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Application of Case for Closed Cultivation System of Solar Greenhouse

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China solar greenhouse cultivation was mainly planted with soil and the continuous production cannot be achieved resulting from the seriously soil-borne diseases. In addition, excessive water and fertilizers from the production process were discharged into soil, not only resources were wasted, but also environment were polluted. In this study, the ditches be made of north-south direction in greenhouse ground, substrate were filled in the bags or completely wrapped by plastic film, and then it was be put into the ditches. Crops were planted into the substrate, so the roots of crops were isolated from the external soil then closed cultivation was implemented, the soil-borne diseases were avoided and heats which were stored by the soil can be used to maintain temperature of the substrate during the winter. In order to achieve the recycling, the recycling system of water and nutrient were constructed, and then excess water or nutrient solution can be connected into a recycling tank, then the nutrient solution will be pumped into the mixing tank. Mixing tank contained nutrient solution that is used for irrigation, water and fertilizers can be mixed according to the desired ratio then it was transferred to the crop to provide water and nutrients by irrigation pipes. Experiments show that, a total of 2380 kL/hm2 of irrigation water were applied during the 12 weeks crop growing period, it was 69.4% of the water consumption of traditional soil planting patter, and the water use efficiency of closed cultivation system was 16.49 kg fresh tomato/kl applied water, it was 1.47times than the water productivity of traditional soil planting pattern.

1. Introduction

In recent years, there are rapid developments of facility horticulture in China. The total area of cultivation was about 3.79 million ha by the end of 2012, which accounted for 25% were solar greenhouses (Li, 2012). Solar greenhouse is a characteristic type of greenhouse in north China, and it is distributed in the north latitude320-410 or even 430. The solar greenhouse maintains the temperature by absorbing and storing solar energy in the winter without heating or heating occasionally for the vegetable production, it can reduce the energy consumption. However, China solar greenhouse cultivation was mainly planted with soil, and the continuous production cannot be achieved resulting from the seriously soil-borne diseases (Qu et al., 2010; Wang et al., 2010). In addition, excessive water and fertilizers from the production process were discharged into soil, not only resources were wasted, but also environment were polluted (Du et al., 2007; Zhou et al., 2009).
In many countries, greenhouse production by closed soilless cultivation, for example, in Holland, Greece and Italy, rock wool is used as substrate (Zhao et al., 2001; Duan et al., 2008; Wan, 2011; Wang et al., 2013).Closed soilless growing systems, in which drainage water is captured and recirculated, reduce water consumption and nutrient leaching (Pardossi et al., 2006; Sonneveld and Voogt, 2009).However, commercial application of these systems is scarce in China, as their management is more difficult compared with open cultivation systems(Pardossi et al., 2006; Gallardo et al., 2009).
In this case study, we built a simple closed cultivation system in solar greenhouse, it can be recycled nutrient solution. The study was focused on how to building the closed cultivation system in solar greenhouse which is can adapt to the actual situation of China and it is cheaper than the Europe. The specific objectives of the study were to :(i) using the closed substrate which is stuffing into the plastic bag instead of soil meanwhile, it can be used the heat storage in greenhouse soil, and (ii) design the circulating irrigation system for nutrient solution.

2. Materials and method

To achieve the research objectives, two solar greenhouses were used to compared that the structure of greenhouses were identical and each with a floor area of 487.5m2, however, one was bullied the closed cultivation system and the other was production according to the traditional soli planting mode. A hydroponic system delivers water and nutrients through drippers to plants. The fruit used for the experiment was the tomato (Clown) and each of the greenhouses had 1500 plants, they were used for this experiment.

2.1 Structure of the system

A closed crop root zone should be established which is isolated from outside environment, the substrate can be used instead of soil, and then the drainage water collected and reused will be probably. For the closed soil-less system, nutrient required for the crop growing provided by nutrition solution. So the irrigation system and nutrient supply system is essential also. The closed cultivation system is shown by Figure 1, it consisted of three subsystems: closed substrate, nutrition supply and recycling irrigation.

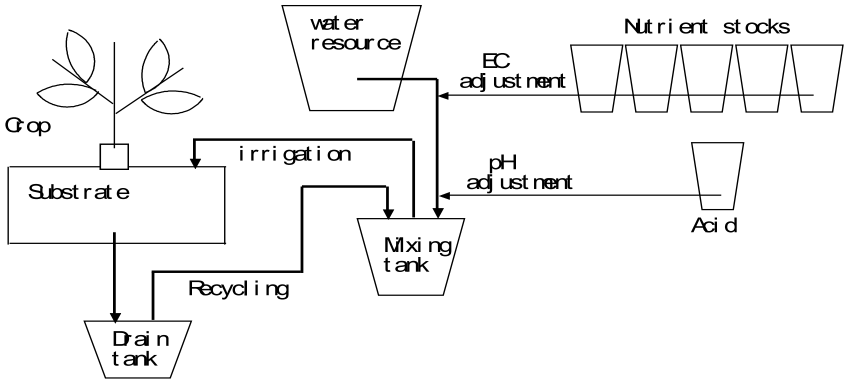
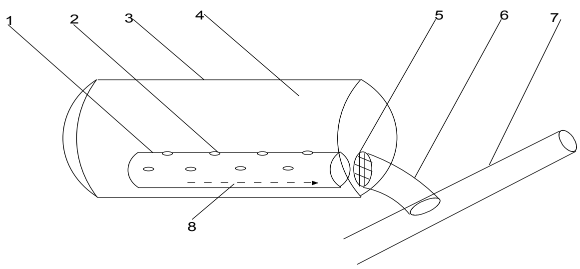


