

Design of an SolidWorks-based household substrate cultivation device

GUO Yi, WANG Yueying

Department of Horticulture, Beijing Vocational College of Agriculture, Beijing,
102442, China

guoyibvca@163.com

Abstract. Rapid urbanization has caused increasingly severe environmental problems and smaller tillable land area. Even worse, negative reports on vegetable production are repeatedly found. In this case, home gardening has become an inexorable trend. To meet demand for vegetable cultivation in the home environment, an SolidWorks-based household substrate cultivation device has been designed. This device is composed of the cultivation tank, upright post, base, irrigation system, supplemental lighting system and control system. The household substrate cultivation device manufactured based on the design results has shown in practice that this device features an esthetic appearance, low cost, automatic irrigation and lighting supplementation, good vegetable growing conditions, full of ornamental value and practicability and thus is suitable for vegetable growing in the home environment. Hence it has a higher promotion value in the home gardening field.

1. Introduction

Rapid social development and quickened urbanization have caused increasingly severe environmental problems and smaller tillable land area [1]. At the same time, social progress has greatly improved standard of living and presented demanding requirements on safety of living materials [2]. In their daily diets, people are no longer satisfied with getting enough to eat, but seek for health and nutrition by taking natural and pollution-free organic foods [3]. Vegetables are indispensable non-staple food in people's daily diets, since they provide necessary mineral substances and vitamins, including 90% Vitamin-C and 60% Vitamin A [4]. Despite their important role in people's life, vegetables are troubled with negative reports repeatedly, like the use of antistaling agent and ripener. As a result, more and more people turn their eyes to balcony vegetables [5]. Balcony vegetables refer to such vegetables that are adaptable to vacant space like balconies of residents and adopt necessary planting materials and technologies in the process, so that the grower cannot only have safe and fresh vegetables, but also enjoy a beautiful environment, good sentiment and enriched leisure life [8]. Balcony vegetables can adopt the soilless cultivation method to minimize pollution and guarantee quality and safety of vegetables, to produce pollution-free and nuisanceless green vegetables. In recent years, balcony vegetables grow fast in China [6] [7]. Soilless cultivation is a cultivation technique to provide nutrition with the prepared nutrient solution to crops, to cut the transport path of plant diseases in soil, thereby to avoid and lessen happening of plant diseases and produce high-quality and nuisance-free vegetables [8]. Substrate cultivation utilizes the substrate to fix and provide nutrients and oxygen to the root system of vegetables. There are a great variety of substrates that can be used for the substrate cultivation, including vermiculite, perlite, gravel, grass carbon and coco coir. These



substrates are added with nutritional ingredients and then act like soil to provide O_2 , H_2O , nutrients and support to plants and at the same time to overcome such deficiencies of other types of cultivation as poor ventilation or incapability to regulate moisture supplied to the root system. A great many families desire to create a warm, comfortable and vital living environment through planting vegetables, but most of them are unable to decorate their living space through adding balcony flower garden due to small housing area. In addition, fast-paced living is also a barrier for people to grow green plants, since they are busy with making a living and unable to spare labor and time for that purpose [9]. Miniaturized soilless cultivation has become an inexorable trend of agriculture, especially home gardening. Its cultivation system and related technologies are gradually developing into a rising industry [10].

To meet demand for vegetable growing in the home environment, a household substrate cultivation device has been developed and tested for its cultivation effect. Tests show that this device features an aesthetic appearance, cleanness, easy management, low cost, good vegetable growing conditions, full of ornamental value and practicability and thus is suitable for vegetable growing in the home environment.

2. Overall structure

The device discussed herein is composed of the cultivation tank, upright post, base, irrigation system, supplemental lighting system and control system. The cultivation tank is used to hold the cultivation substrates and cultivate vegetables. The upright post is designed to support the cultivation tank to form a vertical cultivation mode. The base is used to hold the water tank and controller and support the cultivation tank in the upper part. The irrigation system irrigates vegetables cultivated. The supplemental lighting system serves to replenish light to vegetables. And the control system is used to set irrigation and supplemental lighting time, to realize automated irrigation and lighting supplementation.

3. Design of spare parts

3.1. Design of the cultivation tank

The cultivation tank is a rectangular cabinet structure, with an opening at the top, sealing on the side, venthole at the base and upright post holes in the upper and lower parts. The upright post holes are designed to install the upright posts. Besides, the cultivation tank has two through holes, so that wires of the supplemental lighting lamp and irrigation pipes can pass through (Figure 1).

