The Application Mode of Soilless Culture Facilities on the Rooftop of Rural Cottages

Yanbin Hua[1], Zhongyi Yang[*2], Ken Nagasaka[3]

[1,2]College of Horticulture, Shanxi Agricultural University, Taigu, Shanxi, P. R. China

[3]Department of Electrical and Electronic Engineering, Tokyo University of Agriculture and Technology 2-24-16, Nakamachi, Koganei Shi, Tokyo, Japan

[1]huayanbin2011@gmail.com; [*2]yang_zhongyi092@163.com; [3]bahman @cc.tuat.ac.jp

***Abstract*- The authors proposed a new concept for growing vegetable sprouts and ornamental plants by combining greenhouse design and soilless cultivation technology together with house construction. This new planting design of soilless structure is installed on the rooftop of a house, combined with a small household solar cell module; lightening system of energy-saving lamp and embedded cobblestones on the roof wall is not only fully utilizing the available energy, but also maximizing the preserved amount of heat energy. Considering the design idea, technological process, the selection of raw materials, along with their practical value and future prospects, the authors construct a double-layered, vertically cultivated vaulting greenhouse. As a result, the use of soilless cultivation techniques on the house rooftop in the Chinese countryside shows as the promising potential solution to deal with the shortage of arable land resources now. This new cultivation technique may be more effective in promoting agricultural productivity and sustainable development of the economy and society since it can take full advantage on available resources in order to achieve higher economic benefits. There are three major benefits for rooftop agriculture: 1) maximize the utilization of sunlight energy in the roof area; 2) roof agriculture doesn't require any extra arable land; 3) the vegetables can be planted all year-round. The life circle of crops was shortened as found. This new design will increase economic efficiency and the value of the idle house rooftop in rural and suburban areas.**

Keywords*- *Soilless Culture Facilities; Flat Roof Space in Rural Areas; Economical and Intensive Land Use; Solar Cell Module

I. INTRODUCTION

Land resources are the most fundamental elements for the development of the human society. Quantity and quality of arable land resources available are related to the country's economic development and resource allocation closely. With rapid growth of Chinese population and the tendency of urbanization, China is going to convert its economic structure, which may result in more needs towards natural resources and also generate more impacts on eco-environment just like most developing countries [1]. According to the official statistics, the average arable land per capita in China is only 920 m^2, about 40% of the average worldwide. Meanwhile, the abuse of fertilizer and pesticides has led soil pollution widely. From 1997 to 2009, the available arable land resources have declined significantly by 82 billion square meters. Therefore, how to reduce the pressure on available land resources with increasing population has become an important challenge for Chinese society. How to coordinate the relationship between the resources and economic development, and how to promote intensive land use have become important study fields, and there were many models for intensive land use all over the country [2]. On the research scale, China should strengthen the multi-level, sub-region research on the intensive use of agricultural land, including small- and medium-sized cities and towns [3]. In this paper, we designed the new growing environment technique for the plant cultivation without soil been used on the idle rooftop in the rural and suburban areas. This new design technique will not only relieve the pressure on available arable land resources, but also create much more environment-friendly planting technique compared to the current available methods in China.

II. MATERIAL AND METHODS

A. Materials

The following materials were used in this design: vaulted structure steel frame (pillar 3 m or 2 m, beam length 17 m, subject to the actual situation), bamboo tunnel (Height 2.8 m, length 16.8 m, appropriate to the actual situation), shed roof pillar (2.8 m high), double inflatable plastic solar films, sprout seeds (taking into account large amount), multi-layer vertical sprout cultivation bed (wooden frame with rolling casters, frame length 1.5 m, width 0.6 m, height 2 m), cultivation medium (vermiculite, peat-litter), hard plastic nursery tray with drain holes at the bottom (0.6 m × 0.25 m × 0.05 m), watering pot, rolling, straw mats, and black shade nets.