Figure 1: Structure of closed cultivation system for solar greenhouse

2.2 Subsystem of closed substrate cultivation

In order to reduce the incidence of soil-borne diseases and avoid pollution of the environment, the crop roots must be isolated from soil. But the stored energy of ground soil is the important part for the heat storage in solar greenhouse, so building the closed cultivation system not only isolated from soil, but also used of heat storage in soil for the growth of crops.

Unlike the traditional soil planting pattern in greenhouses from which crops are planted on the ridges of the ground the newly designed circulatory system was to dig a ditch from south to north in the greenhouse. The width of the ditch was 30-35 cm, and the depth of the ditch was 20-25 cm. There was a 5-10 cm drop from the south to the north. The growth substrate was bagged and then was placed in the ditches. In order to be isolated from the outside soil, the substrate was packed by bags. There were some holes (2 cm, dia.) on the bags so that crops can be planted into the substrate though these holes. There was a soft tube with PVC or PP (2 cm dia.) at the bottom of bags; also it had some other holes (0.2 cm in diameter) through which excess water or nutrient solution can penetrated into the substrate. All of these tubes were connected to a recycle pipe, which led to a drainage tank. The drainage tank was a container which store water or nutrient solution from the recycle pipe, and the horizontal position of drainage tank should be lower than recycle pipe. Figure 2 is shown that the closed substrate structure.



1. Collection pipes, 2. Collecting holes, 3. Packing materials of substrate, 4. Substrate, 5. Filter screen, 6. Return pips, 7. Main pipe for recycling, 8. Nutrient solution flow direction

Figure 2: Schematic of closed substrate system for planting

2.3 Subsystem of recycling irrigation system

2.3.1 Nutrition supply and regulation system

There is an irrigation controller for nutrition supply and regulation in the experiments, the irrigation controller contains nutrient solution recipe control and irrigation control two functions, and it was shown in Figure 3.In this system, there are two tanks for fertilizers (tank A and tank B) and one tank for acid, every kind of fertilizers can be mixing in the mixing tank. The recipe of fertilizers depend on fertigation strategy, the irrigation controller can make it according to the specific program through control the valves of tanks to open or close. The EC sensor and pH sensor is placed in the mixing tank, the ratio of the fertilizers can be adjusting based on EC value and pH value by the controller. Nutrient solution which is mixed supply to the irrigation lines by the pump, and those lines can be controlled by the controller through the valve under the program. Excessive nutrient solution can be recycled to the recycling tank, then it can be pumped to the mixing tank when water level in the recycling tank reaches the certain height, so the recycling is achieved.

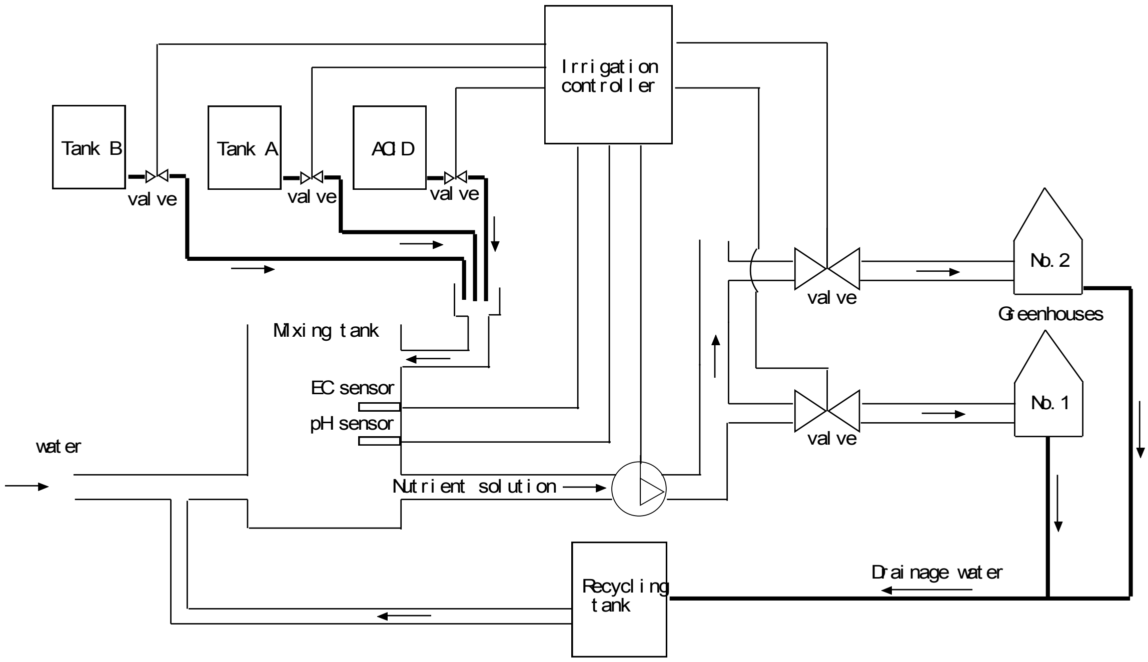
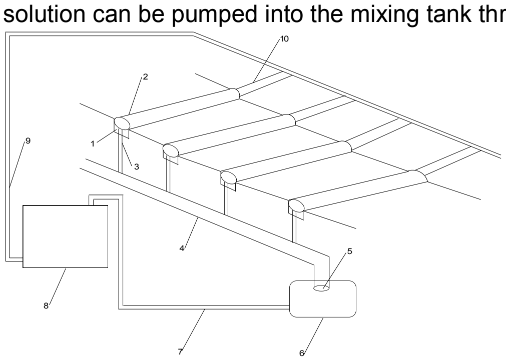