3.2. Design of the upright post

The upright post is composed of several circular pipes with the diameter on both ends smaller than the middle one and diameter of the lower part greater than the upper one. In case of single-layer

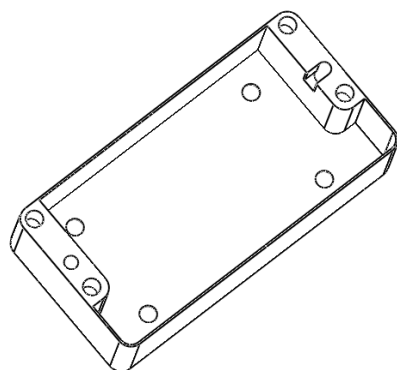


Figure 1. Cultivation tank



Figure 2. Upright post

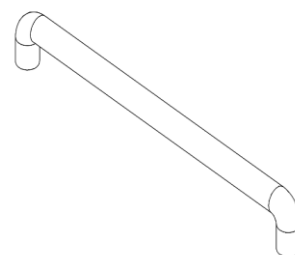


Figure 3. Crossbeam

cultivation, the upright posts can be connected with each other to form a cultivation support. In case of

multilayer cultivation, the upright post is installed into the mounting hole of the upright post to support the cultivation tank (Figure 2).

3.3. Design of the crossbeam

The crossbeam is used to connect the upright post in case of single-layer cultivation, to support vegetables (Figure 3).

3.4. Design of the base

The base is a cabinet structure, consisted of the top, bottom, side wall, interior and the cabinet door (Figure 4). The top edge has a bulge for spacing the cultivation tank of the underlayer. The top has a cultivation tank positioning pin to localize the cultivation tank of the underlayer. The bottom has a stand bar to support the device. One side wall has a control system display and the mounting holes for buttons. The interior is used to install the water tank and controller. The front has a French door for accessing the water tank and controller inside.

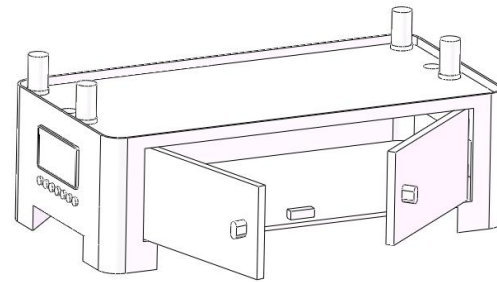


Figure 4. Base

3.5. Design of the irrigation system

The irrigation system adopts drip irrigation and is composed of the water tank, water pump, main pipeline, drip irrigation pipes and connecting pieces (Figure 5). The water tank is used to stock irrigation water and the water pump designed for positive delivery of irrigation water. The main pipeline serves to deliver irrigation water. The drip irrigation pipes and main pipelines are connected through connecting pieces. The drip irrigation pipes drip water to irrigate vegetables, to ensure evenness of irrigation. The pressure compensation type dripper is adopted. The irrigation system can realize fixed-time and fixed-quantity irrigation with the controller.

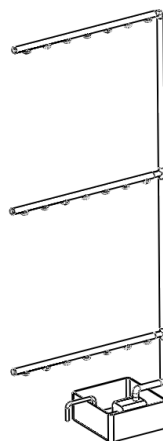


Figure 5. Irrigation system

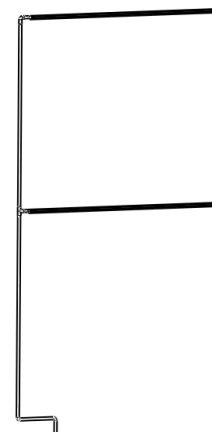


Figure 6. Supplemental lighting system

3.6. Design of the supplemental lighting system

The supplemental lighting system is composed of the power adapter, supplemental lighting lamp and wires (Figure 6). The power adapter converts 220V AC into 12V DC to supply power to the supplemental lighting lamp. The supplemental lighting lamp adopts the LED plant growing lamp for lighting supplementation to vegetables. The supplemental lighting system can realize fixed-time lighting supplementation with the controller.

3.7. Design of the control system

The control system is composed of the main control chip, time control module, display, button and electric relay. The main control chip is SCM, which realizes autocontrol with the preprogrammed programs. The time control module provides the user's set time to the main control chip. There are two electric relays for controlling the water pump and the supplemental lighting lamp, respectively, in a fixed-time manner. Buttons are used to set irrigation and supplemental lighting time by the user and the display shows time input by the user.

3.8. Design of the general assembly

After completion of design of spare parts, the virtual assembly function of SolidWorks is used for virtual assembly of spare parts, which then undergo interference examination. When the examination is qualified, the design of the general assembly is finished.

4. Application cases

The substrate cultivation device designed can be used for multi-layer cultivation of leaf vegetables and also for single-layer cultivation of vegetables as well. When used in the multilayer cultivation, spare parts are installed according to the structure shown in Figure 7; when used in the single-layer cultivation, they are installed according to the structure shown in Figure 8. Then buttons are used to set the time for light supplementation and irrigation. After that, the system enters the autorun mode, to automatically perform fixed-time lighting supplementation and fixed-time irrigation of vegetables.

