which requires strong-light and high-temperature. Meanwhile, studies have been conducted on the transparent film rather than colored film, which was widely used before, to increase effective wave-length range for photosynthesis through light quality changes. Light quality changing transparent film is effectivefor converting the ultraviolet ray scope under 400nm, which is harmful for growth of plants, to 600-700nm range that is good for photosynthesis. Through the studies, the amount of light was increased by approximately 5% and wave length effective for photosynthesis was expanded by about 10% in greenhouses. Those studies helped improve the light environments within greenhouses.

7.3. Technologies for Gas Control

From environmental assessment of various gases within greenhouses in 1976, occurrences of harmful gases were found to increase following increased usage of chemical fertilizers. However, the concentration of CO_2 in the greenhouses was low and not reached to 300ppm in Kimhae and Namji regions, displaying CO_2 shortages. Especially, during the four hours between 11am and 3pm when photosynthesis is active, the CO_2 concentration was lower than 340ppm, which is ambient concentration, interfering with plants'normal photosynthesis and growth.

Through the supply of CO_2 into greenhouses, supplying 1,500ppm of CO_2 increases the yield of lettuces and spinaches by 150% and 177%, respectively, compared to controls. Also, the production of peppers and radishes increased by more than 100% at 2,000ppm CO_2 and 1,000ppm CO_2, respectively, and tomatoes and cucumbers also displayed production increases of 36% and 19%, respectively. During 1990s, the CO_2 supply was an imperative technology to grow paprika whose cultivation acreage became expanded due to increase in export. Also, following studies proved that utilizing CO_2 in insufficient lightcondition in winter can compensate for light intensity and that the damages from high temperatures in summer can be alleviated with supplying CO_2. Therefore, CO_2 supply technology has been widely distributed in greenhouse cultivation.

7.4. Technologies for Irrigation

Since there is no rain in greenhouses, irrigation is necessary for growing. Especially, the root distribution of greenhouse crops is shallower and narrower than field crops and, therefore, the crops are prone to damage from drought when there is not enough soil moisture. Furthermore, as the temperature is elevated in greenhouses, evaporation of soil moisture increases as well. Therefore, soil moisture within greenhouses can greatly affect the productivity and quality of crops.

In the early 1980s, inexpensive spraying hoses were widely supplied and irrigation using spraying hoses was popular in growing leaf vegetables. However, mechanical irrigation control was impossible using spraying hoses, similar to furrow irrigation system, and this caused excessive soil moisture and high relative humidity in greenhouses, the condition favorable to occurrence of diseases and pests.

In the mid-1980s, facilities for drip-watering that can water at desired spots only for desired amounts have been distributed to farmers. Studies were conductedon supplying water evenly using drip-watering tubesand on appropriate irrigation distances and times thereafter. From late 1990s to early 2000s, many researchers studied to develop automated irrigation systems. Semi-automated irrigation system using timers were popular in the beginning but automated irrigation systems were developed by determining appropriate soil moisture contents for each horticultural crop using various soil moisture sensors such as the Tensio-meters and TDR sensors [Figure 3-5]. As hydroponicsand fertigation increased, automated fertigation system that can reduce labor by providing water and fertilizers simultaneously have been developed, responding to labor and water shortages in rural areas. Precise agriculture through precise controls was achieved through the advances in these technologies.

Figure 3-5 | Automated Irrigation System Using Tensiometer in Greenhouse Watermelon Cultivation

8. Improving Soil Environment within Greenhouses

8.1. Identification of Standard Fertilization Rate for Greenhouse Crops

With excessive usage of chemical fertilizers in greenhouse vegetable production, the chemical properties of soils became significantly worsened. Due to continuous cropping and increase in the accumulated number of crops in greenhouses by late 1990s, salt injuries increased with increased EC resulting from salt accumulation. The RDAinvestigated a total of 89 crops (5 grains, 3 fat and oil crops, 11 fruit vegetables, 7 root vegetables, 21 stem and leaf vegetables, 9 wild vegetables and herbs, 8 fruit trees, 16 medicinal crops, 5 ornamentals, 4 mulberry and others) to identify appropriate soil physio-chemical property and set up standard fertilizer application dose. At the same time, detailed standard fertilization methods were assigned for approximately 40 crops and they are still recommended.

8.2. Technologies to Reduce Damages from Successive Cropping

One of the potential risk factors affecting productivity in greenhouse vegetables is successive cropping. When a crop is continuously cultivated at the same location, such practices can lead to increase in insects and soil-transmitted diseases, worsened physio-chemical properties of the soil, and accumulation of poisonous contents, preventing stable crop production. Technologies to reduce damages from successive cropping came to be reviewed during 1980s and soil disinfectants of greenhouse chili peppers to reduce verticillium wilt and other phytophthora rots were identified. During late 1980s, the effects of solar heat sterilization on the control of root-knot nematodes in greenhouses cultivation of green peppers were investigated and results showed that if the ground temperature was maintained at 40°C which was the effective for sterilization up to 20cm of the soil, the result was a drastic decrease in the concentration level of phytophthora rots. Also, through the testing of different soil disinfection methods to control root-knot nematodes on pepper seedlings, disease occurrence rate was brought down to lower than 5% without significant difference amongsolar heat, steam, and chemical disinfection. However, the yield of green chili pepper was highest in solar heat sterilization. Among soil disinfection methods, solar heat sterilization method was considered to have the smallest environmental problems and lowest costs, and to be most advantageous in improving the soil fertility. The method was therefore disseminated to the farmers.

During 1990s, studies on cropping systems to reduce damages from successive cropping were conducted. Radish and spinach were appropriate for proceeding crops of chili pepper. For crop rotation of peppers, the crop rotation system of “small green onions – chili peppers – small green onions” was favorable. By informing of such knowledge to farmers, stable production of chili peppers was achieved. In case of oriental melons cultivated in greenhouses, researches were performed to reduce the density of nematodes during late 1990s. Planting cabbages after harvesting oriental melons increasedthe density of root-knot nematodes while planting upland rice significantly reduced the density. Therefore, the crop rotation system of planting “oriental melon + rice + chives” were developed, and disseminated to farmers suffering from yield decrease due to successive cropping. In 2000s when organic farming was popular, ryes, green manure crops, wereplanted prior to and after chili peppercultivation to reduce damages from phytophthora rots and to supply organic matters. Accordingly, a crop rotationsystem of “rye (20kg/10a) + peppers” has been developed to alleviate the hazards from successive cropping of chili peppers.

8.3. Technologies to Reduce Salt Accumulation Greenhouses

One of the problems that make year-round production of greenhouse vegetables impossible is the salt accumulation in soils. In early 1970s, greenhouse soils near Gimhae were analyzed to collect data on soil chemical properties. Also, the greenhouse soils of chief producing districts for flowers and vegetables were analyzed in detail to study Korea's salination status of greenhouse soil, from early 1990s to early 2000s <Table 3-2>.

The phosphate, exchangeable cation, and ECin 2001 increased significantly when compared to the soil chemical properties in the beginning of Korea's greenhouse industry (early 1970s) The values were significantly higher than the soil nutrition level appropriate for vegetable cultivation. This revealed that salt accumulation of soils in greenhouses had reached a serious level.

Table 3-2 | Chemical Properties of Greenhouse Soil (NIAST, 2003)

Year	pH (1:5)	OM (%)	Av.P_2O_5 (mg/kg)	Ex.Cations (cmol/kg)			EC (dS/m)
				K	Ca	Mg	
1973	5.8	1.8	190	0.34	6.08	1.95	-
1993	6.0	2.3	1,019	0.74	7.20	2.50	2.20
2001	6.2	3.4	805	1.41	7.92	2.73	2.85

Technologies to reduce salt accumulation in greenhouse soil involve detailed analysis of soils and appropriate fertilization methods and it is recommended to gradually reduce the amount of fertilizers in greenhouse crop production <Table 3-3>. The methods that can be directly implemented by farmers include soil dressing, fresh watersoaking, crop rotation with *Gramineaeor* catch crops (corns, ryes, canes or crown daisies) [Figure 3-10], and injection of organic matter into soil to reduce the soil EC. Such methods have been recommended to farmers.

Table 3-3 | Trend in Reducing Standard Amounts of Fertilizers

(kg/1,000m², NIAST, 2003)

	Fertilizer	1950s	1960s	1970s	1980s	1990s (after reduction)
Field vegetables	Nitrogen	-	-	25.9	25.9	23.3
	Phosphate	-	-	18.7	18.7	8.5
	Potassium	-	-	18.7	18.7	15.7
Greenhouse Vegetables	Nitrogen	-	-	25.9	25.9	16.1
	Phosphate	-	-	18.7	18.7	6.2
	Potassium	-	-	18.7	18.7	9.8

Figure 3-6 | Crop Rotation Using Corn to Prevent Salt Accumulation in Greenhouse Soil

Chapter 4

Dissemination of New Greenhouse Technologies to Farmers

1. The Spread of White Revolution and the New Community Movement
2. Training Course for Farmers by Rural Development Administration
3. The Dissemination of Protected Horticulture Technology to the Farmers through Research Institutes

Dissemination of New Greenhouse Technologies to Farmers

1. The Spread of White Revolution and the New Community Movement

1.1. President Park, Chung-Hee and the beginning of New Community Educations

Box 4-1 | President Park, Jung-Hee and 'White Revolution'

It is still unknown who coined the term 'White Revolution' for the first time in Korea. Greenhouses for protected cultivation was distributed rapidly throughout the country after the completion of 1) The Ulsan Petrochemical Complex that provided PE film at a low price and 2) Gyeongbu (Seoul-Busan) Expressway that make possible to transport greenhouse vegetables produced nearby Busan to capital area (Seoul) in just a few hours. Around these years, President Park, Chung-Hee often took tours by a helicopter throughout the country and perceived that an aerial view of rural area covered by greenhouses in rural areas resembled shining silver. President Park rejoiced that farmers overcame their seasonal unemployment (due to no work in agricultural off-season, usually winter in Korea) by greenhouse vegetable production.

Source: Memoirs of Park, Jin-Hwan, former Special Assistant to the President for Economy

Growing agricultural crops in greenhouses is also called cultivation under structure. Growing horticultural crops such as vegetables, flowers and fruit trees in greenhouses is also called protected horticulture. In 1970, President Park, Chung-Hee took tours throughout the country. Noting that the spread of greenhouses in rural areas resembled shining silver, he called such spread Silver Revolution. In mid 1970s, with the celebration of achieving the Green Revolution through self-sufficiency of rice, the emphasis was placed on the need to eliminate agricultural off-season through "the Silver Revolution following the Green Revolution." Along with it, the spread of greenhouses came to be known as "White Revolution."

"The new community Income Increase Program" to increase farmers' income, which is the result of the integration of the IIPFF and the new community movement, is considered to be an important factors led to 'White Revolution.' The success of the new community movement can be largely attributed to the New Community Training to raise leaders of new communities, and the curriculum for the training was designed by President Park, Chung-Hee. President Park identified success cases of farmers who have overcome poverty in agricultural communities for themselves rather than adhering to the plans of the Ministry of Agriculture and Forestry and requested the people who experienced success to present their experiences. Holding discussions over such presentations was the central activity of the New Community Training and farmers' presentation of success experiences was important curriculum content for the New Community Training in 1970s.

While President Park conceived theNew Community Training himself, no new laws were enacted, nor were new structures built for the New Community Training.Excellent New Community Training took place while utilizing previously existing personnel and structures. This indicates that President Park did not consider new laws or regulationsand structures to be critical in enhancing training. In training the New Community leaders, the majority of the time was allocated to listening to success cases of several people and engaging in discussions for various problems occurring at the sites of the new community movements.

1.2. The Self-helping Efforts by Farmers to Increase Income

One of the most frequently mentioned success casesinthe New Community Leader Training was the greenhouse cultivation of cash crops in winter seasons. The vast majority of cases involved failure from the first year, analysis of the causes that led to the failure, and successful income generation in the following years. It appears that many people were able to sympathize with success stories involving severe failures and mockery from the people around, overcoming such failure through detailed analysis of factors that led to failures, and finally achieving success by challenging again later, rather than outright success stories. The trainees mostly listened to 10-15 success stories during training. The success cases presented in the New Community Leaders Training were 80 cases in total, with 60 case presentations by males and 20 case presentations by females. While the number of success cases from female leaders was less, the trainees were more impressed by the stories of females who were disadvantaged. It was noted that female personnel contributed significantly to the spread of the new community movement. The success cases of the new community movement became the most effective tool to spread the new community movement to farmers as well as those who were not engaged in agriculture.

Also, the subjects of group discussion selected by female leaders mainly involved the role of females as well as factors that limited active participation of women in the new community movements. Housewives living in farming communities stated that despite their desires to actively participate in the new community movements, there were significant limitations to their participation due to traditional habits and values held inrural community. Housewives in rural areas discussed plans to simplify ritualistic traditions such as marriages, funerals, and memorials as well as the role of housewives to increase savings of farmers. It is notable that constructing greenhouses required male labor mostly, growing crops in greenhouses required female labors as well; therefore, the contributions of females to'White Revolution' were significant. Also, many evils of rural communities were addressed and improved through the new community movement, and the social status of females as well as their position at homes was enhanced quite a bit through the movement either, contributing greatly to improved rights of women. Most frequently subjects discussed among new community leaders are shown in <Table 4-1>.

Table 4-1 | The Number of Times of Group Discussion Subjects Being Proposed by New Community Leaders from 1972 to 1973

Subjects of discussions	Number of times discussed
Participation of village residents	125
Development of rural income sources	79
Difficulties related to the new community leaders	76
Selection of the new community programs	70
Village fund-raising	70
Local public service employees	34
Generating work force in villages	27

The government initiated the first IIPFF (1968-1972), with the largest component being vegetable cultivation in greenhouses. The reasons why the "Development of Income Sources for Rural Communities" was often selected for group discussion topic in New Community Training courses in 1972-1973 was that the construction of the Ulsan Petroleum Chemical Industrial Complex was completed in 1970, enabling the supply of agricultural plastics to be used in constructing greenhouses at affordable prices. It was not technically difficult to produce fresh vegetables during the winter season in greenhouses and, therefore, it was selected as the most promising business to generate additional income for rural communities inagricultural off-seasons. The rapid expansion of greenhouse vegetable cultivation, which was able to generate much higher income than rice cultivation, is considered to be the important factor led to 'White Revolution' in Korea.

1.3. Similarities between the New Community Movements and the 'White Revolution'

It was notable that the new community movement and the IIPFF had identical ideological directions and implementation plans. 'Greenhouse Vegetable Production Project' in the IIPFF, or 'White Revolution,' was a business that could not be successful without diligence, self-help, and cooperation, the three spirits of the new community movement.

The first was diligence -the farmers would have to be diligent to engage in greenhouse cultivation. Greenhouse cultivation is more difficult and labor-intensive than rice or barley cultivation. For greenhouse cultivation, or cultivation under structure, to be established and be successful as an industry, first the people engaging in it must be diligent. Currently, the nations known to have advanced protected horticulture industry are the Netherlands, Japan, Israel, and Korea. The common factor among these nations isthat their land areas are limited, they have high population densities, and the people are diligent and hard-working. To engage in greenhouse cultivation, the workers cannot be negligent even for amoment. Even with the occurrence of unexpected grave matters such as death in the family, certain tasks must be performed on schedule. Even with a very brief moment of negligence, an entire year's cultivation could go to waste in greenhouse cultivations.

The second was self-helping; greenhouse cultivation is done by the farmers to generate their own income. During the course of 'White Revolution,'government enforcement was not needed at all because the farmers took initiatives on their own to earn income without any enforcement from the government. The spirit of the new community movement, which was self-helping, or "Heaven helps those who help themselves," was in full effect, and loans and subsidies were provided to farmers engaged in hard work to improve their quality of living while farmers who did not want it did not receive such supports. Therefore, during the course of 'White Revolution,' budgets were not allocated evenly region by region at the government level, but instead supports were provided to regions or farmers who have achieved a certain level of success.

