

Current Situation and Development Proposals of Agricultural Facilities (Planting) Application in Beijing

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Abstract: Facility agriculture is an essential carrier for promoting stable production and supply. In 2020, the planting area of facility agriculture in Beijing (290098000 m²) accounted for 29.06% of the total planting area of crops (998078000 m²), and the output value accounted for 46.56%. In 2022, Beijing Agricultural Technology Extension Station organized relevant departments to summarize and evaluate the agricultural facilities in Beijing through consultation materials, interviews, questionnaires, and field trips, combining survey data and statistical data to draw the following conclusions. Facilities play a major supporting role in stabilizing production and ensuring supply. The number of traditional greenhouses is extensive and covers a large area, so special planning and classification upgrades are urgently needed. Facilities are rich in scientific and technological resources, but the mode of production is out of date. It is of great significance to improve the comprehensive production capacity of facility agriculture and promote the healthy and stable development of facility industry in Beijing to increase the utilization rate of facility agriculture land, strengthen the support of facility science and technology, and cultivate the socialized service organization of facility.

Keywords: facility agriculture; stable production and supply; cost benefit; technical support

The 20th Communist Party of China (CPC) National Congress emphasized that it is necessary to establish the concept of “bigger food” and ask for food from facility agriculture. In 2020, the planting area of facility agriculture in Beijing (290098000 m²) accounted for 29.06% of the total planting area of crops (998078000 m²), and the output value accounted for 46.56%. In 2022, the No. 1 central document proposed accelerating facility agriculture development and

adjusting measures to local conditions, including plastic greenhouses, solar greenhouses, and multi-span greenhouses. The Beijing Municipal Government also proposed strengthening the ability to ensure stable production and supply of essential agricultural products during “the 14th Five-Year Plan” period and increasing the self-sufficiency rate of vegetable products from about 10% to 20%. Facilities are essential carriers for the production of vegetables. It integrates environmental engineering, agricultural engineering, and bio-engineering and also adopts modern agricultural engineering and mechanical technology. Using environmental regulation to eliminate the constraints of natural conditions to a certain extent is of great significance for improving the total agricultural production capacity. The facility agriculture described below refers specifically to the facility planting industry.

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1 Total Amount and Type of Facilities in Beijing

The agriculture facilities in Beijing mainly fall into three categories: solar greenhouses, plastic greenhouses, and multi-span greenhouses. According to the data from the facility agriculture standing-book management platform of the Beijing Agriculture and Rural Bureau, the total amount of facilities in Beijing was 120727000 m² and the area of facilities was 110321800 m² in 2022. The specific quantity and area distribution are as follows: the number of solar greenhouses is 64699000 m² (54.0%), and the production area is 52026000 m² (47.2%); the number of plastic greenhouses is 55361000 m² (45.9%), and the production area is 52026000 m² (47.2%); the

number of multi-span greenhouses is 867100 m² (0.7%), and the production area is 6670000 m² (6.0%) (Tab. 1). In terms of new-traditional facilities, 87% of the existing agricultural facilities have been constructed for over ten years. And in recent ten years, the most significant number of new facilities belongs to plastic greenhouses, followed by solar greenhouses, and the smallest number of facilities belongs to multi-span greenhouses. Of these, the number of new plastic greenhouses increased by almost 33350000 m², with an area of 30682000 m². The number of new solar greenhouses increased by approximately 20010000 m², with an area of 16675000 m². The number of multi-span greenhouses increased by more than 464900 m², with an area of almost 3335000 m².

Tab. 1 Summary of existing quantity of facility agriculture in Beijing from 2012 to 2022