B. Main Features of the Design

The design proposed in this paper is focused on the study for the idle rooftops in rural and suburban areas, combined with the horticulture knowledge to create a new planting environment in the rooftop area without soils applied. This new soilless planting environment is suitable for the cultivation of vegetable, medicinal and ornamental plants. Compared to the current planting technologies, this soilless structure is installed on the house rooftop, combined with a small household solar cell module; lightening system of energy-saving lamp and embedded cobblestones on the roof wall design is not only fully utilizing the available solar energy, but also maximizing the amount of heat energy. Sprouts, medical and ornamental plants are suggested to grow in seedling dish under this design. This planting way will not only save the cultivated land use, but also increase the time of their growth period. The medium used for sprout planting in this design is vermiculite and peat grass. Both of them have the characteristics of low cost, water preserving, high venting quality, easy transporting and generating little pollution to the environment. Based on the above-mentioned characteristics, the sprouts will expect to grow with rich nutrition. As the result, huge ecological and economic benefits are expected under this new planting design proposal. According to our study, the average applicable planting area at the rooftop of the house in rural area is about 64.8-108 m^2. Taking 100 m^2 as an example, the maximum area could be used for planting is 90 m^2 (10 m^2 for walkway use). Then this 90 m^2 area is placed by 90 shelves with each shelf contains 5 layers, and each layer has 6 sprout plates with total planting area of one shelf is 4.5 m^2. With 90 shelves in total, the applicable planting area is 405 m^2. Taking 7 days as a picking cycle for sprout, the harvest will reach 405 kg in one month. Based on 10 times (months) harvest per year and 5 RMB per kilogram as market price, gross income for the first year will reach 81,000 RMB. The net income will be about 10,000 dollars by taking away the various investment costs. The net income will increase to 70,000 RMB after the first year operation.

C. Technology Introduction

The technical part of this new design is presented in this section. Please refer to design sketches at the end of this paper (Figs. 1-5).

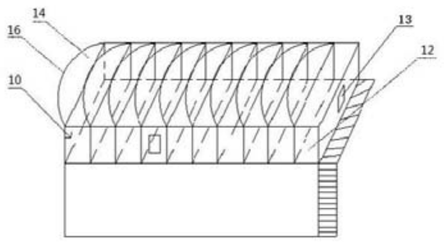

Fig. 1 Design sketch of rooftop greenhouse

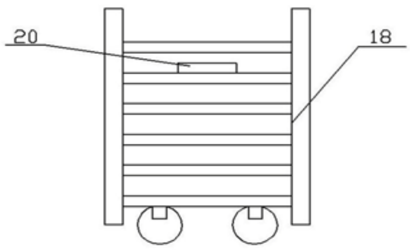

Fig. 2 Sketch of planting beds

Fig. 3 Outlook of planting beds

1) Innovation of the Technology:

The main feature of this new design is that there is no need to soil cultivation in the created planting environment. This design will fully utilize the idle rooftop resource and reduce land pressure.

2) Design Profile:

Fig. 1 presents the design sketch of greenhouse on the rooftop. The structure is a combination of arched steel shed (16 in Fig. 1) with wood frame (14 in Fig. 1) and double inflatable plastic solar films to cultivate. Arch pillars play a perfect supporting role on the shed. It has simple structure with less steel consumption and strong resistance to natural calamities. The configuration with the Chinese word "儿" at the top can effectively reduce the influence of bare greenhouse on the crops. Double inflatable solar films have good heat preservation properties. It achieves great practical value with less investment. Meanwhile, windows and doors (13 in Fig. 1) are installed to supplement sunlight and enhance natural ventilation. The simple operation systems can easily accomplish the greenhouse environment control.