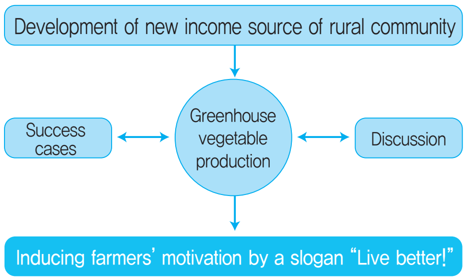
The last, but not least, was cooperation: engaging in greenhouse cultivation involves mutual cooperation. The task of greenhouse construction or covering the structures with plastic films could not be done alone and, therefore, cooperation among several people was needed. Sales of agricultural products also required shared shipment to secure better prices and joint purchases of agricultural goods also led to lower prices. Therefore, forming cooperative organizations among the farmers was one of the keys to the success of 'White Revolution.' As a result of such cooperation, many greenhouse agricultural products came to have main producing district and be produced in specific regions. Such implementation plans of diligence, self-helping, and cooperation of the new community movements perfectly matched with the progression of 'White Revolution' which called for hard work (Diligence) without relying on others (Self-help) and helping and assisting the neighbors (Cooperation), and ultimately experienced huge success.

Box 4-2 | 'White Revolution' through the New Community Movement

1970 The start of the new community movement

1972 Establishment of farmer training institute (currently Agricultural Cooperative College)

1973 Renamed New Community Leader training institute



1976 starting cash crop class in winter agriculture training of RDA

- Protected cultivation training: 11,141,970 farmers participated during 1976–1995
- Dissemination of protected cultivation technologies by training local extension instructors
  - Long term education program → Specialized local extension instructors
  - Short term education program → General local extension instructor

1.4. The Role of New Community Leaders in 'White Revolution'

About 80 success cases were presentedat the New Community Training. We have summarized and included two cases that took place at the New Community Leader Training Center and discuss the steps taken by the leaders to convince the residents of their towns and overcome failures in developing income source for their towns. In the course of technology distribution, it is also helpful to note that, at each town, vegetable cultivation in greenhouses is very often initiated with asuggestion from the New Community leaders who failed in the first year but experienced success in the following year after careful analysis of the factors that contributed to the failures, becoming a new income source at the region.

Box 4-3 | The Success Cases of the New Community Movement

Case 1: Hwang, Se-Yeon, Leader of Hai Community, Yongjin-Myeon, Wanju-gun, Jeolla Buk-do

Achieved per household income of KRW 1.4 million through greenhouse cultivations

(Source: New Community Movements, from beginnings until today, Ministry of Interior, 1975)

In this village, the leader, whose name Hwang, Se-Yeon, lamented the fact that people were barely getting by with selling a few loads of lumber while struggling with debt, and he led the residents on a campaign to cultivate the wastelands with an area of 20,600 pyeongs (3.3 m^2) to produce 150 sacks of rice in fall. This experience taught the residents that with diligence and hard work, they could become self-sufficient. Also, this town successfully implemented greenhouse cultivation eventually, generating an income of 35 million Won in 1974. It has now become a prosperous village, already achieving household income of KRW 1.4 million through various efforts.

Case 2: Song, Sang-deuk, leader of Gwansan 2-ri, Byeokje-myeon, Goyang-gun, Gyeonggi-do

Improvement of income through horticulture in suburban regions

(Source: New Community Movements, from beginnings until today, Ministry of Interior, 1977)

The village is located near Seoul around Tongil-ro highway. The residents lived in poverty, resigned to their fate, and farmed in small cultivation areas. However, the New Community Leader recognized that horticultural crop cultivation was the way to improve the income of the village near cities and instructed the residents in the skills to engage in horticultural crops in greenhouses. Through such activities, the income of the town increased and the residents also raised pigs and chickens at the same time, resulting in average household income of 1.75 million won per household at the end of 1976. It is considered an outstanding self-sufficiency village that also improved the environment by implementing settlement structure enhancement project.

2. Training Course for Farmers by Rural Development Administration

2.1. Training Farmers in Winter Season

As one of the measures to address poverty in rural communities, the government began to offer training courses for farmers during winterseason under the sponsorship of administrative institutions beginning 1961, but the responsibilities were soon transferred to agricultural extension offices. In the beginning, the initiative was introduced as a public education program to prevent the farmers from doing nothing but drinking and gambling during winter, by teaching them to make ropes and baskets as well as reading and writing. In the early days, the education involved simple training offered in small rooms. Later, the training courses were offered by the Agricultural Extension Offices (currently the Agricultural Technology Centers) according to the legislation of Farmers' Training Guidance in 1968 and the establishment of formal farmers' training courses in 1969.

Whereas the initial instructors were town elders and administrative public officials, problems came to a head in offering technical instructions. Soon, agricultural instructors and administrative public officials came to host the education programs. The training was enhanced by involving relevant institutions, single farming households and production champions, and having them provide practical advices such as case presentations. In the beginning, all residents of the community were subject to the training to provide local discussion-type training on general, encompassing topics of rural communities, but after 1969, the program developed into group education of agricultural technologies and targeted farmland owners and, food crop cultivation groups. In 1977, two courses – the general class and the specialized class – were implemented including for farmers growingcash crops. Finally, in 1984, the education curriculum became further detailed into general classes of food crop, cash crop, and the lifestyle improvement class.

Winter agricultural training courses offered by the RDA had focused on the production technology of food crops such as rice, barley and beans. Education for cash crops was initiated in 1976, later than food crops. This is because the focus of governmental efforts on farmers' education was on production of rice as the nation was not rice self-sufficient until mid-1970s. Beginning 1976 when the self-sufficiency of staple food became stable, it is shown that cash crops including greenhouse vegetables came to be included in education courses for farmers.

2.2. Education for Rural Community Instructors and Farmers

As the acreage for greenhouse cultivation expanded and the greenhouse cultivation emerged to be an important source of income for farmers, the RDA realized the need to educate rural instructors on skills for greenhouse cultivation, and selected rural instructors that worked near main locations of production in greenhouses. The period and methods for the education were not uniform, but varied depending on the needs at the moment. The education method could be broadly divided to long-term and short-term education. The long-term education involved assigning rural instructors at the Horticulture Experiment Station (currently the National Institute for Horticultural and Herbal Sciences) from 8 months to 1 year to work at the research site, naturally participating in skills development and acquiring skills through site visits. The initiative was highly effective. However, while it was effective for the instructors to acquire the skills, as it had to fit the circumstances of applied rural instruction centers, the education period could not be set uniformly. Also, the outcome was not consistent depending on the relationship between the rural instructors and the public research officials. Another weakness was that even after the rural instructors returned to their sites of instructions, when their assigned locations changed following personnel assignment shifts, the needed skills were different. Despite such weaknesses noted, many rural instructors across the nation were trainedas experts, and as they served a bridging role of supplying new skills developed at the national research institutions to farmers, the effects of disseminating technologies were highly enhanced.

As for short-term education for rural instructors, education periods ranging from 1 week to 4 weeks were assigned depending on circumstances, and mostly lecture-based education was offered by technical instructions department of RDA. Whereas the achievement of long-term assignment training was enabling in-depth education to rural instructors to raise experts, the outcome of short-term education was to provide broad range of knowledge about greenhouse cultivation, aiming to distribute general skills on greenhouse cultivation.

Farmers' educations to distribute skills for greenhouse cultivation of horticultural crops were offered on a nationwide basis after 1976 as "Winter Farmers' Education" by the Farmers' Training Department of the RDA. However, as the farmers working at greenhouses needed to engage in cultivation activities during the winter, it was difficult for them to participate in the education. For such farmers, "Major Production District Visiting Education" was offered during the summer when the farmers were not engaged in greenhouse cultivations. Such visitation education was offered by expert lecturers from RDA and each provinces' Rural Development Center (currently Agricultural Research and Extension Service). The lecturers visited each major production district and offered education for 2-3 days. Strawberries, tomatoes, and watermelon visitation educations were well received by the farmers.

2.3. Education of Protected Horticulture Technologies for Farmers

The most effective education method for protected horticulture was in line with the saying: "Seeing is believing." or "Seeing once is better than listening 100 times." in Korean as the education stressed the importance of on-site education. For on-site education methods, study sessions, evaluation sessions, and advanced facility visitations were utilized. The reason that such education methods resulted in significant influences was as the educations were not boring,but instead involved entertainment and sightseeing as well as honest exchange of opinions, resulting in addressing and improving problems at their agricultural practices. Since training offered by the government or administrative institutes tended to be formal and were in a lecture format, it was much more effective for the farmers to visit and see the necessary skills and acquire those skills firsthand.

Box 4-4 | Examples of Protected Cultivation Technology Distribution

On-site education	Sanggye-dong, Nowon-gu, Seoul, 1969 The development of "Higher vegetable" production complex (50ha) ※ The first on-site education (Voluntary participation of farmers)
Model farm	The running of open model farms with new technologies - 1960s: food crops such as rice - 1970s: cash crops such as vegetables

	Research meeting	Field evaluation meeting
Sponsors	Rural Development Administration, Agricultural Research Services	Agricultural extension centers
Contents	Presentation and discussion of new technologies	Evaluation of excellent farmer's field in best practice
Participants	Government researchers, prrofessors, private companies, students, farmers	Similar to research meeting but more farmers attended

2.4. Training and Promotion of Protected Horticulture Using Mass Media

2.4.1. Protected Horticulture Training Using the Mass Media

In order to increase the production of food crops, the RDA aired radio programs such as the “Dawning Rural Communities” and the “Advancing Rural Communities” for 1 hour between 5 and 6 o’clock in the morning everyday beginning in late 1960s through broadcasting networks including the KBS, the MBC, and the CBS. The main contents of the programs were developed by the Technology Communication Department inthe RDA, and also created by the broadcasting networks visiting farmers or production complexes. After the late 1970s, programs related to vegetable cultivation in greenhouses began to be aired and the programs became highly popular among the farmers. As most farmers began their agricultural works early in the morning and, therefore, missed the morning programs, such programs were rerun during the day. Therefore, it was fairly frequent for the farmers to turn on the radio in greenhouses as they worked in greenhouses during program hours.

Since protected horticulture education programs using radios were very popular, technology promotion for vegetable cultivation ingreenhouses began to be aired on TV after 1980s when TVs became widespread. Such programs were aired for 1 hour between 5am and 6am at KBS and MBC TV broadcasting stations. As for productions of the programs, the broadcasting networks and RDA closely collaborated. To this end, the networks assigned the producers (PD) to reside at the RDA to produce and operate the programs. As most contents covered cases of higher income generation using new technologies, the viewership and broadcast effects were deemed to be fairly high.

2.4.2. Promotion and Textbook of Protected Horticulture

As for the textbooks used in protected horticulture, most researchers at the Horticultural Experiment Stations used the name “Standard Agricultural Instructions” to write and prepare the textbooks. The published books were provided to farmers that requested them for free of charge. The publication of textbooks began in 1970, and more than five types of books were published for each crop annually. Publication of textbooks were done for most types of vegetables until mid 1970s, and additional contents were included since then to improve the textbooks for greenhouse vegetable cultivation. Many trainingssessions for farmers utilized these textbooks and, therefore, the contributions of “Standard Agricultural Instructions” published by the RDA are considered to be very high.

In addition to the “Standard Agricultural Instructions,” textbooks were prepared for various forums, evaluation sessions, and visitation training and distributed to farmers and rural instructors to enhance the educational effects. Also, the RDA published “Agricultural

Technologies" on a monthly basis and distributed them to public officials involved in agricultural instructions and independent farmers. As the publication included not only greenhouse vegetable cultivation but also other agricultural technologies, the effects of the "Agricultural Technologies" on technology distribution for greenhouse cultivation were fairly limited.

2.5. Horizontal Spreading of Advanced Technologies by Farmers Engaged in Greenhouse Cultivations

2.5.1. The Role of Leading Farmers for Greenhouse Cultivation

Farmers made their own decision to construct greenhouses for growing winter vegetables to increase income. The most effective way of acquiring protected cultivation technologies was sharing the experiences with other farmers or visiting other greenhouses. While agricultural educations provided by national institutions were fairly effective, sharing experience among greenhouse vegetable producers evoked a strong sense of camaraderie, bringing out to great effect skills distribution.

A good example would be the case of Mr. Ha, Sa-Yong who experienced a huge success by first implementing greenhouse cultivation at Gangweh-myeon, Cheongwon-gun, Chungbuk Province. Mr. Ha overcame abject poverty and made a fortune through hard work in agriculture. He spread his experiences of success to others by giving approximately 3,000 lectures, and those who heard his lectures responded very well to his teachings. Mr. Ha worked diligently to prepare his own farmland, and as he was engaged in vegetables cultivation, he desired to increase his income throughearly harvest and shipment. To this end, he attempted seedling production by digging deep holes in a sunny place, burying manures to raise temperature with heat generated from manures, and set up nursery beds covered with oil-rubbed window paper to prevent frost.

Forcing culture of pumpkins or cucumbers in early spring using oil-rubbed window paper was also attempted. This method is called the "hot-cap" method, and as Mr. Ha utilized this method before greenhouses became widespread in Korea, he could be called an early adaptor of technologies. Through such efforts, Mr. Ha was able to gain his own farmland of 90 pyeongs in 1958 and continued to expand his farmland. After the completion of the first NEDP, the government initiated the first IIPFF in 1967. Mr. Ha also participated in the IIPFF. Greenhouse vegetable complexes were assigned at Gangeoh-myeon, Chungwon-gun and Chungbuk Province where Mr. Ha lived.Since the program was a component of the government's initiative, Mr. Ha received loans for buying farmland of 150 pyeongs to expand his greenhouses. Since farmers nearby also wanted to participate in protected cultivation, Mr. Ha came to play the role of aleader for protected cultivation.

Significant amount of experiences had been accumulated on heated cultivation, early harvest, forcing culture, and heat preservation greenhouse cultivation using with oiled window papers. People came from other regions to look and learn about the practices and cooperative works for greenhouse cultivation. This contributed significantly to the distribution of greenhouses nationwide. When there was heavy snow in 1969, Mr. Ha and his wife worked through the night to remove snow on the roof of the greenhouses. When snowing stopped, all nearby greenhouses were collapsed due to the weight of the snow but Mr. Ha's remained intact. As the damages from heavy snowfall were widespread all over the nation, price of vegetables produced in greenhouses were drive up. Mr. Ha generated a lot of income, expanding his greenhouses to 800 pyeongs, and realizedhis dream of becoming wealthy.

3. The Dissemination of Protected Horticulture Technology to the Farmers through Research Institutes

The "Korean Institute of Agricultural Science" (currently the National Institute for Horticultural and Herbal Sciences) was established and Dr. Woo, Jang-chun who had returned from Japan in March, 1950, began working as the head of the Institute. The governmental agency "Central Horticultural Technology Institute" opened at Dongrae, Busan, on May 20, 1953, and research on protected horticulturehad begun. At that time, the facilities at the Central Horticultural Technology Institute was comprised of two greenhouses for flowers and two greenhouses for vegetables, each around 150m^2, and the researches on the development of breeding technologies and early cultivations had been initiated.

There was an incident where President Rhee, Syngman directly requested Dr. Woo to engage in hydroponics for clean vegetables to supply them to the U.S. troops. However, Dr. Woo responded that instead of using hydroponic system that requireshigh costs, the use of the new, uncultivated lands and only chemical fertilizers could produce clean vegetables. However, researches for hydroponics had already begun in Busan at that time. The Central Horticulture Technology Institutehad a branch in Gimhae (currently the Busan Protected horticulture Experiment Station) where most of field experiment was conducted. Especially, seedlings were grown using newspaper pots in hot bedsusing fermentation and early maturation culture became popular using hot-caps in the field in February. Such techniques were first used by nearby farmers. The field in Gimhae eventually transformed from early maturation culture to greenhouse cultivation, resulting in largeprotected horticulture complexes. The Busan branch also bred new varieties of strawberries, onions and tomatoes. In 1972, researches were conducted on the exportation of melon and asparagus to Japanat the Busan branch and four three-quarter glasshouses for melon production were introduced from Japan [Figure 4-1].

Figure 4-1 | Three-quarter Glasshouses Constructed in 1972

The Busan branch played a central role in Korea's protected horticulture researches before the Division of Protected Cultivation was established in 1991 at the Horticultural Experimental Station at Suwon. The institution was located close to greenhouse cultivation complexes and it was also put in charge of research and technological instructions to handle difficulties regarding exportation of fresh vegetables to Japan. In 1980, all types of Japanese standard greenhouses – which represented advanced technology at the time – were installed to strengthen competitiveness of protected horticulture. Fromsuch efforts, researchers at the branch developed prototype greenhouses and greenhouse environment control technologies, which are appropriate for the Korean environment.