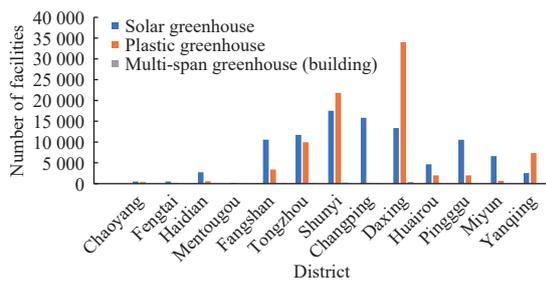
Year	Quantity (10000 buildings)				Production area (667000 m ²)			
	Total	Solar greenhouse	Plastic greenhouse	Multi-span greenhouse	Total	Solar greenhouse	Plastic greenhouse	Multi-span greenhouse
2012	15.7	9.7	5.9	0.1	14.1	7.7	5.5	0.9
2013	17.2	10.3	6.7	0.1	15.4	8.2	6.2	0.9
2014	18.0	10.6	7.2	0.1	16.1	8.5	6.7	1.0
2015	19.1	11.0	8.0	0.1	17.2	8.7	7.5	1.1
2016	20.7	11.4	9.1	0.2	18.7	9.1	8.5	1.1
2017	21.4	11.6	9.6	0.2	19.4	9.2	9.0	1.2
2018	21.8	11.7	10.0	0.2	19.8	9.3	9.2	1.2
2019	21.8	11.7	10.0	0.2	19.9	9.3	9.3	1.2
2020	20.1	10.6	9.3	0.2	18.3	8.5	8.7	1.1
2021	18.4	9.9	8.3	0.1	16.9	8.0	7.9	1.0
2022	18.1	9.7	8.3	0.1	16.5	7.7	7.8	1.0

Data source: Facility Agriculture Standing-book Information Management System

2 Distribution and Utilization of Facilities in Beijing

There is an apparent regional clustering effect in the distribution of facility agriculture in Beijing, mainly concentrated in the Daxing, Shunyi, and Fangshan districts. Based on the type distribution of facility agriculture, solar greenhouses are mainly concentrated in the six districts of Dax-

ing, Shunyi, Tongzhou, Fangshan, Changping, and Pinggu, with the most significant proportion in Shunyi district at 18.0% (Fig. 1). Multi-span greenhouses are mainly concentrated in the five districts of Daxing, Shunyi, Tongzhou, Haidian, and Changping, with the most significant proportion in Daxing district at 32.2%. Plastic greenhouses mainly concentrated in Daxing District and Shunyi District.

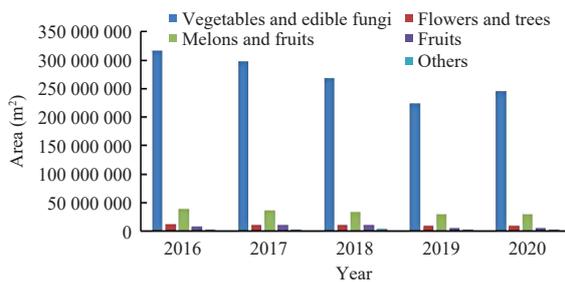


Data source: Facility agriculture standing-book information management system

Fig. 1 Quantity of all types of facility agriculture in 13 districts of Beijing in 2022

3 Situation of Agricultural Facility Industry in Beijing

Among the facility crops in Beijing, the largest acreage is devoted to vegetables and edible fungi, according to the Beijing Statistical Yearbook. During “the 13th Five-Year Plan” period, the sown area ranged from 224312100 m² to 316491500 m². Although it continued to decline from 2016 to 2019, the sown area was more than 80%. It began to rise in 2020, with the sown area reaching 246256400 m² (84.83%), followed by melons and fruits, with a sown area of 29147900 m² (10.03%). The third belongs to flowers and seedlings, with a sown area of 8871100 m² (3.06%), and the last belongs to garden fruits, with the sown area of 4869100 m² (1.67%) (Fig. 2).



Data source: Beijing statistical yearbook (2016–2020)

Fig. 2 Area and proportion of facility crops in Beijing from 2016 to 2020

4 Types and Characteristics of the Main Facilities in Beijing

4.1 Chinese Solar Greenhouse with Earthwall

This is the traditional Shouguang-type green-

house and is dominated by machine-driven earthen walls with a ridge height of 4.0–5.5 m, a span of 12–23 m, a length of 80–120 m, an earthen-wall-bottom width of 6–10 m, a top width of 1.5–2.5 m and a height of 6–8 m (Fig. 3). It adopts a downward extension mode. The cultivation area in the greenhouse extends downward by 0.4–1.2 m, the bottom angle of the arc-shaped front roof is typically 70°–75°, the elevation angle of the rear roof is 35°–40°, and the land utilization rate is about 30%. Under the condition of no heating, the winter greenhouse temperature is not lower than 8°C. Representative agricultural parks include Fangshan Laotian Agricultural Science and Technology Development Co. Ltd., Daxing Siji Yangkun Agricultural Development Co. Ltd., Pinggu Kang’an Lifeng Agricultural Products Development Co. Ltd., and Yanqing Maoyuan Guangfa Agricultural Development Co. Ltd.