5. Conclusions

To meet demand for vegetable cultivation in the home environment, an SolidWorks-based household substrate cultivation device has been designed. This device is composed of the cultivation tank, upright post, base, irrigation system, supplemental lighting system and control system. The household substrate cultivation device manufactured based on the design results has shown in practice that this device features an esthetic appearance, low cost, automatic irrigation and lighting supplementation, good vegetable growing conditions, full of ornamental value and practicability and thus is suitable for vegetable growing in the home environment. Hence it has a higher promotion value in the home gardening field.

Acknowledgements

This paper is co-sponsored by Organic Ecotype Balcony Vegetable Cultivation Model Development and Promotion Project (SQKM 201412448001), part of the Beijing Municipal Education Commission Science and Technology Plan General Projects, and Water-saving Irrigation Technology in the Production of Sprouts project (Project No. 20150203-13), part of the Beijing Municipal Commission of Rural Affairs..

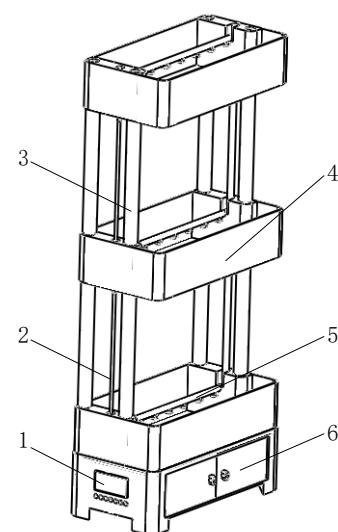


Figure 7. Household substrate cultivation device (For multilayer cultivation of leaf vegetables)
1 Control system 2 Supplemental lighting system 3 Upright post
4 Cultivation tank 5 Irrigation system
6 Base

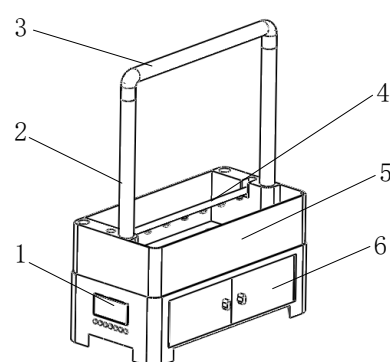


Figure 8. Household substrate cultivation device (For single-layer cultivation of vegetables)
1 Control system 2 Upright post
3 crossbeam 4 Irrigation system
5 Cultivation tank 6 Base

References

- [1] Chen Na, Chen Liping, Li Bin, Guo Wenzhong, Xue Xuzhang. The Design and Implementation for Dimensional Cultivation Automatic Control System of Balcony Agriculture[J]. Journal of Agricultural Mechanization Research, 2014, 36(01): 127-131.
- [2] Li Hugang. The intelligent manufacturing system research of micro intelligent family vegetable cultivation cabinet[D]. Shanxi Agriculture University, 2016.
- [3] REN Ren, WANG Liping, YANG Min, YANG Jing, WEI Xiaoming. Effect Comparison of Different Organic Fertilizers on Potting Green Leafy Vegetables[J]. Journal of Changjiang Vegetables, 2017(20): 78-83.
- [4] HU Yue, JIN Minfeng, WANG Quanxi. Effects of different cultivation patterns on nutrient and safety qualities of vegetables: a review[J]. Journal of Shanghai Normal University(Natural Sciences), 2015, 44(06): 672-680.
- [5] LI Qiang, LIANG Puxing, FENG Weiming, LI Xiangni, DING Chengzhang. Study on Planting Patterns for Three Leafy Vegetables on Family Balcony[J]. Journal of Changjiang Vegetables, 2014(16): 47-49.
- [6] YANG Ruyi, ZHOU Yanjie, ZHANG Lining, PAN Liqin. Effects of Different Substrate Formula on Growth of Several Vegetables[J]. Modern Agricultural Science and Technology, 2015(24): 87-88+90.
- [7] CUI Wenjing, MENG Xiangxia, LIANG Bin, LI Junliang, LI Shuliang. Study on Wormcast as Cultivation Substrate in Balcony Horticulture[J]. Northern Horticulture, 2017(03): 182-187.
- [8] ZHOU Hefang, ZHANG Wen. Effects of Different Soilless Cultivation Methods on growth of Shanghaiqing[J]. Journal of Changjiang Vegetables, 2015(02): 36-37.
- [9] CAO Lijun. Design of small wall mounting multi-purpose plant frame[J]. Chinese Horticulture Abstracts, 2017, 33(12): 222-224.
- [10] YAN Zhiming, SHI Honglin. Development and Application of Two Types of Balcony Vegetable Hydroponic Contraptions[J]. Southern Horticulture, 2016, 27(01): 35-39.