In 1991, a large-scale support program for glasshouses was initiated to strengthen the competitiveness of protected horticulture. In order to support the program, a Greenhouse Cultivation Department was established to develop glasshouse technologies. At the same time, hardware research such as greenhouse model development was started at the National Agricultural Mechanization Research Institute to strengthen the department's functions. Korean greenhouse models, hydroponics technologies and information computerizing technologies for protected horticulture have been developed in the Greenhouse Cultivation Department. The Greenhouse Cultivation Department merged with the Busan Protected Horticulture Experimental Station in 2004.

Due to excessive greenhouse vegetable production and deepening competition among farmers in mid 1990s, there was a growing demand for advanced technologies for greenhouse cultivation. Exporting fresh vegetables to Japan was one of ways to cope with excessive production. Increased export of fruit vegetables such as strawberries, cucumbers, tomatoes, eggplants, and paprikaled to the establishment of an export-dedicated research team in RDA in 1997. The team provided supports for challenging technologies and visited the farmers to support technologies, providing the most advanced technologies to farmers.

In addition to distributing technologies developed by national research institutes, protected horticulture technologies were also distributed through academia-industry joint research groups. One such group was "Protected horticulture Research Group." This research group was established in February 1987, and became the main body for promoting the development of protected horticulture industry. The objectives of researches included structures, materials, environmental controls, special cultivation technologies, and new variety development for greenhouses. Greenhouse management and facility development for protected horticulture were also important subjects in this group. The activities of the group consisted of discussions for information exchanges and site visit to address issues of farmers. Many researchers from national research institutes, universities, andprivate companies as well as farmers participated in these activities. The Korean Society for Bio-Environment Control established in 1991 by merging Protected Horticulture Research Group and Hydroponics Research Group has been at the center of technology distribution, and contributed to dissemination of technologies related to 'White Revolution' of Korea.

Chapter 5

The Effects of 'White Revolution' and Changes in Protected Horticulture Industry

1. The Current Status of Protected Cultivation in Korea
2. Expansion of Protected Cultivation Areas and Changes in Crops Cultivated under Structure
3. Income Increase of Farmers Growing Horticultural Crops under Structure
4. Problems in Protected Horticulture and Its Improvement Plans of Korea

The Effects of 'White Revolution' and Changes in Protected Horticulture Industry

1. The Current Status of Protected Cultivation in Korea

1.1. Vegetables

Protected cultivation in Korea has developed with vegetables. Protected cultivation area of vegetables expanded from 3,721ha in 1970 to 90,627ha in 2000, showing a 24-fold increase <Table 5-1>. Subsequently, the area decreased somewhat, to beat 66,382ha in 2010 <Table 5-1>. The period of rapid increase of protected cultivation acreage was between 1975 and the 1980s, when the acreage was nearly tripled. This isdue to the fact that, with the development of agricultural materials industry, the supply of agricultural plastic films and steel pipes expanded, and demand for fresh vegetables increased as well with the growth of national income.

Total yield of vegetables under structure was only 140 thousand tons in 1970, but the yield gradually increased along with the expansion of greenhouse cultivation areas, reaching 412 thousand tons in 1980 and 1,017 thousand tons in 1990 <Table 5-1>. The yield continued to grow and reached a peak of 3,291 thousand tons in 2005 <Table 5-1>. Subsequently, with the decrease of protected cultivation area, the yield in 2010 was 2,741 thousand tons. The decrease in vegetable production under structure was not large compared to a large reduction in protected cultivation area. This was due to the fact that production per ha increased significantly by enhancing greenhouse environment using control system of combined environmental factors and by improving cultivation technologies such as fertigation and irrigation.

Table 5-1 | Chronological Changes in Cultivation Area and Production of Vegetables under Structure

Years	Protected cultivation areas (ha)	Cultivation area (ha)			Production (1,000 ton)
		Total	Greenhouse	Row cover	
1970	762	3,721	1,289	2,432	140
1975	1,746	6,618	3,349	3,269	137
1980	7,141	17,890	9,228	8,662	412
1985	16,569	28,689	18,835	9,853	680
1990	23,698	39,994	39,994	-	1,017
1995	40,077	81,604	81,604	-	2,423
2000	48,853	90,627	90,627	-	3,247
2005	48,574	86,421	78,469	-	3,291
2010	48,835	66,382	66,382	-	2,741

Source: The yield of vegetables 2005, (Ministry of Agriculture andForestry); Production area of vegetable greenhouses and field vegetables, 2010 (Ministry for Food, Agriculture, Forestry and Fisheries)

1.2. Fruit Trees

As it is difficult to put fruit trees under structure (for example, greenhouse and rain shelter), the proportion of fruit trees in protected cultivation is very low compared to vegetables. Recently, grape semi-forcing culture and tangerine forcing and semi-forcing cultures have shown a consistently increasing trend. As for Korea's protected cultivation of fruit trees, cultivation of grapes first began in Daejeon area in late 1960s, and developed rapidly within a fairly short period of time. The protected cultivation area increased from 453ha in 1991 to 3,402ha in 2000 and further to 6,225ha in 2010, displaying a 14-fold increase over 20 years. While it was a method to prevent damages from natural disasters such as frost, protected cultivation of pineapples and bananas rapidly increased in Jeju-do Island in 1980s, and in case of bananas immediately before importation became completely open, the protected cultivation area exceeded 1,000ha. Since late 1980s, protected cultivation of tangerines became successful, and control of maturing period through heating or heat preservation became possible. In 1990s, with the goal of early shipment, utilization of heating facilities for peaches and persimmons became active. Also, the protected cultivation area of fruit trees such as pears, loquats, round kumquats, kiwi fruits and figs increased significantly with the goal of promoting maturity and achieving stable production through non-heated cultivation under structures.

As of 2011, the cultivation area for Korea's fruits under structures is 6,821ha, accounting for 7.3% of total cultivation areas of 93,416ha. Tangerines account for 3,390ha, which is the highest among protected cultivation areas at a 49.7% share, followed by grapes at 2,467ha. Additionally, citrons, figs, and kiwi fruits are grown in small-scale. While protected cultivation of tangerines has been attempted since 1980, the farmers lost interest in this practice as protected cultivation of bananas increased. Then, the importation of bananas began in late 1980, leading to a conversion to 'Onju' mandarin oranges grown in heated greenhouses. The protected cultivation area significantly increased beginning the 1990s. Especially, as for the protected cultivation of bananas, the market was not open until late 1980s and farmers producing bananas through protected cultivation could generate high income. As the plant height of bananas can reach 5-6m, large-sized, multi-span greenhouses were needed for protected cultivation. Therefore, it is believed that the protected cultivation of bananas provided the motive for conversion of Korea's greenhouses from small single-span to large-sized multi-span structures.

The portion of tangerines under protected cultivation was only 6.1% in 2000, but this proportion increased to 17.2% by 2010. Within the protected cultivation of tangerines, greenhouse cultivation and rain-shelter cultivation maintain similar ratio, each accounting for 57.3% and 42.7%, respectively, as of 2007. Due to importation of oranges and other tropical fruits, the total cultivation area of tangerines is gradually decreasing.

Protected cultivation of grapes began near Daejeon in early 1960 and it was expanded to 1,115ha, or 3.8% of total grapes cultivation area by 2000 and to 2,242ha, or 14.6% of total grapes cultivation area by 2010. Protected cultivation of grapes is mostly cultivation under rain-shelters, and the proportion of greenhouse cultivation is only at 15.3%. Main cultivation areas include Okcheon and Yeongdong in Chungbuk Province, Daejeon and Nonsan in Chungnam Province, Gimcheon and Sangju in Gyeongbuk Province, and Wanju in Jeonbuk Province. Grape varieties for protected cultivation are relatively in small number; Delaware, Campbell Early, Kyoho, and Black Olympia are the most popular varieties, accounting for most of the protected cultivation acreage.

Pear production under structure was not popular in 1980s because of its low price. However, protected cultivation area for pears increased from 0.8ha in 1994 to 64ha in 2000. The aim of protected cultivation was early harvest before Chuseok (Thanksgiving Day in Korea). Recently, the protected cultivation area has decreased.

Protected cultivation of peaches began at Naju Horticulture Experiment Station in 1985 and spread to Suncheon and Jeonju in early 1990s. As of 2003, the total protected cultivation area for peachesis 32.7ha with 139 farms. Most peach trees under structure were grown without heating. Major producing districts include Icheon in Gyeonggi Province, Bo-eun, Cheongwon, Yeongdong, and Okcheon in Chungbuk Province, and Cheongdo and Gyeongsan in Gyeongbuk Province.

Compared to the open field, protected cultivation of fruit trees allows stable production in situations where climate-related crop damages increase. Rainfall is blocked in protected cultivation and, therefore, disease control is easy in an environment-friendly manner and highquality fruits with high sugar contents can be produced within a short period of time by controlling the moisture level within the soil. However, increase in heating costs due to unstable international oil price as well as product price decreases due to the increase of imported fruits with opening of trades and increased production of fruit-vegetables competing with fruit-trees are also expected. Considering such strengths and weaknesses, heated greenhouse cultivation is expected to gradually decrease, and greenhouse cultivation that can result in lower production costs and stable production of higher quality fruits from rain proof cultivation or non-heated cultivation is expected to increase.

1.3. Floricultural Crops

Korea's floriculture industry was maintained as hobby horticulture until 1950s but in late 1960s, the industry was expanded with the establishment of the flower market at Namdaemun and Seocho-dong. At that time, the crops grown were mostly flowering and ornamental trees, with very few protected cultivation. Along with the flower market at Seocho-dong in Seoul, a chrysanthemum production complex was established at Masan in Gyeongnam Province and greenhouses that control sunlight and temperature were installed as well.

Subsequently, protected cultivation of floricultural crops grew very rapidly along with the development of national economy during 1990s. After 2000, the growth rate gradually slowed down and after 2005, the cultivation area somewhat decreased with corresponding reduction in protected cultivation areas. The proportion of protected cultivation among the total flower cultivation area reached 61% in 1995, but dropped to 48% by 2010. This is deemed to be because the cultivation of cut-flowers and pot-flowers which account for most protected cultivation have remained at the same level since 2000 while the field cultivation of flower-trees and ornamental trees have increased. In 2010, among the floricultural crop cultivation area of 6,829ha in total, the portion of protected cultivation was 3,268ha (48%) and most of it was plastic film greenhouses (3,069ha, about 94%). Ninety percent of cut and potted flowers were grown under structure; in contrast, only about 5% of ornamental or flowering trees were grown under structure. The production of cut and potted flowers has slightly decreased and the growth rate of ornamental and flower trees have decreased as well.

2. Expansion of Protected Cultivation Areas and Changes in Crops Cultivated under Structure

2.1. Chronological Changes in Vegetable Crops under Structure

Twelve major vegetable crops cultivated under structureare listed in order by their protected cultivation area from largest to smallest at five year intervalsfrom 1970 to 2010 <Table 5-2>. This is to investigate chronological changes in vegetable cultivation area under structure over time. In the early stage of protected cultivation, the area of Chinese cabbages under structure was the largest for the first ten years, from 1970 to 1980. One reason that Chinese cabbage cultivation under structure was popular at that time was due to the fact that it is easily grown in unheated greenhouses since it grows well in low temperature. The other reason was possibly due to its relatively short growing period and its flexible harvest time; it was usually grown before or after cultivation of watermelon, cucumber, and tomato and intercropped between two vegetable cultivation periods.

Table 5-2 | Chronological Changes in the Rank of Vegetables' Protected Cultivation Area and Proportion (%) from 1970 to 2010 in Korea

Rank	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total Area	3,263 (100)	6,054 (100)	17,103 (100)	26,703 (100)	34,816 (100)	72,549 (100)	79,673 (100)	62,271 (100)	56,422 (100)
1	Chinese Cabbage	Chinese Cabbage	Chinese Cabbage	Oriental Melon	Watermelon	Watermelon	Watermelon	Watermelon	Watermelon
	806 (24.7)	1,279 (21.1)	3,779 (22.1)	4,231 (15.8)	5,404 (15.5)	18,977 (26.2)	20,952 (26.3)	19,125 (28.4)	14,103 (25.0)
2	Watermelon	Cucumber	Oriental Melon	Chinese Cabbage	Strawberry	Oriental Melon	Oriental Melon	Strawberry	Strawberry
	711 (21.8)	1,031 (17.0)	2,838 (16.6)	3,642 (13.6)	4,715 (13.5)	9,745 (13.4)	9,449 (11.9)	6,709 (10.0)	6,841 (12.1)
3	Tomato	Tomato	Strawberry	Strawberry	Oriental Melon	Chinese Cabbage	Radish	Oriental Melon	Oriental Melon
	596 (18.3)	858 (14.2)	1,914 (11.2)	3,449 (12.9)	4,209 (12.1)	6,506 (9.0)	6,697 (8.4)	6,655 (9.9)	6,097 (10.8)
4	Cucumber	Oriental Melon	Radish	Watermelon	Cucumber	Strawberry	Strawberry	Tomato	Pepper
	507 (15.5)	583 (9.6)	1,764 (10.3)	3,292 (12.3)	3,929 (11.3)	6,201 (8.5)	6,555 (8.2)	6,493 (9.7)	5,392 (9.6)

Rank	1970	1975	1980	1985	1990	1995	2000	2005	2010
5	Oriental Melon	Lettuce	Pepper	Radish	Chinese Cabbage	Cucumber	Chinese Cabbage	Pepper	Tomato
	207 (6.3)	523 (8.6)	1,611 (9.4)	2,488 (9.3)	3,673 (10.5)	5,948 (8.2)	6,274 (7.9)	5,213 (7.7)	5,270 (9.3)
6	Pepper	Pepper	Cucumber	Cucumber	Radish	Lettuce	Lettuce	Cucumber	Lettuce
	123 (3.8)	505 (8.3)	1,392 (8.1)	2,426 (9.1)	2,485 (7.1)	5,556 (7.7)	5,918 (7.4)	4,497 (6.7)	4,539 (8.0)
7	Pumpkin	Radish	Lettuce	Pepper	Lettuce	Pepper	Cucumber	Radish	Chinese Cabbage
	114 (3.5)	484 (8.0)	1,262 (7.4)	2,412 (9.0)	2,393 (6.9)	4,729 (6.5)	5,843 (7.3)	4,373 (6.5)	3,700 (6.6)
8	Lettuce	Watermelon	Watermelon	Lettuce	Spinach	Radish	Pepper	Lettuce	Cucumber
	109 (3.3)	258 (4.3)	1,027 (6.0)	1,875 (7.0)	2,224 (6.4)	4,466 (6.2)	5,659 (7.1)	4,281 (6.4)	3,589 (6.4)
9	Eggplant	Pumpkin	Tomato	Tomato	Pepper	Spinach	Tomato	Pumpkin	Pumpkin
	27 (0.8)	255 (4.2)	888 (5.2)	1,648 (6.2)	2,096 (6.0)	3,866 (5.3)	4,746 (6.0)	3,585 (5.3)	3,246 (5.8)
10	Radish	Strawberry	Pumpkin	Pumpkin	Tomato	Tomato	Pumpkin	Chinese Cabbage	Spinach
	26 (0.8)	162 (2.7)	368 (2.2)	695 (2.6)	1,992 (5.7)	3,334 (4.6)	3,918 (4.9)	3,056 (4.5)	2,400 (4.3)
11	Strawberry	Eggplant	Spinach	Spinach	Pumpkin	Pumpkin	Spinach	Spinach	Radish
	20 (0.6)	65 (1.1)	192 (1.1)	477 (1.8)	1,647 (4.7)	2,956 (4.1)	3,272 (4.1)	2,978 (4.4)	1,001 (1.8)
12	Spinach	Spinach	Eggplant	Eggplant	Eggplant	Eggplant	Eggplant	Eggplant	Eggplant
	17 (0.5)	51 (0.8)	68 (0.4)	68 (0.3)	49 (0.1)	265 (0.4)	390 (0.5)	307 (0.5)	244 (0.4)

Source: 2010 The Status of Protected Horticulture and Vegetables Production, Ministry for Food, Agriculture, Forestry and Fisheries, 2011.05

Since 1990 when protected cultivation system was established, watermelons have been recorded as the crop with the greatest protected cultivation acreage, and this trend has continued until now. As the protected cultivation of vegetables had higher profits than field cultivation, the farmers engaged in acquiring protected cultivation technologies. They also wanted to grow most profitable crops rather than the crops that are easy to grow since large amounts of capital would be invested in greenhouse construction and cultivation.

