Sustainable Horticulture Crop Production in

The People's Republic of China

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I. Introduction

The People's Republic of China is the world's largest producer of horticultural crops, contributing over one-third of global output in 2003 (Carter and Li, 2005). Located in the Eastern Hemisphere on the Asian continent, China offers a large population, a wide range of landscapes, varied climates, and lots of biodiversity. I chose China because the people have such a long, storied history of using their dynamic environmental factors to their advantage and cultivating horticultural crops.

More than 1.3 billion people live in China, which makes up about one fifth of the world's population. Ninety-one percent of the population is Han Chinese and large ethnic minorities include: Zhuang (16 million), Manchu (10 million), Hui (9 million), Miao (8 million), Uyghur (7 million), Yi (7 million), Tujia (5.75 million), Mongols (5 million), Tibetans (5 million), Buyei (3 million), and Koreans (2 million). The large population provides an ample supply of labor, which contributes heavily to the success of the Chinese horticulture industry.

The majority of China's population inhabits the eastern part of the country that borders the Yellow Sea and the East China Sea. For thousands of years the Chinese civilization has thrived on the alluvial plains between the low-lying deltas of the Yellow River and the Yangtze River. Northeastern China borders North Korea and is primarily temperate grassland. The west half of

China is covered by deserts (Gobi and Taklamakan) and mountain ranges (Himalayan and Tian Shan). The southeast, bordering Vietnam, Laos, and Myanmar is a thick subtropical forest.

The range of climate zones, topography, altitude, and rainfall provides rich germplasm resources. Native China ornamental plants comprise 113 sections, 523 genera, 10,000-20,000 species, and many flowering plants such as plum, peony, chrysanthemum, lily, camellia, azalea, and Chinese rose originated in the country (Rae, 2006).

Over the past several decades, China has experienced a period of industrialization that boosted the economy but has had negative effects towards the environment. According to the Netherlands Environmental Assessment Agency, China's CO_2 emissions are now estimated to be about 14% higher than those from the USA. With this, China tops the list of CO_2 emitting countries, having about a quarter share in global CO_2 emissions (24%). Heavy deforestation has caused erosion of arable land and water is in short supply. China is using up all their limited natural resources and it's time they look towards finding sustainable ways to grow horticultural crops.

II. Sustainability

"The Sustainable development of horticulture in China emphasizes coordinative and sustainable development of production, benefit, resources and environment to meet the needs of quantity and quality of horticultural produce and of environmental beautification" (Chongyang et al. 1998). According this definition, sustainability is using reusable production methods that will not deplete the natural resources and environment, all while producing a sufficient quantity of a quality product. The description is vague-there is no example of what resources are sustainable. I think the sustainable resources are solar energy, rain, manure, compost, and organic farming practices. These resources combined with low input horticultural technology will allow people to continue practicing horticulture in China without depleting valuable resources and polluting the ecosystem.

III. History of Production

The ancient history of Chinese horticulture began along the fertile plains of the Yellow River around 2000 B.C. the writings of Confucius (552–479 B.C.) are the first source to mention horticulture. Some crops grown back then were peaches (*Prunus persica*), plums (*Prunus salicina*), Japanese apricot (*Prunus mume*), jujube, chestnut, mulberry, quince, Chinese cabbage, bottle gourds, and various melons (Janick, 2003).

The Chinese developed cultivation techniques like row planting to space out plant root zones. Tools such as wheelbarrows, pottery, and hoes were utilized. The creation of irrigation canals allowed farmers to produce healthy crops in larger numbers. Eventually the Chinese began to fertilize their crops with "night soil" (human feces). They had an organic system where everything was composted, including bones, leather, manure, and straw (Janick, 2003).

Between 221 and 550 A.D. ornamental horticulture became a part of Chinese culture and spread throughout Asia with the development of emperor's rural and urban gardens. Biological control of insects was used in the culture of orange and litchi (Zhou, 1998). The appearance of flower markets, flower arranging, bonsai and a great number of ornamental varieties of many plants allowed the ornamental horticulture of china to flourish in the first century (Janick, 2003).

The beginning of greenhouse growing structures in China dates back to the Han dynasty (206-23 B.C.E.) when alliums were grown in heated structures during the winter. Later on during the Tang dynasty (618-907 B.C.E.), natural hot springs were used for forcing vegetables in the winter. Simple greenhouses were made using translucent oiled paper as covers to grow vegetables and flowers during the Song dynasty (960-1279 A.D.) (Janick, 2003).

By the late 19th century, glasshouses were imported but these proved to be too expensive in terms of capitalization costs and heating. In the second half of the 20th century the use of fertilizers, pesticides, tractors, protected horticulture, and advances in genetic improvement were acquired from western countries. Windbreaks and solar lean-to greenhouses with polyvinyl chloride or polyethylene surfaces were built near Beijing and Shanghai (Jiang, 2004). These structures shielded crops from the elements while transparent plastic surfaces provided the crops with ample light transmission.