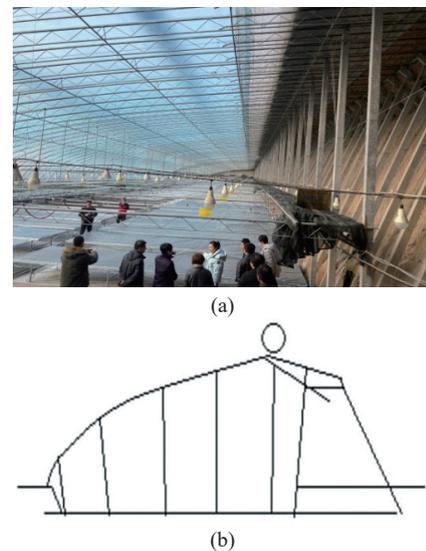


Fig. 3 Chinese solar greenhouse with earthwall: (a) inside of the greenhouse; (b) schematic diagram of the greenhouse

4.2 Chinese Solar Conservatory with Brick Wall

This is a steel-framed greenhouse with red bricks, or hollow bricks as walls, with a span of 10–12 m and a ridge height of 4–6 m. The bottom angle of the arc-shaped front roof is 70°–75°, and the elevation angle of the rear roof is 35°–40° (Fig. 4).

The structure is solid and durable, with a land utilization rate of 50% to 60%. Its heat retention is slightly lower than that of an earthen-walled greenhouse, but it can accommodate the production of multiple-season crops. Representative agricultural parks include Tongzhou International Seed Industry Technology Co. Ltd., Changping Yinhuang Agricultural Co. Ltd., Shunyi Food-First Ecological Agriculture Park Co. Ltd., and Miyun Aoyi Kaiyuan Vegetable Planting Cooperative.

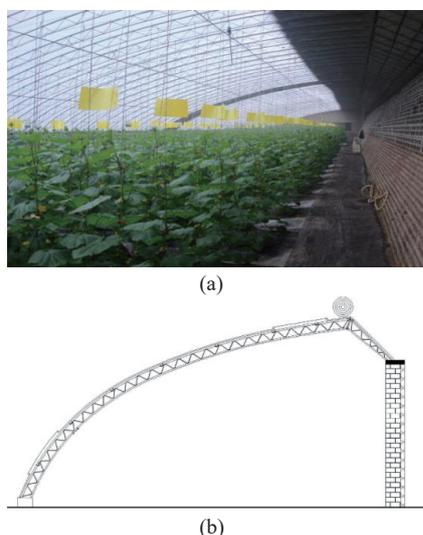


Fig. 4 Chinese solar conservatory with brick wall: (a) Chinese solar conservatory with brick wall; (b) schematic diagram of Chinese solar conservatory with brick wall

4.3 Chinese Solar Greenhouse with Quilt Wall

A new type of greenhouse is developed in Beijing in recent years. It is a greenhouse designed with the “tent” thermal insulation theory. Its structure is essentially the same as that of an ordinary brick wall greenhouse, with a span of 10 m to 14 m, a ridge height of 5 m to 6.5 m, a bottom angle of 70° to 75° of the arc front roof, and an elevation angle of 35° to 45° of the rear roof (Fig. 5). It does not require civil construction, so it slightly damages the original land. The land utilization rate ranges from 50% to 65%, which is convenient for mechanized operation and suitable for producing fruits and vegetables in spring and autumn, leafy vegetables in winter, and strawberry or seasonal seedling cultivation. Rep-

resentative agricultural parks include Changping Jinhuinong Agricultural Professional Cooperative, Daxing Yunong High-Quality Agricultural Products Planting Co. Ltd., Pinggu Tuotuo commune Ecological Agriculture Co. Ltd., Shunyi Yitai Huafu Ecological Farm Co. Ltd., etc.