In the early stages of protected vegetable cultivation, crops or cropping systems were determined by each farmer and farmers usually preferred to grow in small, single-span greenhouses, without heating, vegetables that grow well in low temperature, which are relatively easy to grow. As greenhouses became lager and were equipped with heating systems and consumer demand for various vegetables increased along with an increase in national income, however, farmers armed with enhanced protected cultivation technologies diversified the types of greenhouse vegetables and preferred to grow fruit vegetables that grow well in high temperature. It is notable that the protected cultivation of leaf vegetables for side dishes such as Chinesecabbages, radishes, spinaches, lettuces, peppers, squashes, and eggplants decreased while the cultivation of fruit vegetables for desserts such as watermelons, strawberries, tomatoes, and oriental melons increased from 1970 to 2010. Also, crops and cropping systems previously determined by each farmer is now determined by cooperative group of farmers and joint greenhouse management, productions, shipment and sales are in common.

2.2. Chronological Changes in the Proportion of Protected Cultivation to Total Cultivation Area in Different Vegetables

In order to assess which vegetables has a certain percentage of protected cultivation area, major vegetables are ranked from 1 to 11 based on the proportion of greenhouse cultivation area to total cultivation area in each vegetable at five year intervals from 1970 to 2010 <Table 5-3>. A vegetable with the highest percentage of greenhouse cultivationarea was tomatoes in most of the years from 1970 to 2010, except for 2005. This is because tomatoes shows much more stable quality and yield in greenhouse cultivation than in field cultivation in Korea and provides farmers with a relatively higher income. Vegetables with relatively low percentage of greenhouse cultivation area include peppers, radishes, Chinese cabbages and spinaches. In case of peppers, most peppers produced in Korea are grownin open fields and consumed as powder. Peppers produced ingreenhouses include green peppers and paprika and their cultivation areas are extremely small compared to peppers grown in open field.

Table 5-3 | Changes in Ranks of Proportion of Greenhouse Cultivation to Total Cultivation Areas (%) among Vegetables by Year and by Crop

Rank	1970	1975	1980	1985	1990	1995	2000	2005	2010
1	Tomato (14.1)	Tomato (31.4)	Tomato (33.8)	Tomato (54.3)	Tomato (80.2)	Tomato (84.9)	Tomato (96.5)	Strawberry (96.3)	Tomato (100)
2	Watermelon (8.8)	Lettuce (29.6)	Lettuce (28.2)	Strawberry (45.5)	Strawberry (68.8)	Strawberry (83.9)	Oriental Melon(92.6)	Tomato (96.2)	Oriental Melon(98.1)
3	Cucumber (5.8)	Cucumber (19.9)	Cucumber (22.0)	Lettuce (41.8)	Cucumber (56.5)	Oriental Melon(81.2)	Strawberry (92.5)	Oriental Melon(94.0)	Strawberry (97.0)
4	Oriental Melon (2.3)	Pumpkin (15.1)	Oriental Melon (21.9)	Oriental Melon (38.6)	Oriental Melon (51.6)	Cucumber (69.6)	Cucumber (80.4)	Watermelon (82.5)	Lettuce (86.5)
5	Pumpkin (1.3)	Oriental Melon (4.9)	Strawberry (18.8)	Cucumber (37.8)	Lettuce (48.9)	Lettuce (66.9)	Lettuce (77.0)	Cucumber (76.8)	Watermelon (86.0)
6	Chinese Cabbage (1.1)	Strawberry (4.1)	Pumpkin (13.3)	Pumpkin (21.6)	Spinach (42.5)	Spinach (47.0)	Watermelon (68.8)	Lettuce (76.3)	Cucumber (81.6)
7	Spinach (0.5)	Watermelon (3.6)	Chinese Cabbage (7.3)	Watermelon (13.4)	Pumpkin (40.3)	Watermelon (42.0)	Pumpkin (46.5)	Spinach (44.5)	Spinach (44.9)
8	Pepper (0.3)	Chinese Cabbage (3.2)	Watermelon (6.1)	Chinese Cabbage (8.1)	Watermelon (21.0)	Pumpkin (41.8)	Spinach (44.0)	Pumpkin (38.4)	Pumpkin (36.2)
9	Radish (0.04)	Spinach (1.7)	Radish (3.5)	Spinach (7.4)	Chinese Cabbage (7.7)	Chinese Cabbage (14.0)	Radish (16.6)	Radish (16.1)	Chinese Cabbage (13.1)
10	Lettuce (-)	Radish (1.3)	Spinach (3.1)	Radish (6.1)	Radish (6.7)	Radish (12.6)	Chinese Cabbage (12.1)	Chinese Cabbage (8.2)	Pepper (10.8)
11	Strawberry (-)	Peppers (0.5)	Pepper (1.2)	Pepper (2.0)	Pepper (3.2)	Pepper (5.1)	Pepper (7.1)	Pepper (7.8)	Radish (4.6)

Source: 2010 The Status of Protected Horticulture and Vegetables Production, Ministry for Food, Agriculture, Forestry and Fisheries, 2011.05

It is notable in <Table 5-3> that protected cultivation of strawberrieshas increased rapidly since 1970. The protected cultivation area of strawberries in 1970 was just 20ha, indicating almost no protected cultivation for this crop. If ranked, it would be placed 11th among the crops <Table 5-3>. However, the percentage of protected cultivation areas was at 4.1% in 1975, ranking 6th, and by 1980 18.8% of areas was converted to protected cultivation, ranking 5th. The percentage of protected cultivation reached 45.5% in 1985 (2nd), 68.8% in 1990 (2nd), 83.9% in 1995 (2nd), 92.6% in 2000 (3rd), and 96.3% in 2005, placing 1st, indicating that the conversion into protected cultivation of strawberry took place very rapidly. By 2010, 97% of strawberries were grown in greenhouses, and field cultivation of strawberries had almost disappeared.

Summarizing the above results, most fruit-vegetables consumed as desserts such as tomatoes, oriental melons, strawberries, and watermelons have become cultivated under structure. Also, while they were omitted from the table because of their relatively smaller cultivation areas, other fruit-vegetables such as melons are being produced almost entirely through protected cultivation. Therefore, most fruit-vegetables consumed in Korea are produced ingreenhouses and it is clear that such tendency will continue in the foreseeable future. As such, this topic merits in-depth review in Korea's agricultural policies.

3. Income Increase of Farmers Growing Horticultural Crops under Structure

While Korea's agricultural production was around 18 trillion won until 1990, the amount exceeded 30 trillion won in 2000 and reached 40 trillion won in 2010 [Figure 5-1]. After 2000, the production of food crops gradually decreased but the production of livestock and horticultural crops continued to increase. However, the growth rate of horticultural crop production has slowed down after 1995, growing from 10 trillionwonin 1995 to about 13 trillion won in 2010 [Figure 5-2].

Figure 5-1 | Changes in Agricultural Crop Production

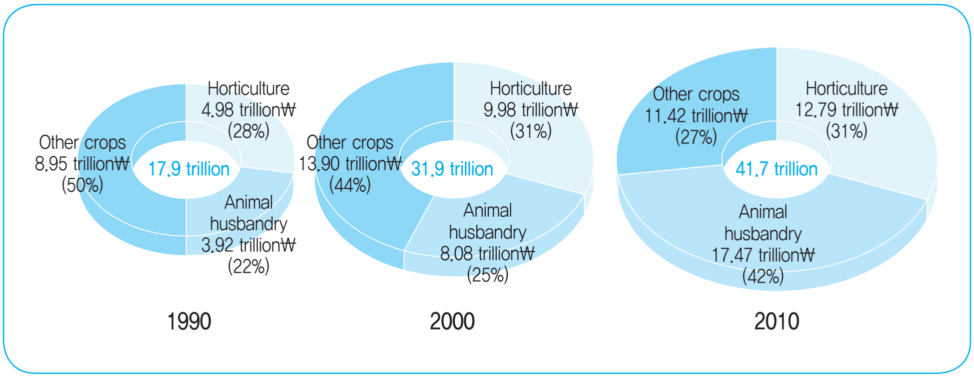
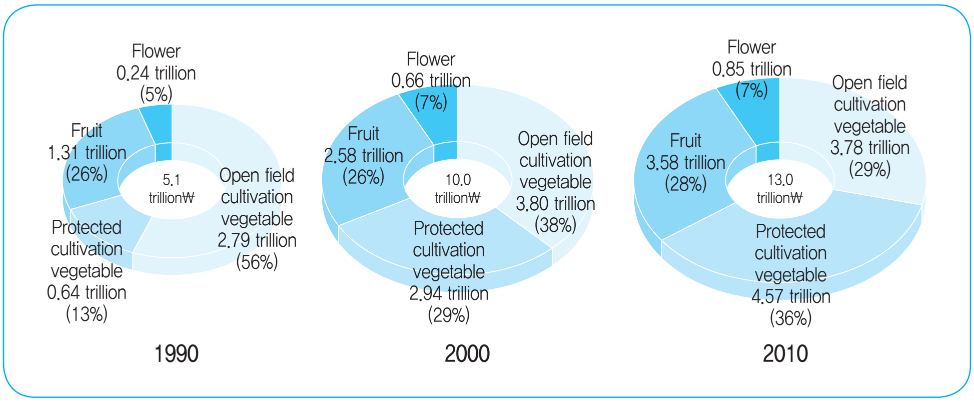


Figure 5-2 | Changes in Horticultural Crop Production



In 1989, the production of horticultural crops was about 4.5 trillion won. This has been increased to 6 trillion won in 1992, 9 trillion won in 1995, and exceeded 12 trillion won in 2010. Among vegetables, field grown vegetables continued to decrease or remained stagnant after 1995 while the production of greenhouse vegetables consistently increased. As for fruit trees and floricultural crops, the increase was rapid until 1995, but the pace of increase slowed down subsequently. Therefore, among the production of horticultural crops, the increase of greenhouse vegetables has the greatest production.

During the early stages of 'White Revolution,' vegetable consumption of city dwellers increased in accordance with the growth of their income. The demand for high-quality vegetables gradually increased, resulting in consistent growth of greenhouse vegetable production. Therefore, farmers changed their crops from food crops to greenhouse vegetables that guarantee higher income. While the areas of protected cultivation increased after 1990, the shortages of labor in farms were deepened. Greenhouse facilities were modernized, enlarged, and mechanized to address the issue but the facility improvement that can reduce the need of labor significantly have not been developed yet. After1990s, therefore, most farmers encountered limitations in labor and their income did not increasesignificantly. On the other hand, because protected horticulture requires advanced technologies and is influenced by regional climates, major producing districts of different horticultural crops were formed. Unions of greenhouse vegetable producers have been organized in each major producing district and union members work together for cooperative shipping and purchasing. The factors affecting income increase of farmers through protected cultivation are described from 5.3.1 to 5.3.4 in detail.

3.1. Increase of Crop Yield per Unit Area

Production per unit area has significantly increased through facilities modernization in protected cultivation, such as precise environmental control in greenhouses. It was possible through greenhouse modernization to establish environmental control technologies in greenhouses, which would optimize the growth environment of crops and increase crop yield by a marked amount. The increase in yield was also due to increased harvesting periods for most crops and the increase was greater in suchcrops as cucumber whose fruits can be harvested continuously, but smaller in crops harvesting one fruit per plant, such as watermelon. Such trends continued subsequently, with doubled yield per unit area in cucumber, tomato and strawberry in 2010 compared to 1990, but the increase was only about 70% in watermelon during the same period.

3.2. Increase in Labor Productivity

Modernization and automation of greenhouses are methods to minimize labor input through installation of labor saving equipment. One of the goals in glasshouse distribution program in early 1990s was laborsaving through automation. Compared to plastic film greenhouses, glasshouses have higher level of automation, resulting in relatively higher labor saving effects. When comparing labor hours and productivity, in case of growing cucumber in automated greenhouses, there was no change for labor hours in 2010 compared to 1990 but labor productivity increased by fourfold due to the pricein laborand yield increases, at 15% average annual increase during the past 10 years. Labor input for protected cultivation of tomatoes decreased by 40% for the past 20 years and labor input decrease of oriental melon, watermelon and strawberry were 55%, 71%, and 32%, respectively, thanks to mechanization and automation of greenhouse facilities. More striking results were observed in labor productivity than in labor input, with labor productivity for tomato doubled in 2010 compared to 1990, and experiencing 24% increase annually for the past five years. Using mechanized and automated facilities in greenhouses, labor productivity for strawberries increased tenfold for 20 years and average annual increase was 30% for the past 10 years. This reduction in labor input and increase in labor productivity were possibly due to adopting automated environment and fertigation control and using natural enemies that reduce labor input for applying pesticides.

3.3. Quality Improvement of Greenhouse Vegetables

Whereas the early goal of protected cultivation was crop production in agricultural off-season, the current goal of it is improving the quality of agricultural products. This is due to the fact that the greenhouse crop production has reached a saturation point after ‘White Revolution,’ and the consumer demand for high-quality agricultural products have increased. In accordance with this trend, farmers also introduced high-quality crop production technologies to gain comparative advantage. Mechanized and automated facilities in protected cultivation enabling precise control of greenhouse environment also helped producehigh qualitygreenhouse vegetables.

3.4. Increased Exportation of Protected Horticulture Crops

Greenhouse cultivation area increased significantly through 'White Revolution,' and this increase caused excessive supplyand price competition of vegetables after 1990s. The price drop of greenhouse vegetables due to excessive supplyand price competition led to increased interest in exports. In early 1990s, the export to the Japanese market began in fruit vegetables such as cucumber, strawberry, pepper, and eggplant produced in southern regions such as Gyeongnam and Jeonnam provinces. While the amount of export was not significant at the time, it led to the stabilization ofdomestic markets and prices. It was not until the mid-1990s that international competitiveness of greenhouse vegetables was strengthened through greenhouse modernization and automation projects and expansion of greenhouse sizes. It made the government increase support to farmers who export vegetables and also resulted in farmers becoming more interested in exports. Export support teams, together with the National Horticultural Research Institute and other agricultural research services, have also contributed significantly to the increase in exports, by providing farmers with advanced technologies. The increased exports resulted in increased income for farmers who adopted advanced greenhouse technologies and led to farmers' recognition of the importance of technologies, which elevated theaverage level of greenhouse technologies of farmers.

4. Problems in Protected Horticulture and Its Improvement Plans of Korea

4.1. Problems of Protected Horticulture Industry in Korea

After 1980, the horticultural industry had rapidly grown through government support and technology development and dissemination for year-round production of horticulture crops. After 2000s, however, government support has ceased, international oil price has increased, and labor and materials costs have increased. All three factors led to reduced income of farmers. Because of these changes, the following problems have surfaced in the course of quantitative and qualitative expansion of protected horticulture industry.

4.1.1. Policies

From 1991 to mid-2000s, the Korean government supported protected horticulture in a variety of ways in a short period. This not only significantly contributed to the income of farmers engaged in protected cultivation but also was one of the driving forces in elevating Korea's protected horticulture industry to world-class. However, it is also true that problems involving selection of target farmers and construction firms, managements and business equitability occurred as well. This is because government supports were divided into cities or counties, which caused the inability of forming a systematic protected horticulture complex. Also, due to the small scale of the operations, the competitiveness was not enhanced.

Based on governmental support at the time, large numbers of construction firms were crowded, resulting in shoddy and fault construction, fighting for order, lack of preventive or breakdown maintenance, and conflicts between owners and constructors. There also existed poor management problems in protected cultivation in glasshouses supported by the government and ultimately governmental support ceased altogether. Many construction firms went bankrupt and maintenance of already constructed greenhouses became very difficult. As precise environmental control in greenhouses became difficult due to the deterioration of facilities, the quality of greenhouse vegetables decreased. More efforts were needed with the breaking down of automation facilities and the safety of greenhouse structures were threatened by the deterioration of facilities.