Fig. 2 is the design sketch of planting beds. The greenhouse can contain several multi-storey bed frames (18 in Fig. 2) with wooden construction and rolling casters. Vertical design of planting beds can save floor space. Wooden structures are less expensive, and the rolling casters make it much easier to move. The frame with length 1.5 m, width 0.6 m, height 2 m, can put 5 or 6 layers. The distance between each layer is 0.3 m. The bottom layer is 0.1 m above the ground. Six trays are placed on each layer, and each frame may contain a total of 30 or 36 trays. Fig. 7 is the inside of greenhouse in rooftop area.

Nursery tray (20 in Fig. 2) is designed as 0.6 m × 0.25 m × 0.05 m by hard plastic with drainage holes in the bottom. Nursery tray should be cleaned and disinfected before use. Fig. 3 gives the outlook of planting beds.

Figs. 4-7 are the outlook of greenhouse on rooftop from back, side, bottom and inside of view, respectively.

Fig. 4 Outlook of rooftop greenhouse from back view

Fig. 5 Outlook of rooftop greenhouse from side view

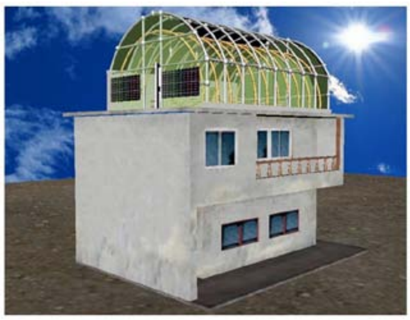

Fig. 6 Outlook of rooftop greenhouse from bottom view

Fig. 7 Inside of rooftop greenhouse

3) Cultivation Practice:

Vermiculite and peat litter are generally used as soilless culture media. They have characteristics of low cost, good water-holding capacity and air permeability. They are also easy for handing and suitable for sprouts planting in the rooftop area. After cleaning up the matrix, spread appropriate amount of media in each seedling tray. If the matrix was used several times, it should be sieved into the pool and stirred constantly with water washing. Then add 0.1% of the formalin, soak for 12 h, and wash again. The seed was treated with screening, cleaning, disinfecting and soaking (takes about three days). Then appropriate amounts of seeds were placed into the tray under the dark culture for 3 to 7 days by covering with black shade nets (50%-70% shading). Once seedlings grow to about 10 cm, they were moved to bright light environment for training. According to plant size and seasonal variation, the culture medium is essentially watered 2 to 3 times daily by watering can. Furthermore, in order to keep a proper growing environment during the winter time, mats may be needed to cover the greenhouse which acts as thermal insulation to keep at a certain temperature during the night time. Usually, mats could be uncovered in the morning after sunrise and be covered after sunset.

4) Uses:

There are three great outstanding features for sprout planting and these are the right reasons why we selected sprout for planting in this research:

(1) Good health benefits

Sprout is very nutritious because it is rich in vitamins, especially vitamin C. For example, alfalfa sprouts contain abundant calcium, potassium and various vitamins, thus can reduce blood cholesterol level based on several study reports. Buckwheat sprouts were found to have anti-inflammatory function. Besides, studies indicated that Chinese mahogang (*Toona sinensis*) had functions in the stomach healthcare, detoxification and cancer prevention.

(2) Green food standard

Sprout can grow without cultivated land. Therefore, there is no need to fertilize the lands and to use the pesticide for sprout planting. This makes the sprout can meet the green food standard easily.

(3) High economical benefits

The average germination time for sprout is about a week, this speed is about 10 to 15 times faster than the other vegetables. With this short germination time and high return profit (5-8.5 RMB/kg), it can be expected to bring a significant financial profit to the farmers.

Based on the three main features described above, the market potential of sprout cultivation is promising.

III. CONCLUSIONS

In view of low efficiency of land use and waste of lands, there is a potential in saving land use. Thus, the design for rooftop soilless cultivation will play an important role in alleviating the pressure of land use, reducing land pollution, and promoting the establishment of a harmonious society. This design makes full use of flat roof spaces and natural resources, achieving new soilless cultivation techniques without affecting the normal life of residents. It needs less power, fertilizer and water, and has a strong lightening capability. It is useful for sprout planting, and a better income can be expected.