Fig. 5 Chinese solar greenhouse with quilt wall: (a) outside the greenhouse; (b) inside the greenhouse

4.4 Plastic Canopy Covered with Quilt

This arched greenhouse with thermal insulation capacity is developed based on a traditional plastic greenhouse and can be used for winter production. The structure is mainly made of galvanized steel frame and is equipped with steel pipe or reinforced concrete column, insulation quilt, greenhouse film, and film recoiler machine (Fig. 6). The orientation is primarily north-south. The thermal insulation performance is significantly better than plastic greenhouses, with a span of 20–30 m, a length of 100–200 m, and a height of 4.5–8 m. Representative agricultural parks include the Daxing Jingyifeng Ecological Agriculture Development Center, Changping Jinhuinong Agricultural Professional Cooperative, Daxing Siji Yangkun Agricultural Science and Technology Development Co. Ltd., and Fangshan Kangshuyuan Planting Agricultural Cooperative.



Fig. 6 Plastic canopy covered with quilt

4.5 Plastic Canopy

Commonly known as a cold greenhouse, it is a simple protected cultivation facility with a galvanized steel frame as the main body and plastic film as the covering (Fig. 7). The structure of most plastic greenhouses is steel pipe assembly vertical side wall type or floor type. The span is 8–12 m, the ridge height is 2.6–3.5 m, the shoulder height is more than 1.5 m, and the arch bar spacing is 0.9–1.5 m. It has the characteristics of a simple structure, convenient construction, and disassembly, less one-time investment in construction, and can be completely illuminated. It is suitable for early spring and late autumn vegetable production.



Fig. 7 Plastic canopy

4.6 Multi-Span Glass Greenhouse

It is a greenhouse constructed by conjoining glass greenhouses with two or more spans, generally of Dutch Venlo type with steel frame structure, and the top-covering material of this greenhouse is float glass, scattering glass, or PC board, surrounded by double-layer insulating glass or sun panel covering (Fig. 8). The overall light transmittance of the greenhouse reaches the percentage between 60% and 70%. The span of the greenhouse varies from 8.0 m to 9.6 m, and the bay is 4 m to 5 m. Representative agricultural parks include Daxing Hongfu International Agricultural Technology Co. Ltd., Haidian Cuihu

Agricultural Technology Co. Ltd., Daxing Jingnong Smart Agriculture Co. Ltd., Miyun Jixing Agriculture Co. Ltd., etc.



Fig. 8 Multi-span glass greenhouse

4.7 Multi-Span Plastic Greenhouse

This type of greenhouse uses greenhouse film as a simple protective cultivation facility with a single cover (Fig. 9). The general single-span width is between 6 m and 9 m, and most of them are 8 m. The bay is between 3 m and 4 m, and the shoulder height is between 3 m and 5 m. Representative parks include Tongzhou Sunshine Manyuan Planting Co. Ltd., Tongzhou Zhongnong Lvtong Agricultural Development Co. Ltd., Shunyi Lvfunong Fruit and Vegetable Production and Marketing Professional Cooperative, Yanqing Lvfulong Agricultural Technology Development Co. Ltd., and Shunyi Lvao Vegetable Cooperative.



Fig. 9 Multi-span plastic greenhouse

5 Application of Facility and Equipment in Beijing

Greenhouse equipment is divided into five categories, namely ventilation system, heat preservation system, irrigation and fertilization system, heating system, and cooling system.

5.1 Ventilation System

The types of vents are divided into four cate-

gories according to the setting positions, namely front-foot vents, ridge vents, rear-wall vents, and

rear-roof vents. The ratio of various vents and opening methods is shown in [Tab. 2](#).