The lack of systemized government polices and support caused greenhouse construction in such regions as Gangwon Province not suitable for economic protective cultivation. Such unsystematic policies led to highly increased operating costs for protected horticulturein these region especially with the increase in oil prices. Location for greenhouse construction should be the region with relatively high minimum temperature and more sunshine in winter to save heating costs. Less snowfall and wind are desirable for structural stabilities of greenhouses. However, Gangwon Provinceis mountainous and has very low minimum temperature and much snowfall in winter. The other problems are major producing districts. Strawberries and tomatoes, which grow well in low temperature, are grown in the southern parts of Korea where climate is temperate. In contrast, cucumbers and paprikas, which are warm temperature vegetables, are grown in the northern parts of Korea which is colder than the southern parts. Therefore, a redistribution of crops would be needed during the period of high oil prices.

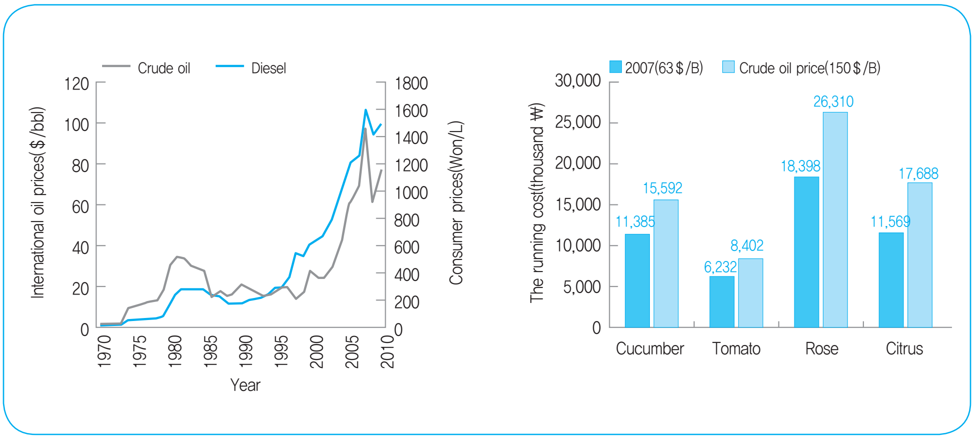
4.1.2. Technologies

Technologies related to protected horticulture include development of new varieties appropriate for greenhouse cultivation, and technologies for seedling production, fertilization and pest control using agricultural chemicals or natural enemies. Technologies for improving greenhouse structure and construction include designs, structure materials, material conservation and construction efficiency. Environment control technologies include precise and integrated environment control technologies by understanding of heat, humidity and atmosphere. Also, as for automation technologies, device development, automatic production equipment, robot technologies, and machine development technologies for greenhouse cultivation are included. Korea's protected horticulture technologies are considered to have developed to beworld-class. Nonetheless, foundational science and technology must be further strengthened to develop new technologies, and applied technologies must be developed on the basis of such foundational technologies.

Protected cultivation in Korea is of a relatively low productivity compared to other developed nations. Productivity of Korea is about 50% of that of the Netherlands and this is due to the different climate condition, lack of production model development, and less use of hydroponics. Also, technologies using natural enemies to prevent damages from pests are in its infancy, with most such natural enemies needing to be imported.

With the recent rapid increase of international oil prices [Figure 5-3], the costs of heating for protected horticulture have increased, adding to the burden of greenhouse management expenses. Greenhouse cultivation of roses needs the largest cost for heating; compared to $63/ barrel, if the oil prices rose to $150/barrel, the heating cost for rose cultivation under structure would rise from 18 million Won/10ha to 26 million Won, reflecting a 44% increase. Such results indicate that there is an urgent need to develop technologies to reduce heating costs.

Figure 5-3 | Changes in International Oil Prices (left) and Cost of Heating in Different Greenhouse Vegetables (right)



In regards to greenhouse structures and materials, standard greenhouse design strong enough to endure disaster in Korea have been developed and distributed but farmers have still experienced losses from natural disasters. Especially for cover materials, plastic films are weaker in strength and lower in light penetration than fluorinated polyimide film and PO film used in Japan. Greenhouse automated facilities such as movable spraying systems, automated ventilation, and automation systems for heat preservation have been installed in some greenhouse but many greenhouses do not have such facilities. Among environment control technologies, most computer programs needed for glasshouse controls rely on foreign technologies and, therefore, development of programs well-suited to Korea's climates and crops is still needed.

4.1.3. Industry

Currently, the few existing construction firms are very small in size and it is difficult to expect technological developments or advancements from them at this point. Social environments will need to be formed so that appropriate number of construction firms with experiences and technologies can continuously be developed. Moreover, firms that construct greenhouses have no specialty since they are operating in conjunction with the construction field, placing further strain on the firms in getting equipped with proper level of competitiveness in greenhouse construction.

The companies that produce agricultural plastic films do not develop new agricultural films due to the small domestic market in Korea. Many other items such as fertilizers for hydroponics, nursery soils, and irrigation materials also rely on import and, therefore, domestically producing those items will help a balanced development of domestic industriesin Korea.

Compared to other developed countries, technologies are distributed mostly by the governmental research institutes and very few technology consulting companies are in Korea. Therefore, the dissemination of technologies is very slow and farmers often face difficulties in obtaining advanced information.

4.2. Improvement Plans for Protected Horticulture Industry in Korea

4.2.1. Structural Improvement of Greenhouses

There have been frequent abnormal and/or high-impact weather for the past 10 years, greatly influencing the protected horticulture industry in Korea. Frequent typhoons and heavy snowfall that destroyed numerous greenhouses resulted inan annual disaster compensation budget of more than 200 billion won. In order to prepare for abnormal weathers, greenhouse design strong enough to resist such weathers must be developed and provided. To this end, greenhouse design standards must be prepared and adopted in greenhouse construction and standardized greenhouse materials should be distributed. Glasshouses that are light-weight but strong enough to resist natural disasters should be also developed for constructing glasshouses on reclaimed lands with soft ground condition, which require high expenses for earthworks and foundations.

4.2.2. Development and Distribution of Energy Saving Technologies

Heating costs for protected horticulture are being driven up because of depletion of fossil fuels and an increase in international oil prices.In accordance with green energy policies such as regulations on carbon dioxide emission, technology development to reduce energy consumption of protected horticulture is required. In order to achieve this, heat preservation materials to enhance energy efficiency and heating systems to increase thermal efficiency must be developed and supplied. Also, researches on utilization of renewable energies are needed in the protected horticulture industry. In addition, new cropping systems and cultivars with low temperature tolerance need to be developed and distributed. Technologies to identify appropriate region for different crops and appropriate seasons are also needed.

4.2.3. Development and Distribution of Production System

It is necessary to develop an optimal crop production models in greenhouses for each crop. Including state-of-the-art glasshouses required for year-round crop production for export, greenhouse facilities are required for single cropped crops such as watermelons and oriental melons. Manuals are needed for both the greenhouse facilities and equipments to guarantee stable productivity of each crop and for optimized greenhouse cultivation system as well. In order to improve the efficiency of the production system, automated systems could be installed to enhance labor productivity. Furthermore, conversion into hydroponic system is also required, which can optimize underground environments of crops to improve productivity. For stable production during the high temperature periods in summer, cooling systems using geothermal and atmospheric heat and/or fog systems are required, and along with such systems, technologies to control greenhouse environment should be developed to secure a stable exportation market.

4.2.4. Advancement of Agricultural Materials and Lowering Their Costs

High-quality seedling or seed production technologies are required for stable production of greenhouse horticultural crops. Since most greenhouse crops have relatively long growing period, varieties that display stable growth in such unfavorable environment as high or low temperatures is much more advantageous in protected cultivation. When raising seedlings, the technologies, such as grafting, to increase seedling quality in order to ensure good growth in unfavorable conditions. Technologies to produce and supply good quality fertilizers and agricultural chemicals as well as to reduce agricultural water are also prerequisite for improving the horticultural industry.

4.2.5. Raising Experts for Protected horticulture

It is important to strengthen the curriculum in college education and agricultural expert development courses should be offered in colleges to provide education connected to the field. It is desirable to provide these protected horticultural experts with opportunities to work ina recent corporate agricultural development program or advanced glasshouse complex. For nurturing of farmers specialized in protected horticulture, continuing education courses would be need to provide customized education. Leaders for protected horticulture should be trained for leading horticultural crop export complexes and for nurturing skilled people. Expert consultants are needed to provide protected horticulture farmers with consulting for energy efficiency assessment, safety evaluation system and hydroponics.

4.2.6. Policy Supports and Development of Industries Related to Protected Horticulture

The policy support programs for protected horticulture, which began with IIPFF in 1970s continued on Standard Greenhouse Distribution Program in 1980s and Competitiveness Improvement Program in Preparation for UR in 1990s, were ceased in 2000s. However, the lack of government support made the development of protected horticulture and related industries difficult. As a result, many construction firms went bankrupt, and greenhouses deteriorated rapidly, which makes precise greenhouse control impossible, resulting in the low quality of greenhouse crops. Therefore, government support rather than solely focusing on providing loans must be continued and expanded since greenhouse support projects are necessary to sustain agricultural basis to improve competitiveness. Meanwhile, industries related to protected horticulture such as steel, plastic film, seedling production, pesticides, fertilizers, and agricultural material industries should be developed concurrently. Especially, there are many opportunities for the export of plants (the export of factories needed for greenhouse construction) to countries in demand for protected horticulture technologies from Korea. Therefore, governmental support is needed to result in an establishment of greenhouse cultivation technologies overseas.

Chapter 6

The Implication of 'White Revolution' and Overseas Distribution of Protected Horticultural Technologies

1. Suggestions from 'White Revolution' of Agriculture in Korea
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The Implication of 'White Revolution' and Overseas Distribution of Protected Horticultural Technologies

In Korea, self-sufficiency of rice was achieved in mid-1970s and greenhouse cultivation of vegetables using plastic film-covered greenhouses rapidly expanded. This phenomenon is referred to as 'White Revolution.' Greenhouse cultivation of agricultural crops is a complex industry requiring technologies and materials from a variety of fields. The structures of greenhouses require construction technologies and internal and external covers require plastic films which are petrochemical products. Technologies from other fields such as light transparency and heating preservation of such materials as well as thermodynamic interpretation of atmosphere within the greenhouses and knowledge about weather of the limited spaces are all comprehensively involved in the protected horticulture industry.

Also, for the expansion of vegetables production through greenhouse cultivation, consumer income increase is a prerequisite for an active demand market. Moreover, infrastructure industries such as production of agricultural plastics for establishment of greenhouses and steel industry for the structures are needed to support the industry. Transportation of the products must be facilitated as well. In Korea, protected horticulture industry began along with the self-sufficiency of rice, and when the GNP rose above $500, the areas for greenhouse cultivation rapidly expanded. Around the time that GNP reached $1,000 - $2,000, the population in rural areas decreased and rapid urbanization took place. With the population of rural community aging, more women engaging in agriculture and increased consumer demand for high quality vegetables, various technologies for mechanization of agricultural industry came to be required.

Until 1995, when GNP reached $10,000, the acreage of protected vegetable production was highly correlated with the increase of national income, displaying positive correlation. However, after the GNP reached $10,000, areas for greenhouse cultivation did not increase and instead remained stagnant. This can be attributed to the fact that for Korea's vegetable production, sufficient areas for year-round production were secured and, therefore, no more acreage for greenhouse cultivationwas required. In this chapter, a few implications from the course of ‘White Revolution’in Korea’s agriculture will be summarized.

1. Suggestions from ‘White Revolution’ of Agriculture in Korea

1.1. Staple Food must be Secured to Cultivate Cash Crops

For the first time in history, Korea’s rice self-sufficiency level recorded 101% in 1975. During the period beginning in the late 1960s until the early 1970s, global population increased while food production remained stagnant, leading to shortages in total stock of grains and discussions about food shortage crisis. In Korea, rice self-sufficiency rate was 81% and other grains self-sufficiency rate was 74% in early 1970s, indicating that the people experienced basic food shortages. Even until early 1970s, rice self-sufficiency rate remained at the 90% level. When a nation is experiencing staple food shortages as such, it is difficult to accomplish cultivation of income-generating crops. Korea needed to put forth a national effort to achieve self-sufficiency of rice. The RDA, which is the government agency in charge of the development and distribution of agricultural technologies, offered education on agricultural techniques to farmers, but focused only on production techniquesfor staple food crops until 1975 without offering education on income-generating (cash) crops. Per capital GNP of Korea was only $602 in 1975, meaning that even if the farmers cultivated cash crops to raise their income, a demand market to sufficiently consume the crops did not exist.

1.2. The Necessity of Accompanied Growth of Protected Horticulture and Related Industries

Protected cultivation, unlike open field cultivation, requires capital, technology, and intensive input of labor with a large consumption of various agro-materials. Among those agro-materials, the mulching material such as polyethylene (PE) film is essential. In Korea, domestic production of PE film was possible by the construction of Ulsan petrochemical industrial complex. Before 1970, the production of agricultural plastic was impossible. Therefore, all the films were imported and the high price prevents the settlement of Korea’s protected horticulture. In fact, prior to 1970, some of the farmers tried to use greenhouses using PE film imported from Japan, and earned high income by growing vegetables in winter. Even as these success stories gave an opportunity to settle the protected cultivation, but those successful farmers were only a few. However, if Korea cannot domestically produce agricultural plastics, a dramatic increase of protected horticulture may not be possible. In Korea, an other example of a related industry is the 'Pohang integrated Iron and Steel Company (POSCO)' that secured steel production and its parent process. Before the achievement of self-sufficiency of iron, almost all Korean greenhouses were built with bamboo frame structure, since bamboo are common and grow well in southern areas of Korea where protected cultivation originated from. The bamboo greenhouses had a shorter usable lifespan, but had the advantage of low installation costs. However, the size of bamboo-greenhouses was very limited and also the mechanization of agricultural operations was almost impossible. The Korean steel industry started from the Japanese colonial era, and most of the steel mills were constructed in the northern area of Korea where iron ore, coal, and hydroelectric plants are readily available. Therefore, after the Korean War, the development of South Korean's steel industry was limited. However, after the construction of POSCO in 1973, domestically produced steel pipes rapidly replaced the bamboo material in the construction of greenhouses. This kind of change made it possible that the size expansion and mechanized agricultural operations. And eventually the new materials, PE film and steel pipe, trigged the rapid development of Korean protected horticulture.

1.3. A Virtuous Cycle for Activation of Consumers' Market and Expansion of Protected Horticulture

The vegetables that were produced by protected cultivation in winter usually sold at high price. Therefore, to secure the stable consumption of these high price products, consumer's income should be high enough too. Due to the success of the NEDP since the 1960s, Korea showed a rapid economic growth rate. This economic growth could secure the growing consumption of fresh vegetables in winter. There is a high correlation between the growth of GDP per capita and cultivation area of protected horticulture. Over 20 years from 1975 to 1995, Korea showed an explosive increase of acreage of protected horticulture. This trend was supported by enough consumption based on the rapid economic growth of Korea.

The construction of Gyeongbu Expressway in 1970 is one of the factors that contributed greatly to the expansion of protected cultivation of vegetables. With the reduced transportation time between production and consumption areas, the vegetable's freshness could be maintained longer and could satisfythe customer's taste. During this period, one of the most significant changes was the explosive increase of vegetable consumption per capita. Korea's per capita vegetable consumption was 60kg/year until 1970s that was significantly less than the recommended amount by the UN's WHO (73kg/year). However, the per capita consumption increased up to 120kg in the 1980s. Currently it's almost 140-150kg, an almost 2.5 fold increase.

1.4. The Completion of Annual Vegetable Production System Limits Acreage-increase in the Protected Horticulture

Because vegetables that were produced by protected cultivation could guarantee high income for the farmers, the acreage of protected horticulture has been increasing at a faster rate. Until 1995, the Korean GPD increase was almost directly proportional to the increase of the acreage for protected horticulture. But the trend did not continue after 1995. It is reported that the Korean per capita acreage of protected horticulture is approximately 4m^2 in 1988, surpassing the Japanese one. It is assumed that it was saturated at 10m^2 in 1995. However, we believe the saturation is related to the completion of annual production system for fresh vegetable by the protected cultivation. Many developing countries are located in lower latitude than Korea, and have longer vegetable cultivation period. These conditions may reduce the saturation point to a smaller point than the Korean one. This phenomenon may be a good reference for the developing countries.