At present, the majority of rooftops in Chinese countryside are idle. This design adopted environment-friendly operation systems by taking into account of the idea of green design. The environment meets the need of modern green production. The soilless cultivation on the rooftop can not only be used in planting sprouts, flowers, and vegetables because of the favourable conditions for plant growth, but also serve as a nice garden for people to get refreshment and entertainment with fresh air and natural environment. The new facilities may be used as a model and base for green production in China. The design has applied to Chinese New Practical Patent (Patent No.ZL201120106523.6).

REFERENCES

[1] Wang Yafei, *China's resource consumption and economic growth in the inspection and analysis of the dynamic relationship*[J], Resources Sciences, 2011 (01) p. 25-30.

[2] Sun Wensheng, *Who gave us the land - one hundred cases of the economical and intensive land use (new)*, Beijing, China Land Press, 2005.

[3] Shao Xiaomei, *Intensive Land Use Progress and Prospects*[J], Progress in Geography, March 2006, vol. 25 (2) p. 85-95.

Yanbin Hua was born in Shanxi, China, in 1990. He is an undergraduate student now, and studies in College of Horticulture of Shanxi Agricultural University. He has published 3 scientific papers and has been authorized two Chinese new practical patents (ZL201120106523.6 and ZL201120059056.6). He has attended the International Conference on Materials Science and Information Technology sponsored by Singapore Institute of Electronics (ICMSIT 2011, Singapore, 2011.9.16-9.18). The paper submitted to the conference has been indexed by EI Compendex. His major research field is horticultural facilities and medicinal ornamental flowers.

Zhongyi Yang was born in Shanxi, China. He received Ph. D degree from Shanxi Agricultural University in 2008. He is an associate professor. He teaches courses of Crop cultivation, Medicinal plant cultivation, Soil and fertilizer, Chinese herbal medicine production of standardized GAP (good agricultural practices) environmental certification, Medicinal plant cultivation and breeding, Medicinal plant physiological ecology. He was a chief researcher for horticultural facilities and medicinal ornamental flowers. He has taken part in six research projects, including the National Natural Science Foundation and the provincial and ministerial research projects. He chairs the Shanxi Key Technologies R & D Program: the Shanxi geoherbs resource optimization and GAP base construction. He has published more than 20 scientific papers.

Ken Nagasaka was born in Kermanshah, Iran, in 1956. He received the B.S. degree in electrical engineering from Nihon University, Tokyo, Japan, in 1985, and the M.S. and Ph.D. degrees from Tokyo Metropolitan University, Tokyo, Japan, in 1987 and 1990, respectively. From 1990 to 1991, he was a chief researcher for a computer software development company in Tokyo, Japan. From 1991 to 1994, he was a visiting professor in the University of Manitoba, Winnipeg, Canada. From 1994 to 1998, he was a scientist in the Central Research Institute of the Electric Power Industry, Tokyo. From 1995 to 1998, he was an associate professor in the Department of Electrical Engineering, Tokyo Metropolitan University. He is currently an associate professor in the Department of Electrical and Electronic Engineering, Graduate School of Engineering, Tokyo University of Agriculture and Technology, Tokyo, Japan. He has published more than 600 scientific papers, and many of them have won paper prizes, including the Institute of Electrical Installation Engineers (IEIE) of Japan in 1991. Professor Nagasaka was a recipient of three awards from the PSC in 2001, 2002, and 2006. Also, in 2006, he was a recipient of a medal from the University of Tehran, Tehran, Iran, for his contribution to the First Conference on Control and Management of Energy Systems. His current research projects concern environmental energy engineering, particularly power system analysis, power deregulation, wind power, micro-grid, smart grid, energy saving, load forecasting, and application of intelligent systems to power systems. He is a member of the IEEE.