Tab. 2 Classification and proportion of vents and opening method

Vent location	Open method	Quantity (building)	Proportion (%)	Total (%)	Note
Front-bottom foot vents	Manual film rolling	447	15.75	57.05	
	Manual stitching	1172	41.30		
	Electric film pulling	781	27.52		
Ridge vents	Manual film pulling	2042	71.95	100	
	Manual film rolling	15	0.53		
Rear-wall vents	Manual opening and closing	390	13.74	13.74	Normally closed in winter
Rear-roof vents	Manual opening and closing	87	3.06	3.06	Use in cold season

Greenhouses with vents on the rear wall accounted for 13.74%, and greenhouses with vents on the rear roof accounted for only 3.06%. The vents at the front-bottom foot of the solar greenhouse are mainly opened by manual seams and film rolls, accounting for 41.30% and 15.75%, respectively. There are three opening methods for ridge vents: manual pull-film-window opening, electric pull-film window opening, and manual roll-film opening accounting for 71.95%, 27.52%, and 0.53%, respectively. This shows that the solar greenhouse mainly relies on the manual opening of windows for ventilation, and a small amount of automatic control is also in manual control mode due to imperfect control functions.

5.2 Insulation System

Among the solar greenhouse insulation materials

investigated in this survey, 315 buildings use straw curtains, accounting for 11.10%, and 2523 buildings use needle-felt insulation quilts, accounting for 88.90%. Regarding the roll-up methods of thermal insulation quilts, in this survey, the proportions of various thermal insulation quilt roll-up methods are shown in [Tab. 3](#). From the perspective of the installation position of the roller shutter machine, the proportion of medium-installer roller shutters is the highest, which is 82.88%. From the perspective type of roller blinds, the proportion of double-link roller blinds is the highest, which is 87.07% ([Tab. 3](#)). For the control of roller blinds, the manual control is mainly used, and automatic control is still less.

Tab. 3 Classification and proportion of roll-quilt system in solar greenhouse

Location and type of roller shutter		Quantity (building)	Proportion (%)	Subtotal (%)
Top roller	Manual roll-up quilt	50	1.76	1.76
	Electric roll rope	206	7.26	7.26
	Two connecting rods	151	5.32	
Side roller	Roller	76	2.68	8.10
	swing arm	3	0.11	
Medium roller	Two connecting rods	2320	81.75	82.88
	Running car type	32	1.13	
Total		2838	100	100

5.3 Irrigation and Fertilization Systems

The irrigation and fertilization systems used in solar greenhouses mainly include mobile sprinkler, water fertilizer integrated machine, water pipe flood irrigation and dropper and Venturi fertilizer absorption in the survey. The proportions

of each type are shown in [Tab. 3](#). Venturi fertilizer applicator is the leading product, accounting for 78.12%. It has the advantages of easy installation, operation, and low price. However, the amount of fertilization is large, and the decision-making of irrigation is unscientific. And 14.34%

of the greenhouses still use water pipe flood irrigation and have not achieved water-saving irrigation (Fig. 10).

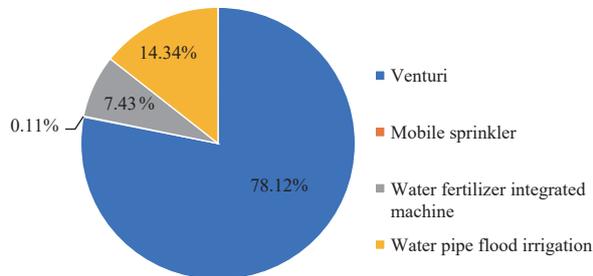


Fig. 10 Classification and proportion of solar greenhouse irrigation methods

5.4 Heating and Cooling Systems

In this survey, there are 43 solar greenhouses equipped with heating systems, accounting for 1.51%. The heating methods are divided into four

categories: air conditioners, solar collectors, electric furnaces, and air source heat pumps, which are 20 buildings, 3 buildings, 15 buildings, and 5 buildings, respectively. Seven solar greenhouses are equipped with cooling systems, six of which are fan cooling systems, and one is a high-pressure micro-mist cooling system.

6 Beijing Facility Design and Construction Standards

Facility agriculture integrates land, capital, technology, and equipment. There are nine national standards, industry standards, and landmark buildings related to Beijing facilities, involving five aspects: design, construction, renovation, acceptance, and technology (Tab. 4).