2. Dissemination of Korea's Protected Horticulture Technologies in the World

2.1. Operating Exhibition Complex for Greenhouse Vegetable Production Technology in Mongolia

Mongolia is located on a plateaued area and its people has been nomadic for a long time. Their diet is mainly composed of meats, resulting in nutritional imbalance and various metabolic diseases. The average life expectancy of a Mongolian is less than 70. Winter in Mongolia lasts for longer than 6 months and during the winter, it is difficult to grow vegetables. Most field vegetables can be grown for a short period of time only in summer, between June and September. Therefore, from October to May (nine months), excluding summer, when field vegetable cultivation is possible, most vegetables are imported. Even in summer, it is difficult to expect a stable production of vegetable crops because of unstable weather such as low precipitation, frequent hails, and strong winds. Protected cultivation is required for stable production while ensuring the high quality of fruit vegetables suchas tomatoes, cucumbers, and bell peppers since they have long cultivation periods.

In order to address these problems, the government of Mongolia implemented the Green Revolution National Program during 2005-2012 to raise the self-sufficiency level of vegetables to above 30%, and requested a transfer of Korea's 'White Revolution' technologies to achieve their goals rapidly. The Korean government constructed and distributed Korean-type greenhouses in Mongolia through KOICA (Korea International Cooperation Agency).

The project was for two years beginning 2009. Major components of the project included installation of exhibition farms with four plastic film greenhouses of areas of 4,200m^2 at Ulan Bator as well as installation of glasshouses and plastic film greenhouses with areas of 1,500m^2 for training in Plant Science Agricultural Center at Darhang region. Also, in order to support the production technology of protected horticulture, agricultural experts from Korea stayed in Mongolia for eight months, providing local farmers with educations [Figure 6-1] and [Figure 6-2] through practices of fruit vegetable cultivation such as tomatoes, cucumbers, paprika, and eggplants.

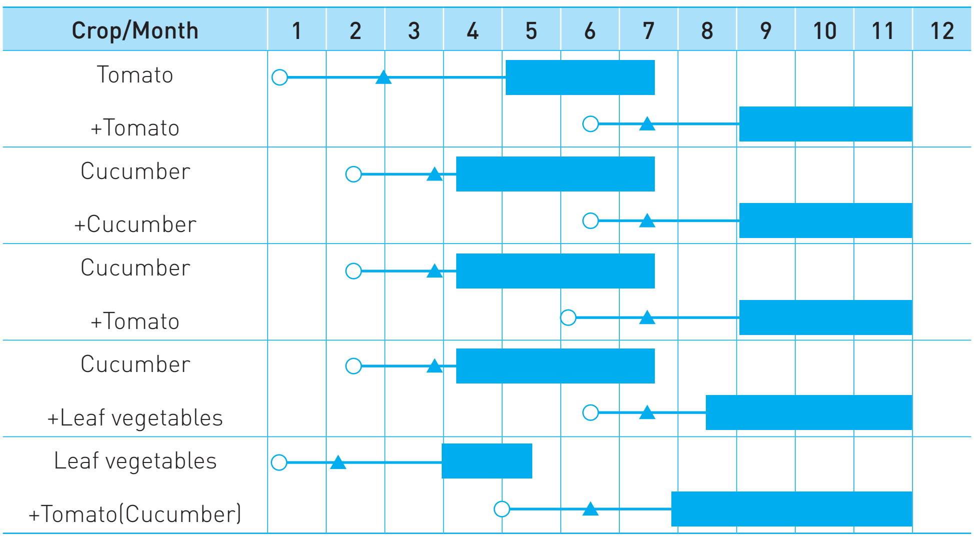
Figure 6-1 | Vegetable Production in Greenhouses in Mongolia

Figure 6-2 | Invitation and Education of Mongolian Farmers

Appropriate vegetables for Mongolia <Table 6-1>were identified by cooperative work between Korea and Mongolia, cropping systems appropriate for Mongolia's climates were developed, and technologies were disseminated to local farmers. The results are as follows: for greenhouse cultivation of fruit vegetables such as cucumber, tomato, chili pepper, and eggplant, electric heaters were installed to enable sowing in early April and, therefore, the transplanting date for cucumber has been brought forward to early May. For other fruit vegetables, the planting date has been brought forward to late May. Cucumbers could be harvested continuously for three months beginning early June, but were then removed from greenhouses as they could not be grown well. Tomatoes, cherry tomatoes, chili peppers, and eggplants were harvested from mid-July to early November. All types of crops could be grown through protected cultivationin Mongolia, and high productivity could be achieved.

Based on the economic analyses, single cropping fruit vegetables resulted in an income of 72,120 thousand won per 10a. This is quite high compared to other industries in Mongolia and made the prospect of future greenhouse vegetable cultivation in Mongolia fairly positive. Among the crops evaluated, the income of cherry tomatoes was the highest as cherry tomatoes had not been cultivated much in Mongolia. By seeing Korea's modernized greenhouse technologies and their productivities, the farmers of Mongolia became assured of the potential for protected horticulture in Mongolia. In case of field cultivation, crops can be grown for four months at most, but using modernized greenhouses, crop cultivation period increased up to nine months excluding the period between December and February due to high heating costs.

Table 6-1 | Appropriate Cropping Systems for Vegetables in Mongolia



* ○: Seeding, ▲: Planting, –: Harvesting

Analyzing the results of combining Korea's advanced greenhouse vegetable cultivation technologies to agriculture in Mongolia, the following are expected: first, by spreading vegetables cultivation technologies in greenhouses to farmers, the vegetable cultivation area in Mongolia will be expanded, nutrition level of the people will increase, and their diets would become richer as the supply of vegetables increases. Farmers can grow vegetables in winter and their income will also increase since cultivation period of vegetables increaseusing greenhouses. Also, the wooden greenhouses traditionally used in Mongolia will eventually be converted to steel pipe greenhouses and revitalization of related industries for agricultural materials is also expected. Moreover, by using modernized steel pipe greenhouses, the environment within greenhouses will be greatly improved, resulting in a greater yield and higher quality of vegetables.

Another advantage is that through automation of heating and irrigation devices, labor for cultivation can be saved, resulting in a significant increase of production. By providing Korean greenhouse vegetable cultivation technologies, management technologies such as local-specific seeding, growth stage-dependent fertilizer application, and temperature, water and pest controls were demonstrated on site, which provide the opportunity to acquire basic production technologies to Mongolian farmers. This is one of the successful cases of transferring the technology of Korea's 'White Revolution' overseas, providing basic technologies to farmers inMongolia. Also, as the program supported the "Green Revolution National Program ('05-'12)" implemented by the government of Mongolia, it is expected to significantly contribute to improving the health of the people of Mongolia by providing additional vegetables and increasing the income of farmers.

2.2. Modernization of Greenhouses in Uzbekistan Using Korean-type Greenhouses

Uzbekistan hasa large population and a highly favorable environment for agriculture among Central Asian nations and, therefore, agricultural production led by the state government was actively implemented ever since the country was part of the Soviet Union. The portion of agriculture in the economy of Uzbekistan is fairly high and its agricultural population is large as well. While the climate of Uzbekistan is temperate, the precipitation level is low, resulting in lack of water to be used in agriculture. The agriculture of Uzbekistan has been largely depended on irrigation but its productivity is fairly low. Along with wheat and cotton, horticultural crops are the major exported crops. The quality and productivity of crops in Uzbekistan are relatively low and this is possibly due to poor seedling production and crop cultivation technologies.Vegetables are usually grown in open field and, therefore, there are short-term supply and demand imbalances that result in price fluctuation across seasons. Greenhouse cultivation area of Uzbekistan is about 4,000ha and among this, 600ha is glasshouses. Primary crops being cultivated are tomato and cucumber, and crops cultivated in smaller areas include melon, eggplant, pepper, cabbage, and strawberry.

As the demand for vegetables has rapidly increased recently in Uzbekistan, cultivation technologies that can significantly improve productivity are urgent, along with stabilizing their prices. Accordingly, the government of Uzbekistan has embarked on a campaign to establish agricultural firms through presidential decree beginning 2006. The Korean government initiated a support project to disseminate greenhouse cultivation technology as a part of economic collaboration and support program. One such projects is the exhibition greenhouse project in Tashkent and Ahmad Yassabi region with a budget of $4 million between 2011 and 2013, which includes greenhouses for raising seedlings of 1,500m^2 and those for growing vegetables of 10,000m^2 [Figure 6-3] and [Figure 6-4]. Korean agricultural experts stayed in those regions to carry out vegetable cultivation and on-site educations. The farmers as well as agricultural officials have been invited to Korea to be trained. In particular, the Rural Development Administration established the KOPIA (Overseas Agricultural Technology Development Center) in Uzbekistan, providing agricultural support appropriate for local environments.

By supplying Korea's protected horticulture technologies to Uzbekistan, the areas for greenhouse cultivation will be expanded and vegetable production will increase as well, allowing for a stable domestic supply. Exporting to nearby Russia or Kazakhstan will be possible, increasing the income of farmers of Uzbekistan. It is also expected that along with the improvement of cultivation technologies or income increases, but other related agricultural industries such as agricultural plastic, steel, and fertilizer industries can grow together, bringing positive influence to the overall economy of Uzbekistan. The industries for small- to medium-sized machineries such as cultivators, management tools, pest control machines, and heating and cooling machines will grow also. As there is a shortage of water resources in Uzbekistan, infrastructure constructions such as irrigation facilities will need to be established and logistics and distribution structure of agricultural products will need to be improved as well, from which an overall development of the agricultural industry can be expected.

Figure 6-3 | Plastic Film Greenhouses under Construction in Tashkent (left) and Tomato Hydroponic Culture in a Demonstration Farm (right)

Figure 6-4 | On-site Training in the Demonstration Farm (left) and Quality Evaluation of Tomato Fruits (right)

2.3. Operating Plant Factories in Antarctica

A plant factory refers to a plant production system that can produce agricultural crops continuously regardless of season or location in a closed environment by controlling light, temperature, humidity, carbon dioxide, water, and fertilizers. Such plant factory production technology is a partof protected horticulture technology. Due to the success of 'White

Revolution' in Korea, state-of-the-art precise environment control technologies in greenhouses resulted in the development of plant factory production technology. Few countries have the capacity to control the environments in greenhouses as precisely as Korea. It is a technology of "choices" that can allow production of vegetables at regions where agricultural production in the open field is entirely impossible, such as Antarctica [Figure 6-5].

To minimize heat loss under extreme climate conditions of Antarctica with the temperature ranging from -40~-50°C, thick polyurethane panels were installed at the inner walls of the container to increase energy efficiency. The factory utilized 20 feet containers at 5.9×2.4m, and polyurethane panels that were thicker than 20cm were attached to the inner wall. In order to utilize the narrow space within the containers efficiently, 3-layer beds have been installed, and also in order to enhance the lighting efficiency, a combination of LEDs and fluorescent lights have been installed. To maximize the utilization of the lighting further, the lighting was varied for different vegetables and reflective panels were also installed. In addition, other conditions such as the temperature and humidity could be automatically adjusted. Within the container in plant factory, lighting density can vary for each ofthe three bench shelves. For leaf vegetables such as lettuces [Figure 6-6] for which leaves are harvested for a relatively long duration, strong lighting is provided at the top. In the middle shelf, vegetables for young leaves that can be harvested after one month are produced with medium light intensity and at the bottom shelf, sprout crops including barley, wheat and radish sprouts that can be harvested after one week are grown with the lowest light intensity [Figure 6-5].

Hydroponic systems have been installed on all of the benches to allow automatic circulation of nutrition and water, making the cultivation procedure very convenient. When operating one such plant factory, 72 sheets of plug trays of 60×30cm size can be used. This is sufficient to produce more than 1kg of fresh vegetables in a day. Therefore, normal operation of this plant factory will supply more than 50g of fresh vegetables to each researcher assigned at Sejong Center [Figure 6-5].

For smooth operation of the plant factories installed at Antarctica's Sejong Center, technical information over cultivation of fresh vegetables have been exchanged through internet video conferences, and also cultivation methods have been provided to enable stable production year-round. Manuals regarding productions of leafy vegetables within the container plant factories have also been prepared and provided.

Among the various challenges facing Sejong Center, located in Antarctica, are physical problems of indigestion and constipation resulting from lack of available fresh vegetables and fibers, as well as emotional depletion and depression resulting from living in an isolated environment year-round. Studies have demonstrated that the plant factory contributed significantly in addressing these problems. To a question asking whether the vegetables helped with physical health, 89% of respondents answered that the vegetables helped ("very helpful" and "somewhat helpful"), displaying that continuous supply of vegetables helped maintain an overall balance of the body and prevented conditions such as indigestion and constipation. In fact, according to the data from Sejong Center's clinic, there were no visitations for constipation treatment during the entire year of 2010. Furthermore, 83% of the respondents answered that the vegetables were either "very helpful" or "somewhat helpful" to mental health. This further proves that the green plants available from the plant factory provided help in stabilizing the minds of researchers at Sejong Center who lives isolated lives.

The plant factory technology is perceived as a future green-growth industry and is a high-value added industry combining multiple advanced environment control technologies. Therefore, the competition to develop related technology is fierce across the various nations in the world. While the plant factories are being operated only for the research centers of certain nations such as the U.S. or Australia, it is expected that Korea's excellent technology can be displayed through this opportunity and Korea can lead the world in the field of plant factory productions. Also, there is a need to transfer the technology to other corporations, not only Sejong Center, and develop it as an export industry. Various equipments within the container plant factories, environmental control technologies, and crop cultivation technologies will be transferred to private industries so that they can be commercialized and put into practice. Additionally, the plant factory should be supplied to deserts or open sea fishing vessels to help improve the health of those living in far-off areas and make green vegetables available for them.

Figure 6-5 | Sejong Research Center in Antiarctica (left) and Plant Factory Installed in the Sejong Research Center (right)

Figure 6-6 | Lettuce Growing in the Plant Factory (left) and Lettuce Grown in the Plant Factory is being Served (right)

3. Expansion of Korean Protected Horticulture Industry across the World

3.1. Greenhouse Plants

Withthe growth of Korea's greenhouse plant industry (industry to construct greenhouses or factories needed for greenhouse construction), hundreds of companies have successfully operated with governmental support policies during the 1990s, but after the reduction of glasshouse support programs, the businesses began to face difficulties. In Korea, glasshouse construction business has decreased and the orders of glasshouses from farmers decreased rapidly as well, along with the foreign currency crisis in 1997 and ensuing economic slowdown. The industry attempted to expand overseas plastic film greenhouse installation businesses for example in Shandong Province in China, but most companies in the greenhouse business did not survive. By 2000, a handful of companies have continued on their business in greenhouse construction, and are striving to develop greenhouses well-suited for Korean climate to have competitiveness against foreign greenhouse companies.

Among greenhouse companies, 'G' (the company's initial) ventured into the greenhouse business in 1996, and beginning with the installation of greenhouses for the Gumi Horticulture Agriculture Complex, the firm has experiences in the greenhouse installation and plastic film greenhouse modernization of major agricultural complexes in Korea. 'G' internally produced most materials needed for greenhouse installation in addition to construction of the greenhouses to save management expenses, making it highly competitive. In particular, as 'G' has technology in extrusion and processing of aluminum, 'G' is more competitive in production and supplying of steels than other entities.

'G' also has experience in installing glass and plastic greenhouses overseas. Among such overseas projects, as the Kagome region in northern Kyushu in Japan was reclaimed lands with grounds that were soft, the firm developed and constructed light-weight greenhouses for the project. Fluorescence films were used in 2007 to install a multi-span, large-sized greenhouse (9ha), and facilities have been installed to grow tomatoes through hydroponics. The greenhouses have been in operation until now without any damages. There are many other cases of overseas supplying including El Salvador, Mongolia, and Uzbekistan. The project at El Salvador covered an area of 0.7ha, which is not large, but Korean-type plastic greenhouses were remodeled to be better suited for the region's climate [Figure 6-7]. In addition to the installation, technical supports to enable crop production at installed greenhouses have also been provided. With overseas transfer of various technologies such as seedling production technology for greenhouse vegetables, hydroponic cultivation technologies, and greenhouse environment management technologies, the firm is contributing to the development of protected horticulture overseas.