Modern greenhouses from foreign countries began to appear around China by the late 20th century, they were made of glass, polycarbonate, or polyethylene, and had steel frames (Jiang, 2004). These new greenhouses utilized advanced computerized control systems with automatic irrigation and environmental controls. These houses were too expensive and complicated for many Chinese growers. Low-cost, low-input plastic tunnels and solar lean-to houses experienced a sharp rise in popularity.

Today plastic high-tunnels and low-tunnels are widely used for commercial horticultural crop production all over China. In the north, northeast, and northwest, where winter is cold, plastic tunnels are mainly used in early spring and late autumn. In the south where winter is mild, plastic tunnels can be used all year round (Zhang, 2001).

Growers raised their own vegetable plants from seed, which took a long time, so in 1987 China established the first mechanized vegetable seedling production farm to produce mass quantities of plug-seedlings for peppers, cabbage, and cauliflower (Jiang, 2003). This process allowed growers to grow a lot more crops, a lot faster.

IV. Current production statistics

The three main commodities of Chinese horticulture in China are vegetables, fruit, and flowers (Table 1.0). The majority of horticultural crops grown in protected growing structures are vegetables. The top five vegetables grown in protected cultivation are tomato, cucumber, pepper, eggplant and squash (Jiang, 2004). In 2005 only 7% of the protected horticulture area (greenhouses, high and low-tunnels) was devoted to tree and vine fruits (peach, nectarine, grape, cherry, strawberry, and watermelon), and to flowers. Cut flowers are seldom grown in greenhouses, and if they are, it most likely roses. Chrysanthemum, carnation, gladiolus, and lilies are other popular cut flowers in China (Jiang, 2004).

Table 1.0 Area of Chinese Protected Horticultural Commodities

Vegetables (ha)	Fruits (ha)	Flowers (ha)	Total (ha)
1,301,000	60,000	40,000	1,401,000

(Jiang, 2004)

Table 1.1 Area of Different Protected Horticultural Structures in China

Year	High tunnel (ha)	Low tunnel (ha)	Heated greenhouse (ha)	Solar lean-to greenhouse (ha)	Energy-saving lean-to (ha)	Total (ha)
2004	1,039,487	890,427	8,847	91,820	506,300	2,536,881

(Jiang, 2008)

In Table 1.1 it shows the area taken up by each type of protected horticultural growing structure. It shows that the plastic filmed tunnels are the most popular structures (1,929,414 ha combined), followed by the energy saving lean-to greenhouse (506,300 ha). I believe these structures are more popular because they are less expensive and more sustainable than the heated greenhouse and solar lean-to greenhouse.

China's G.D.P. for 2007 was 24661.9 yuan ($3425.3 billion US).

V. Current production practices

Two state-of-the-art production practices I have found are the energy efficient solar lean-to greenhouse and eco-organic soilless media. Both are models for sustainable horticulture in China and they both require a low initial investment to start growing with.

In northeastern China, the energy-saving solar lean-to greenhouse also known as "Yang Qi" is very popular. It is used to grow any kind of plant but it can be used for growing cool season vegetables during the winter. There is no heat source, just solar energy. The structure has double layer insulated brick wall on three sides to act as a thermal layer for the crops within. The curvature and orientation of the polyethylene covering is designed for maximum light penetration in the winter. On winter afternoons, when the temperature inside the greenhouse falls below 17° to 18° C, an insulating mat made out of waterproof chemical fibers is rolled on top of the plastic cover to prevent heat loss. This traps the heat inside the house, keeping the plants warm. This greenhouse can grow vegetables without supplemental heating when the outside temperatures get as low as -20° C, since the continental climate of northern China receives high winter solar radiation (Jiang, 2004). The low energy inputs allow for a more sustainable production of high quality, cool season crops.

Eco-organic Soilless media is used in China to provide a sustainable system for crop cultivation. The media is a mix of locally available substrates (coal cinder, peat moss, vermiculite, coir, sawdust, sand, rice husks, sunflower stems, maize stems, and mushroom waste) to keep the cost low. A trough is made out of three layers of brick and polyethylene plastic film covers the bottom to prevent pests and diseases from infiltrating the media. Plants are propagated in the media and fresh water is used to irrigate the trough via flow pipe. Solid manure is used for fertilization because it is cheap and reduces crop nitrate levels from 30-67% (Jiang, 2004). The eco-organic soilless media is a great way to cultivate crops with a little money and low environmental impact.

VI. Integration of Historical and Current Production Practices: Ranked Strategies.

Automated multi-span greenhouses can provide an ideal environment for plants, but such a high amount of energy is consumed when simulate ideal environment. It is very expensive and wasteful. The materials used to build the structure, like steel, aluminum, and plastic, are expensive and require a lot of energy to be made.

Solar Lean-to greenhouses are environmentally friendly because they have very few inputs. The polyethylene covering is made with oil, so it's not entirely sustainable, but a structure that can be used to grow cucumbers or watermelons without having to use any sort of fuel burning heat source is a step in the right direction. The structure itself is cheap and can be made by anyone with a small amount of capital.