Tab. 4 Beijing facility design and construction standards

Category	Serial number	Standard number	Standard name
Design standards	1	GB/T 51424-2022	Design standard for greenhouse structure
	2	NY/T 3223-2018	Code for design of solar greenhouses
Construction and renovation standards	3	JB/T 10594-2006	Structure and performance requirements for solar greenhouses and plastic greenhouses
	4	NY/T 3024-2016	Solar greenhouse construction standard
	5	DB11/T 291-2005	Code for solar greenhouse construction
Acceptance standards	6	NY/T 1832-2009	Code for installation and acceptance of steel structures for greenhouses
	7	NY/T 2134-2012	Construction and installation acceptance regulations for solar greenhouse main structure
Technical standards	8	JB/T 10286-2013	Technical conditions for solar greenhouses
	9	DB11/T 550-2018	Technical conditions for electric roller blinds for solar greenhouses

6.1 Design Standard

“Design standard for greenhouse structure”, GB/T 51424-2022, is applied to the structural design of agricultural greenhouses. The loads involved in the structural design shall not only comply with the provisions of this code but also comply with the relevant current national standards.

“Code for design of Chinese solar greenhouse”, NY/T 3223-2018, is applied to the single-building design of solar greenhouses and the site planning and design of solar greenhouse groups.

6.2 Construction and Renovation Standard

“Structure and property requirement for sunlight greenhouse and plastic tunnel”, JB/T

10594-2006, is applied to the construction and strict compliance of new construction, renovation and expansion projects of single solar greenhouses and plastic greenhouses with steel structures, and other greenhouses which can be used for reference.

“Construction criterion for Chinese solar greenhouse”, NY/T 3024-2016, is applied to the new construction projects of solar greenhouses mainly producing fruits, vegetables and flowers in the north latitude 32°–48°, and the reconstruction (expansion) construction projects which can be implemented as a reference.

“The regulation of sunlight greenhouse building”, DB11/T 291-2005, is applicable to the

construction of steel frame solar greenhouses in Beijing.

6.3 Acceptance Standard

“Code for acceptance of construction quality of greenhouse steel structure”, NY/T 1832-2009, is applied to multi-span greenhouses with light steel structures as the main body, but is not suitable for large-span special-shaped steel structure greenhouses. The installation and acceptance of steel structure plastic greenhouses and solar greenhouses can be referred to as the implementation.

“Code of practice for construction and acceptance of solar greenhouse main structure”, NY/T 2134-2012, is applied to the construction and installation acceptance of the frame, heterogeneous composite wall, and raw earth wall (excluding the rear roof) of the solar greenhouse without a column steel frame. Other forms of solar greenhouses can be implemented by reference.

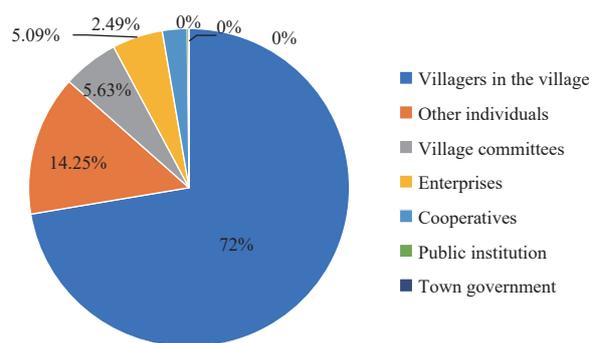
6.4 Technical Standard

“Specifications for solar greenhouse”, JB/T 10286-2013, is applied to solar greenhouses with column-free steel frames for facility agriculture.

“Technical specification for solar greenhouse motor-driving rolling machine”, DB11/T 550-2018, is applied to electric roller blinds (blind rollers) for solar greenhouses.

7 Conditions of Agricultural Facility Operators

There are currently 38153 business entities of facility agriculture in Beijing, mainly including villagers in the village, other individuals, village committees, enterprises, and cooperatives. Among them, the villagers of the village account for nearly three-quarters of the business entities, followed by other individuals (non-village villagers) accounting for 14.25%, and the proportion of other business entities doesn't exceed 6% (Fig. 11).



Data source: Facility agriculture standing-book information management system

Fig. 11 Situation of business entities of facility agriculture in Beijing

8 Main Conclusions

1) The facilities have played an important role in supporting the stable production and supply of vegetables in this city. Among the crops grown in Beijing, the areas of vegetables and edible fungi are the largest. Although the planted area dropped from 316491500 m² to 224312100 m² from 2016 to 2019, the planted area accounted for more than 80% of the total area. It began to pick up in 2020, and the planted area reached 246256400 m², accounting for 84.83%. It is still the main body of vegetable production and supply in this city and plays an important role in stabilizing production and supply.