(Source: Green Plus Inc. President: Park Yong-Hwan, Website: greenplus.co.kr)

Figure 6-7 | Training on Seedling Production in the Greenhouse Installed in El Salvador (left) and a Large Scale Greenhouse Built with Light Materials at Gagome, Japan (right)

3.2. The Development and Export of Grafting Robots

Korea's horticulture industry experienced remarkable advancements during the past 20 years, bringing an income increase for farmers and providing fresh vegetables for the people all year-round. A hidden contributor tosuch developments is seedling production technologies. The greenhouse cultivation farmers can generate income within a short period of time since healthy seedlings can be supplied at an appropriate time from specialized seedling nurseries. Farmers requested grafted seedlings to enhance the stability of cultivationsince fruit vegetables are more profitable than other vegetables. Also, rather than selling fruit vegetable seedlings directly raised from seeds, producing grafted seedlings result in additional values that are greater by threefold. Therefore, production technologies of grafted seedlings for fruit vegetables have become commonly disseminated in Korea. The grafts are usually the varieties that are resistant to diseases transmitted through soil and grafted seedlings usually grow well under continuous cropping and abnormal climates.

Hand grafting work requires a lot of skilled works and it is difficult to acquire those skilled workersin a short period of time. To address this difficulty, the RDA and a company jointly developed GR-800CS, a grafting robot [Figure 6-8]. The C-type is forgrafting of *Cucurbitaceae* vegetables (watermelon and cucumber) and the S-type is for grafting of *Solanaceae* vegetables (tomato and pepper). The CS-type can be used for both *Cucurbitaceae* and *Solanaceae* vegetables.The CS type has comparative advantages over grafting robots from Japan. Grafted seedlings have not been planted in North America and Europe, and Korea and Japan are the only countries where grafting robot are commercialized.

As North America and Europe realized the advantages of grafted seedlings of fruit vegetables,grafting robots are now commercialized and their visits to the website of companies producing grafting robots have increased rapidly (search keyword: Grafting Robot). The demand for grafting robots will increase, considering that the robots have been exported to about 30 countries in the past 5 years and have been well received. The export of Korean grafting robot will certainly increase, compared to Japanese, since their prices are lower but their productivity and precision better than the Japanese robots. As Korea's grafting technologies have developed in low-cost, high efficiency manner and are very stable, the technologies will be rapidly disseminated across the world.

Figure 6-8 | Grafting by Human Labor (left) and by Robot in Mexican Tomato Farm (right)

3.3. Automated Roof and Side Wall Ventilation Windows for Plastic Film Greenhouses

For ventilation of plastic film greenhouses, opening and closing of the roof or the side wall windows involve rolling of the film sheets and lifting them up and down. Ventilation is very important to control temperature, humidity, and CO_2 in greenhouses. In the early stages of protected cultivation, the ventilation was conducted manually but later by automated facilities. Manual and automated ventilation systems are compared in <Table 6-2>. It is difficult to maintain the curvature of pipes installed at the structures or the consistency of rolling films. Therefore, if just a little bit of balance is lost when opening and closing the roof and the side windows, there will be resistance at the opening and closing motors, and there can be frequent breakdowns. It was difficult to implement automatic opening and closing due to such issues during the early periods of 'White Revolution' and frequent motor breakdowns resulted in unstable crop production. In order to address such structural problems, a company'W'developed a stronger and more precise electric opening and closing devices [Figure 6-9].

The automated roof and side wall windows utilized recently DC-24V voltage, with light-weight, high torque, and self-break and limit control devices to make it convenient to use. As the product is very unique and practical, it is well-suited for the opening and closing of cover materials in roll-up-down method. Also, this electric opening and closing device has various models with differing operation capacities and limit switches such as film opening/

closing types, thin heat insulation materials opening/closing types, and multi-layer heat insulation opening/closing types.

'W'company developed DC-24V electric switch for the first time in the world in 1992, and through various revisions and on-site performance tests, developed anoptimal product. As the firm has a production line fit for mass production, the firm can produce high-quality products with low prices and easy maintenance and repair. With such excellent performance, the firm is producing more than 1 million counts of electric switches, accounting for more than 70% of domestic market share and continuously exporting overseas to 15 nations including the United States, China, Japan, and countries in Europe.

During the early stages of development for electric switches, the operation was manual and it allowed simple opening and closing of ventilation windows, but now precise environment sensors measure data on the environment to feed to the controller, and an automatic switch system is included in the device, allowing the creation of optimal crop cultivation environment. This provides savings in manpower and also significantly improves the productivity of crops.

Table 6-2 | Comparison between Manual and Automated Side Wall Window Ventilation

	Manual roof and side wall window	Automatic roof and side wall window
Costs	-	Based on 10 unit of greenhouses: About 4 million Won
Labor	Per day opening/closing time about 5 minutes Opening/closing frequency per day roughly 40 times (open, close) Opened time per day 200 minutes (3.3 hours) *Based on single 10-unit facilities houses (20 units)	Results in saving of labor (As it s operated automatically or turned on/off just with switches, almost no labor is needed)
Crop cultivation environment	As the opening and closing took place with personal senses, optical crop raising environment cannot be maintained.	As it is automatically controlled by precise measurement sensors, even and consistent optimal cultivation environment produced.
Notes	- Increased leisure time and income results in improved quality of life - Economic benefits generated: labor cost reduction (3.3 hours/day= 20,625 Won) → Facilities Costs(2,190 Won/day) ※ Based on labor cost of 50,000 Won for 8 hour/day	

Figure 6-9 | Automated Roof Wall Window (left), Automated Side Wall Window (middle) and Opening/Closing of Curvature Part of a Multi-Span Greenhouse (right)

3.4. Technical Supports for Protected Horticulture Technologies to Other Developing Nations

The government of Korea initiated the Overseas Development Assistance (ODA) programs in 2000, which has been expanding. While several fields related to national development are involved in the program, the characteristics of the business involve the 'Green Revolution' of Korea, which allowed self-sufficiency of food in Korea, and 'White Revolution,' which led to enhanced quality of life for the people and, thus, increased national income. Among the ODA programs, cooperation on agricultural fieldis conducted by the RDA. Such programs include the KOPIA (Korea Project on International Agriculture), which established overseas branch offices at agricultural research institutions or colleges in15 countries including Vietnam, and assigned experts to jointly develop and support technologies, and continue on technology collaboration.

All such nations have selected vegetable crops as a new income source for farmers and also seedling nurseries and exhibition greenhouses are being operated. Cooperative institutions working with the KOPIA offices and experts from Korea include the Vietnamese Agricultural Science Center (VAAS), Myanmar Agricultural Research Agency (DAR), Cambodia Agricultural Research Development Center (CARD), Philippines Rice Research Center (PhilRice), Sri Lanka Department of Agriculture (DOA), Thailand Department of Agriculture (DOA), Uzbekistan Department of Agriculture and Oceanic Resources (UzSPCA), Kenya Agricultural Research Institute (KARI), DR Congo Kinshasha University (UNIKIN), Algerian Institute of Agricultural Research (INRAA), Ethiopean Agricultural Research Center (EIAR), Brazilian Agricultural Research Center (EMBRAPA), Paraguay Agricultural Research Center (IPTA), Bolivian Agricultural Research Center (INIAF), and

Ecuadorian Agricultural research Center (INIAP) and so on. One thing in common among the nations is that vegetable consumption per capita is very little.

The reason that vegetable consumption of these developing nations is less than the UN's recommended amounts is due in part to their traditional dietary preference but in large part tothe complex problems of economic structures such as lack of vegetable production technologies, poor transportation infrastructure, and the inability to purchase such vegetables at markets. The success case in Korea is very well received by nations pursuingthe KOPIA projects and the effects of 'White Revolution' accomplished in Korea are expected to be spread widely.

In addition to the KOPIA Center program in which the RDA in Korea assigned researchers to stay and participate, the APACI (Asian Food & Agriculture Cooperation Initiative) program, which is a program in which 12 nations in Asia are participating in, have been implemented including Nepal, Laos, Mongolia, Bangladesh, Afghanistan, Indonesia, Kazakhstan, and Pakistan. Also, the KAPACI (Korea-Africa Food & Agriculture Cooperation Initiative) program have been implemented with nations including Ghana, Gabon, Nigeria, Rwanda, Malawi, Morocco, Mozambique, Senegal, Sudan, Angola, Uganda, Zambia, Zimbabwe, Cameroon, Ivory Coast, Tanzania, and Tunisia. The APACI and the KAPACI programs have been expanded every year and exhibition farms to test and distribute seedling nurseries and cultivation technologies are being operated in all the sites of the initiative. Therefore, it is expected that the greenhouse cultivation technologies developed through 'White Revolution' in Korean agriculture can be utilized well in these initiatives.

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Supplementary Tables

Supplementary Table 1 | The Aims and Results of Five-year National Economy Development plans

	Economic development (average increase or decrease within each plan)												
	First ('62 -'66)		Second ('67 -'71)		Third ('72 -'76)		Fourth ('77 -'81)		Fifth ('82 -'86)		Sixth ('87 -'91)		Seventh ('92-'96)
	Goal	Result	Goal	Result	Goal	Result	Goal	Result	Goal	Result	Goal	Result	Result
GDP ($100,000,000)	-	126	-	-	416	490	669	643	933	971	-	2,312	4,500
Economic growth rate (%)	7.1	8.5	7.0	9.7	8.6	10.3	9.2	7.2	7.5	10.0	7.5	10.0	7.4
per capita national income ($)	79	125	225	357	1,211	1,723	1,723	1,669	2,229	2,344	-	5,437	10,009
• Gross investment (%)	222	15.1	19.9	25.7	24.9	25.6	26.0	30.3	29.5	29.5	30.7	34.5	37.0
• Total rate of savings (%)	9.2	8.0	14.4	16.4	21.5	23.9	23.9	20.5	21.7	32.5	32.3	36.3	36.2
• Current account ($100,000,000)	Δ 4	Δ 4	Δ 3	Δ 3	Δ4	Δ3	12	Δ47	4	45	48	Δ70	Δ88
- Export ($100,000,000)	1.4	2.5	5.5	11	35	78	202	207	357	336	544	696	1,019
- Import ($100,000,000)	4.9	6.8	8.0	13.5	28	84	189	243	351	293	496	766	1,107
• Industrial structure (%)	-	100	-	100	100	100	100	100	100	100	100	100	100
- Primary industries (%)	-	31.7	-	28.8	22.4	23.5	18.5	15.8	12.2	12.8	8.9	7.7	5.8
- Secondary industries (%)	-	25.7	-	20.9	27.9	28.4	40.9	30.7	31.0	30.1	29.1	28.5	32.0
- Tertiary industries (%)	-	42.6	-	51.3	49.7	48.1	40.6	53.5	56.9	57.1	62.0	63.8	68.2
• Employment growth rate (%)	-	2.6	-	3.8	2.9	4.5	3.2	2.3	2.5	1.9	2.5	3.1	2.3
• unemployment rate (%)	14.8	7.1	5.0	4.5	4.0	3.9	3.8	4.5	3.8	3.8	3.6	2.4	3.7

Source: The bank of Korea, National Statistical Office, Ministry of Employment and Labor and Export-Import Bank of Korea

Supplementary Table 2 | Chronological Changes in per Capita GNP in Korea (1961-2010)

Year	GNP ($)	Year	GNP ($)	Year	GNP ($)	Year	GNP ($)	Year	GNP ($)
1961	82	1971	290	1981	1,800	1991	7,105	2001	10,159
1962	87	1972	320	1982	1,893	1992	7,527	2002	11,479
1963	100	1973	401	1983	2,076	1993	8,177	2003	12,717
1964	103	1974	554	1984	2,257	1994	9.459	2004	14,206
1965	105	1975	602	1985	2,309	1995	11,432	2005	16,413
1966	125	1976	818	1986	2,643	1996	12,197	2006	18,732
1967	142	1977	1,034	1987	3,321	1997	11,176	2007	20,045
1968	169	1978	1,432	1988	4,435	1998	7,355	2008	19,162
1969	210	1979	1,676	1989	5,418	1999	9,438	2009	17,110
1970	254	1980	1,645	1990	6,147	2000	10,841	2010	20,756

Supplementary Table 3 | Periodical Changes in the Numbers of Researchers and Technical Advisors in Rural Development Administration

Year	Researcher	Technical advisor	Total
1960	310	1,192	1,502
1965	609	6,354	6,963
1970	635	6,369	7,004
1975	818	7,626	8,444
1980	858	7,980	8,838

Supplementary Table 4 | The Scale of the First and Second Increasing Income Program of farmers' and fishers'

	First (1968-1971)	Second (1972-1973)
No. complexes (ea)	90	137
No. farms (Thousand)	410	750
No. crops (ea)	43	21
Gross investment (100 million won)	452	716

Supplementary Table 5 | Comparison between IIPFF and SIISP

year	Greenhouse area increased (ha)	Price (thousand won/ ha)	Program cost (million won)		
			Total	Government financing	Farm investment
Total	318.5	-	2,354	1,581	739
1968-1971	115.0	1,756	662	463	165
1972-1973	48.9	3,510	172	120	52
1974	46.3	6,306	292	204	88
1975	58.3	10,772	628	435	193
1976	50.0	12,000	600	359	241

Supplementary Table 6 | Designation and Notification of Absolute Agricultural Land (1977. 12. 31)

(Unit: thousand ha)

Total			Rice paddy			field		
Agricultural land area	Absolute agricultural area	Ratio (%)	Total area	Absolute agricultural area	Ratio (%)	Total area	Absolute agricultural area	Ratio (%)
2,231	1,134	50.8	1,303	867	66.5	928	267	28.7

Supplementary Table 7 | Chronological Changes in Agricultural Plastic Production in Korea

(Unit: 1,000 ton)

	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
1.Ethylene	-	-	95.0 (100)	372.6 (-)	561.6 (505)	1,065 (1,155)	3,722 (3,950)	5,537 (5,250)	6,124 (5,885)	7,396 (7,920)
1.1. LDPE	-	-	63.8 (50)	111.8 (-)	201.2 (150)	371 (343)	1,196 (742)	1,591 (902)	1,700 (902)	2,078 (998)
1.2. HDPE	-	-	3.9 (35)	89.2 (-)	147.1 (140)	495 (743)	1,235 (1,313)	1,673 (1,792)	1,989 (2,035)	2,028 (2,325)
1.3. PVC	0.2	36.9	68.5 (86)	237.1 (-)	409.2 (500)	527 (610)	899 (1,100)	1,187 (1,240)	1,334 (1,320)	1,403 (1,420)
2.1 PP	-	-	60.0 (45)	146.0 (-)	260.4 (185)	616 (805)	1,613 (1,675)	2,363 (2,518)	2,872 (2,863)	3,805 (3,988)

Supplementary Table 8 | The Types of Steel Frames for Agricultural Pipes and their Periodical Changes in Production

(Unit: 1,000 ton)

Year	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010
Total production of steel frames (A)	266	1,276	2,937	8,795	14,305	24,867	39,698	48,731	55,066	65,941
Production of iron sheet (B) (B/A, %)	57 (21.4)	454 (35.6)	1,534 (52.2)	4,520 (51.4)	7,864 (55.0)	14,707 (59.1)	22,379 (56.4)	28,063 (57.6)	30,715 (55.8)	39,684 (60.2)
Production of steel pipe (C) (C/B, %)	19 (33.3)	134 (29.5)	336 (21.9)	1,122 (24.8)	1,867 (23.7)	2,611 (17.8)	3,572 (16.0)	4,117 (14.7)	4,072 (13.3)	4,855 (12.2)
Steel pipe for greenhouse (D) (D/C, %)	-	-	-	-	-	73('92) (2.8)	179 (5.0)	168 (4.1)	135 (3.3)	116 (2.4)

Supplementary Table 9 | Change in Agricultural Chemicals Consumption in Korea

		Total	pesticide	Insecticide	Herbicide	other	note
1950	Total	1,486	-	-	-	-	-
1955	total	4,017	-	-	-	-	-
1960	Total Production Import	5,857.3 2,139.7 3,230.3	3,453.0 350.2 2,564.7	2,372.1 1,780.5 665.0	- - -	32.2 9.1 0.6	- 17 companies 23 companies
1965	Total Production Import (AID fund)	12,729 10,237 1,836	- 7,517 -	- 2,621 -	- - -	- 99 -	- - -
1970	Total Production Import	31,339 26,350 4,989	- 10,677 -	- 9,456 -	- 5,889 -	- 313 -	- - -
1975	Total Production Import	99,110 88,760 10,350	- 12,823 -	- 49,773 -	- 25,508 -	- 656 -	- - -
1980	Total Production Import	33,065 8,646 12,050	9,873 3,933 5,940	10,824 4,713 6,110	6,972 - -	5,397 - -	- - -
1985	Total Horticultural crops & other Rice	42,351 27,782 14,569	- - -	- - -	- - -	- - -	- - -
1990	Total Horticultural crops & other Rice Herbicide	11,414 982 7,660 2,772	- - - -	- - - -	- - - -	- - - -	- - -