Fertilizing with synthetic chemicals in soil mixes is the traditional way of growing plants that most people know. It is fast, gets good results, and is not sustainable. Certain components of soil mixes such as perlite or vermiculite, are in limited supply and require lots of energy in order to gain that excellent water holding capacity. Synthetic fertilizer can leach into ground water and mess with the ecosystem. Fertilizer leaves behind salts and can ruin soil if improperly applied.

Its important to shift towards a sustainable substrate like eco-organic soilless media. It is cheap, effective, and recycles local ingredients for a beneficial use. Organic fertilizer can contain heavy metal, which is bad for some plants, but the slow release of nutrients from the organic solid fertilizer will not cause any damage if applied correctly.

High-tunnels and low-tunnels are minimal input structures. They are made of plastic which is made with petroleum, but other than that unsustainable mention, they are great and cheap structures for crop cultivation.

Table 1.2 Ranking of future production practices

1. Energy efficient solar lean-to greenhouse
2. Eco-organic soilless media
3. High-tunnels and Low-tunnels
4. Organic farming practices
5. Synthetic fertilizer and soil media
6. Automated multi-span greenhouse

VII. Finalized Sustainable Development Strategy

China has various problems that are preventing horticulture from becoming more sustainable. There is a shortage of resources in China. The amount of arable land has been decreasing at a rate of 360,000 ha annually (Chongyang,1998).

The rural economy is backwards and the quality of farming needs to be enhanced. Inefficient attention has been paid to the improvement of horticultural products. Growers often utilize products that have low levels of post harvest treatment and commercialization, which do not help produce competitive produce.

According to the population prediction, population will reach 1.3 billion by the year 2020 (Chongyang et al. 1998). Farmers engaged in horticultural production should be assured of sustainable improvement of economic returns in order to bring their initiative into full play in the horticultural industry. Consideration must be given to both the development of horticultural production and the improvement of economic benefit, social benefit, and ecological benefit.

To implement sustainable development into China's horticulture industry it is important to make a rational distribution of horticultural production, protect and improve resources, develop production and pay attention to economic efficiency in order to have a sustainable development. Two solutions are very possible, improving the resources of structures, plants, and soil available to growers and to educate them on the advantages of the new techniques and methods.

Yang Qi's eco-organic soilless media and organic farming practices can meet the needs required to improve the sustainability of vegetable production of vegetables in China. In order to promote their use an educational marketing campaign about these structures and methods will be put in place. Construction of model farms that utilize these components of would show growers that the technology and methods are effective. The low cost, low input, and quality yield from this farming method can be on display for the public to learn about. Making sure these products are available to the horticulture community is important so that growers can obtain them in effort to change.

The major challenges to vegetable production in Yang Qi's are soil deterioration and severe plant disease and pest problems. Future study should address the integrated pest control, diversification of vegetable species and cultivars, and improvement of soil quality.

A research question that would benefit the future use of energy efficient greenhouses would be: What soil and cultivar choices can produce the largest yields with the least amount of inputs? The difficulty in testing this is that the plastic used for Yang Qi's are made with petroleum, which is an unsustainable material.

VIII. Future Sustainable, Controlled-Environment Production Facility

A sustainable production facility for China would utilize energy efficient solar lean-to greenhouse. The basic structure of a Yang Qi includes three brick/soil walls which are over 1 m thick and a 0.5 m thick corn-stalk/soil "roof". The south side is covered by polyethylene plastic (film). At night, one thick layer of non-transparent mat that used to be made of straws would be released to cover the plastic films. Yang Qi's have three remarkable features. First, it is effective in energy use (only solar energy), it has a simple structure that can be constructed easily, and third, it is cheap (less than $3/m^2). However, it is also labor intensive and might be more suitable to countries that have lots of relatively cheap manpower, fortunately China does.

The production facility will be located in the province of Shandong in east China. It is located between latitude 34"25' and 38"23' north, and longitude 114"35' and 112"43' east. The total area is 156,700 km2, with only 55% of it arable land. Shandong has a temperate climate, with moist summers and dry, cold winters. Annual precipitation is 550 to 950 mm. The four seasons in Shandong are clearly demarcated. January is the coldest month with an average low temperature about -2°C to -4°C, although cold extremes could be possible under -15°C in some areas (Chonyang et al. 1998). Ample sunshine in winter, which is critical to vegetable productions, takes place most of the time. This environment is ideal for growing high quality vegetables year-round because the temperature does not get below 10° C.

The test facility will consist of three separate Yang Qi's, each located on a south-facing slope in a parallel row. They will all have the same dimensions of 2m in height, 9m in span (south to north), and 60m in length (east to west). A building for the storage, utilities, and soil mixing will be located up the slope to the north. Watering will be done by a drip irrigation flow system to conserve water. One house will be for testing cucumber cultivars and another will be for tomatoes cultivars. In order to research which plant material performs the best I have decided to separate the plants to utilize the benefits of monoculture for those two houses. The most competitive plants will be selected and continually be trialed against other cultivars. The third and final house will be used to test eco-friendly soilless media. I will trial different mixes of soilless media with both species, cucumber and tomato. The soilless mixture components will be coal cinder, peat moss, vermiculite, coir, sawdust, sand, rice husks, sunflower stems, maize stems, and mushroom waste.

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