2) With a large number of traditional greenhouses and a large area, the upgrading and renovation task is arduous [1]. Among the 2840 solar greenhouses in Pinggu in this investigation, 833 traditional greenhouses have existed and been used for more than 10 years, accounting for 29.33% of this survey, and 523 high-risk greenhouses have existed for more than 20 years, accounting for 18.42%, and accounting for about 50% in total. The park uses a large number of traditional and high-risk greenhouses for production. These greenhouses have the characteristics of very low height, poor production conditions, poor structural safety, low mechanization, and low automation of greenhouse equipment. The transformation and upgrading work shoulder heavy responsibilities.

3) The production of facilities is poorly organized, and social services need to be extended. Facility vegetables are labor-intensive and technology-intensive industries, especially with highly specialized and labor-intensive technical links, such as covering material replacement, soil disinfection, and agricultural machinery operation. In Beijing, the villagers in this village account for more than 72% of the existing facility agriculture business entities. However, the existing socialized service organizations are still dominated by large-scale enterprises or park production-operation entities, which is seriously mismatched with the current situation that the facility agriculture industry is dominated by individual production-operation, and the service capacity and service scope are far from enough. There are various cooperation mechanisms between facility agriculture operators and farmers, but there is still a long way to go to “risk sharing and benefit sharing”.

4) Beijing has outstanding advantages in developing facility agriculture. There exist some advantages in developing facility agriculture in Beijing. As a political, economic, technological and cultural center, Beijing has a strong industrial market demand, a deep scientific and technological resource base, a unique geographical advantage, and a solid innovation support platform.

5) Beijing faces certain challenges in developing facility agriculture. The challenges faced by the development of facility agriculture in Beijing include the following aspects. The first aspect is the environmental level. The production environment of old facilities is poor, and the facilities are not suitable for mechanization. The second is the production level. The production level of protected vegetables is not high, and the production mode is backward. The third is the industrial level. The low efficiency of agricultural operation is not commensurate with the high cost of agricultural production. The fourth is the organiza-

tional level. The “old” of the practitioners does not match the “new” of the industry, and the production scale is small and scattered, which is not conducive to the application of a series of modern equipment. The social service capacity is insufficient. The fifth is the technical level. The bottleneck problem of the seed industry is prominent, the precision irrigation and fertilization technology needs to further expand the coverage, and the key production technology needs to be promoted.

9 Development Proposals

9.1 Improving the Utilization Rate of Land for Facility Agriculture

We should carry out planning research to improve land utilization and production efficiency in good areas. Through exceptional support for the traditional production areas of facility agriculture, the transformation of traditional greenhouses is with outdated facilities, poor thermal insulation performance, low carrying capacity, complicated agricultural machinery operations, low land utilization rate, and potential safety hazards, and encourages the development and construction of large-span greenhouses and the solar greenhouse. Promote land-saving, energy-saving, and other new environmental protection facilities and materials, and promote upgrading facility structure to scale and opportunism.

9.2 Increasing Greenhouse Production Capacity

Support villages and towns to independently develop appropriate facility agriculture industry according to the resource endowment of their regions, vigorously promote one product for each district and one product for each village, and enhance the vitality of regional development by strengthening their hematopoietic function [2]. Further, facilitate the efficient and stable transfer of land, help capable growers and professional cooperatives, and lead agricultural enter-

prises to expand the production and operation area. Give play to the agglomeration effect, promote the scale and specialization of facility production, and improve the total productivity of facilities.

9.3 Fostering Facilities and Social Service Agencies

We should develop social services for facility agriculture. Improve the level of social services in the construction, maintenance, operation and trusteeship of facilities and equipment. Cultivate all kinds of socialized service organizations, and support and guide socialized service organizations to participate in the whole industrial chain services such as pre-production links, production links and post-production links of facility agriculture. Drive the overall development of the facility industry. Strengthen crop cultivation and technical services, and make up for the shortcomings of the agricultural technology extension system after the reform of the grassroots extension system.

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