* Source: Annual agriculture report

Supplementary Table 10 | Production Costs in Greenhouse Cucumber Cultivation Depending on Irrigation Systems (National Horticultural Research Institute, NHRI 1999)

Watering methods	Harvest (kg/10a)	Harvest index	Cost (Won/10a)	Wage (Won/10a)	Total (Won/10a)	Cost cutting (%)
Nozzle watering	2,660	112	55,250	4,800	60,050	29.3
Drip watering	2,645	112	47,375	4,800	52,175	37.7
Perforated pipe	2,539	107	35,000	4,800	39.800	52.8
Hose watering	2,366	100	2,780	81,000	83,780	0.0

Supplementary Table 11 | Comparison of Production Efficiency between Conventional Seedling and Plug Seedling (NHRI: 1994)

Category	Conventional seedling production	Plug seedling production
Timing of seedling production	Difficult to raise seedlings during winter and summer	Year-round seedling production
Seedling quality	High proportion of non-uniform, low-quality seedlings	Good quality, uniform seedlings
Germination Rate	80-85%	Over 95%
Amount of soil	Around 300ml/week	Varied, around 20-150ml/ week
Seedling transportation	Difficult	Convenient (Long-distance transportation enabled)
Seedling productivity	1,000 plants/3.3m² (6cm ports)	3,000-9,000 plants/m²
Environment for seedling	Unfavorable (low temperature, high humidity, weak lights etc.)	Optimal environment can be provided
Seedling production	Depends on human labor	Machination, automation enabled
Seedling planting time	35 hours/10a (Field peppers)	Less than 20 hours
Transplanting	Human labor	Mechanization Enabled

Supplementary Table 12 | Grafted Seedling Proportions and Grafting Methods of Some Fruit Vegetables

Crops	Proportion of grafted seedlings	Grafting Methods		Rootstock type
		Conventional seedlings	Plug seedlings	
Cucumber	70%	inarching	cleft (root pruning) > inarching> insertion	Heuk-Jong, Shintojwa, FR-bodyguard
Water melon	95%	insertion, inarching	cleft (root pruning) > insertion > inarching 〉 pin	Chamback, FR-Bodyguard, FR-Dantos, FR-10, FR-Top, Tojwagye
Melon	95%	insertion, inarching	Insertion, cleft	-
Eggplant	20%	cleft	cleft, insertion grafting > pin grafting	Naebyung VF, Dolbal Biga, Daetaerang
Tomato	10%	inarching, cleft	cleft (root pruning) ≥ pin (root pruning), inarching	Yeongmuja, Anka-T
Oriental Melons	85%	inarching, insertion	Cleft (root pruning) > inarching	Shintojwa
Chili Pepper	-		Pin > cleft > inarching	Yeokgang, Geumsang

Supplementary Table 13 | The Composition and Concentration of Nutrient Solution in DifferentCrops (NHRI, 2004)

(Unit: me/ l)

Crops	Nitrogen (T-N)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Sulphur (S)
Green peppers	12	3	7	4	2	2
Eggplants	10	3	6	3	2	2
Tomatoes	9.7	2	5	4	2	2
Cucumbers	12.7	2	7	5	2	2
Watermelons	13	3	5	7	3	3
Strawberries	15	3	6	8	4	4
Water parsleys	7.7	2	4	3	1	1
Spinach	7.7	2	3	4	2	2
Lettuces	9.2	3.6	5	3	1.5	1.5
Crown Daisy	10.5	4.5	5.8	2.5	0.7	0.7
Small green onions	9.7	3	5.5	2.5	0.7	0.7
plug seedlings	8	2.4	2.4	4.8	1.6	1.6

Supplementary Table 14 | Light environment and heat accumulation characteristics as affected by covering materials (NHRI 1996)

Covering Materials	Light penetration rate (%)	Light diffusion rate compared to fields (%)	Geothermal heat inflow time (Hour. minute)	Inside temperature (at 11 o'clock:˚C)
Glass	64.7	69.7	09:06	28.5
PC	61.3	68.9	09:30	26.6
PET	60.7	58.6	09:12	25.0
PE	56.4	54.4	10:12	24.3

Supplementary Table 15 | Standard Fertilization Amount of Major Facilities Vegetables (kg/1,000m²): National Institute of Agricultural Science and Technology (NIAST, 1991)

Crop Name	Category	Standard fertilization dose		Total (N-P-K)
		Basal fertiliation (N-P-K)	Additional fertilization (N-K)	
Chili Peppers	Greenhouse	12.2-6.4-6.1	10.3-4.0	22.5-6.4-10.1
Tomatoes	Greenhouse	11.6-10.3-4.1	8.8-8.1	20.4-10.3-12.2
Cucumbers	Greenhouse	9.2-10.3-8.1	10.5-4.1	19.7-10.3-12.2
Oriental Melons	Greenhouse	9.7-6.3-5.7	9.0-5.2	18.7-6.3-10.9
Watermelons	Greenhouse	5.5-4.9-4.4	8.3-4.3	13.8-4.9- 8.7
Pumpkins	Greenhouse	10.0-8.4-4.4	10.0-5.5	20.0-8.4- 9.9
Strawberries	Greenhouse	3.5-4.9-5.6	6.1-1.8	9.6-4.9- 7.4
Eggplants	Greenhouse	8.3-8.7-4.1	11.0-7.1	19.3-8.7-11.2
Radishes	Greenhouse	6.2-4.9-5.2	11.3-5.2	17.5-4.9-10.4
Beets	Greenhouse	3.7-3.8-2.9	3.7-2.8	7.4-3.8- 5.7
Lettuces	Greenhouse	5.1-4.9-4.3	5.1-4.4	10.2-4.9- 8.7
Chinese cabbages	Greenhouse	7.5-6.4-6.1	14.7-4.9	22.2-6.4-11.0
Spinaches	Greenhouse	3.8-4.9-6.1	5.6-3.2	9.4-4.9- 9.3
Green Onions	Greenhouse	3.0-5.5-5.7	4.5-3.8	7.5-5.5- 9.5
Cabbages	Greenhouse	8.0-7.1-6.6	14.8-5.5	22.8-7.1-12.1
Celeries	Greenhouse	5.5-10.9-4.6	10.1-3.7	15.6-10.9- 8.3

Supplementary Table 16 | The Number of Farmers Participated in Winter Farmers Training Course

Year	Attendance	Food Crop	Cash Crop	Lifestyle Improvement	Successor Class	4-H Class
1969-1970	5,889,436	5,889,436	-	-	-	-
1971-1975	12,934,704	12,934,704	-	-	-	-
1976-1980	13,376,827	10,313,341	3,054,486	-	-	-
1981-1985	12,032,015	8,300,221	3,448,887	282,907	-	-
1986-1990	10,405,554	5,458,720	4,027,204	919,630	-	-
1991-1995	4,272,313	2,888,710	611,393	702,204	34,657	34,349
1996-2000	3,181,217	2,667,396	-	513,812	-	-
2001-2005	2,795,007	2,411,668		383,319	-	-
2006-2010	2,039,217	1,814,557		223,265	-	-
After 2011	335,562	304,425		31,137	-	-

Supplementary Table 17 | Changes in Fruit-trees Protected Cultivation Area

Year	Protected cultivation area of fruit trees (ha)				
	Total	Tangerines	Grapes	Pears	Other fruit trees
1991	453	87	204	-	162
2000	3,402	1,623	1,115	64	600
2002	3,872	1,918	1,438	70	446
2004	4,717	2,315	1,781	76	545
2006	5,470	2,720	1,842	-	908
2008	6,027	3,013	2,009	-	1,005
2010	6,225	3,102	2,242	-	881
2011	6,821	3,390	2,467	-	964

Source: National Statistics Portal, http://kosis.kr

Supplementary Table 18 | Changes in Cultivation Area for Ornamentals

Year	Cultivation Area (ha)	Protected cultivation (ha)			Field cultivation (ha)
		Total (%)	Glasshouses	Plastic film houses	
1986	2,381	764 (32)	17	747	1,617
1990	3,503	1,752 (50)	59	1,693	1,751
1995	4,950	3,023 (61)	134	2,889	1,907
2000	5,890	3,336 (57)	385	2,951	2,554
2005	7,569	3,448 (46)	322	3,126	4,120
2010	6,829	3,268 (48)	199	3,069	3,561

Supplementary Table 19 | Cultivation Area of Different Types of Ornamentals (2010)

	Total cultivation area(ha)	Facilities area (ha)			Covered fields (ha)
		Total (%)	Glasshouse	Plastic film greenhouse	
Total	6,829	3,268 (48)	199	3,069	3,561
Cut flowers	1,975	1,805 (91)	113	1,691	170
Potted plants	1,250	1,108 (89)	72	1,037	141
Flowering plants	314	164 (52)	7	157	150
Ornamental trees	2,134	83 (4)	3	80	2,052
Flower trees	1,087	81 (7)	2	79	1,006
Seed	70	28 (40)	3	25	42

Supplementary Table 20 | Yield per unit Area Changes of Greenhouse Vegetables

(Unit : kg/10a)

Crops	Category	Year			
		1980	1990	2000	2010
Cucumbers	Field cultivation	2,279	2,371	3,837	4,047
	Protected cultivation	3,230	3,677	6,825	7,617
Tomatoes	Field cultivation	2,827	2,918	4,256	-
	Protected cultivation	3,103	3,180	5,677	6,163
Watermelons	Field cultivation	2,133	2,204	2,365	2,866
	Protected cultivation	2,688	2,708	3,332	4,347
Strawberries	Field cultivation	1,018	1,252	1,473	1,493
	Protected cultivation	-	1,735	2,633	3,342

Supplementary Table 21 | Level of Labor Saving in Different Greenhouse Types due to Greenhouse Modernization

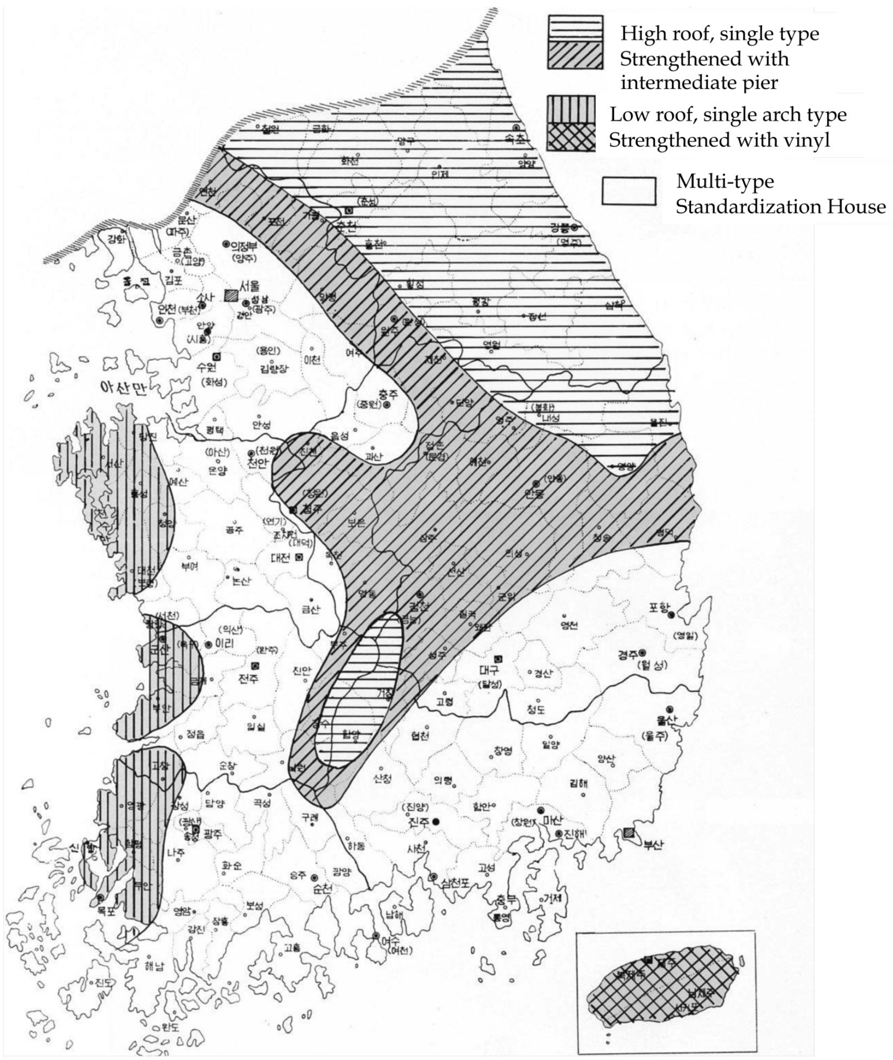
Labor reduction level	Greenhouse types			
	Glasshouse	Rigid plate greenhouses	Plastic film Greenhouse	Average
Reduction over 30%	52.1	27.5	43.1	41.3
Reduction of 10-30%	38.7	55.8	46.4	46.9
Similar	5.0	15.8	7.7	9.2
Increase in labor input	4.2	0.8	2.9	2.6

Supplementary Table 22 | Labor input Hours in Different Crops for Forcing Culture of Greenhouse Vegetables and Changing Trends in Labor Productivity

Crops	Category	Year				
		'90	'95	'00	'05	'10
Cucumber	Labor Hours (h/10a)	779.6	821.9	829.2	867.0	822.0
	Labor Productivity (KRW/h)	3,306	8,515	9,816	13,529	21,771
Tomato	Labor Hours	830.7	757.6	573.8	482.4	488.0
	Labor Productivity	3,184	9,482	5,290	17,019	20,329
Oriental Melons	Labor Hours	681.0	648.9	450.2	387.5	312.3
	Labor Productivity	2,610	5,637	5,256	10,205	15,669
Watermelons	Labor Hours	573.9	405.9	267.2	189.5	166.3
	Labor Productivity	3,378	6,603	7,598	15,122	17,942
Strawberry	Labor Hours	865.2	810.6	723.1	639.7	584.7
	Labor Productivity	2,662	6,877	8,932	12,293	29,496

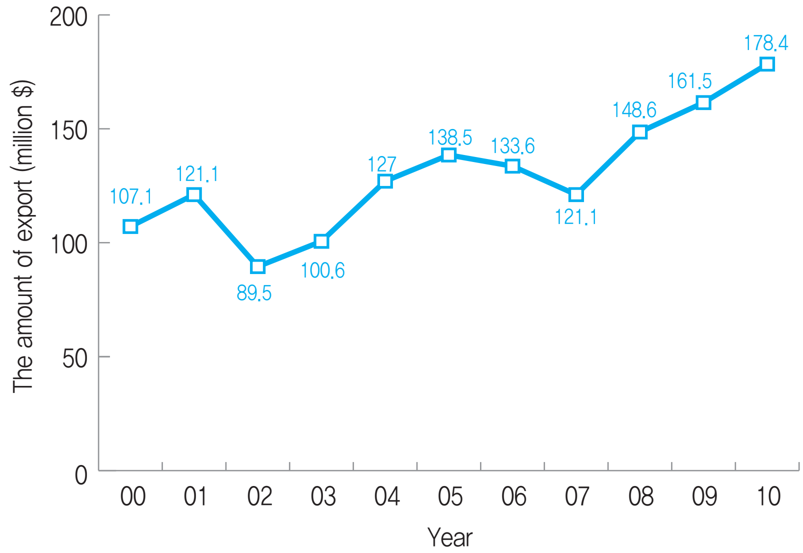
Supplementary Figures

Supplementary Figure 1 | Structural Designs Depending on Different Environments (NHES, 1987)



Supplementary Figure 2 | Appropriate Heat Demands in Different Regions (NHES, 1987)

Supplementary Figure 3 | Changes in the Export of Vegetables in Korea (2000-2010)



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ISBN 979-11-5545-052-9

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