Figure 3: Structure of nutrition supply and regulation system

2.3.2 Irrigation and recycling system

Drip irrigation was used to construct irrigation system, and the irrigation and recycling system is shown in Figure 4.The main water supply pipe was placed at the south of greenhouse which is 5cm diameter and extending from west to east at the surface of ground. Recycle tank buried underground and nearby the west wall of greenhouse which the capacity is 400L and it was the same level that the top of recycle tank and the lowest point of the main pipe for recycling. A submerged pump was placed in the recycle tank; the nutrient solution can be pumped into the mixing tank through the recirculating pipe, so the recycling was achieved.



1. Planting ditches, 2. Substrate, 3. Return pipes, 4. Main pipe for recycling, 5. Water outlet, 6. Recycle tank, 7. Recirculating pipe, 8. Mixing tank, 9. Irrigation pipes, 10. Dripper lines

Figure 4: Structure of recirculating irrigation subsystem

2.4 Greenhouse experiments

In order to verify the effect of the closed cultivation system, Two identical greenhouse were used for comparative test, tomato (variety is clown) plants were grown in the greenhouses; closed cultivation system was used in the No.1 greenhouse (Table 1 shown the components of the substrate) and the traditional soil cultivation to be used in the No.2 greenhouse.

Table 1 Components of the substrate

Materials	Proportion
Material Coconut husk	35%
Turfy soil	30%
Perlite	28%
Vermiculite	7%

Plants were mostly irrigated with nutrient solution comprised of potable water and nutrients according to an industry accepted formula. An environmental monitoring node was placed each of greenhouses to monitor temperature, humidity and solar radiation at 3-min intervals. A set of integrated water and fertilization irrigation control equipment was serviced for two greenhouses for experiments which is can automatic control for irrigation, ratio of nutrient solution, and recycling through control solenoid valves for greenhouse.

3. Results and discussion

3.1 Consumption of water

Crop water use and drainage varied during the 12 weeks of crop production (Figure5).

It can be seen by Figure 5, the water use of No.2 greenhouse significantly less No.1 greenhouse, there are two reasons for this, one is the recycling of the nutrient solution be implemented in No.1 greenhouse, so excess water and fertilizers can be recycled an reused; another one reason is the closed cultivation system used in No.1 greenhouse, the loss of water from the leaf transpiration, but it is different in No.2 greenhouse, traditional soil cultivation used in this greenhouse and the some evaporation through the ground except the leaf transpiration.

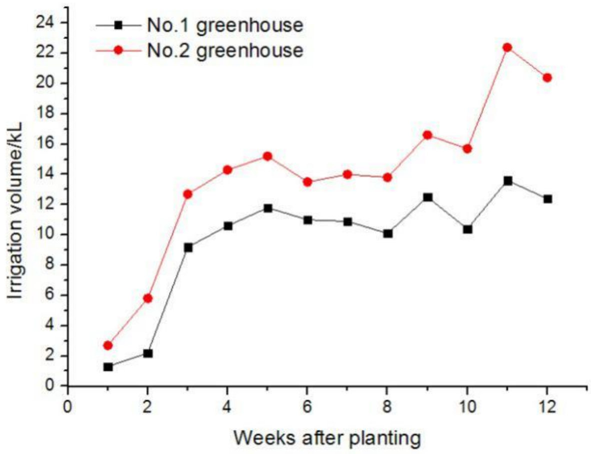


Figure 5: Consumption of water weekly for two experiment greenhouses

3.2 Tomato fruit yield

The 1st harvest at the July 26th in No.1 greenhouse, it happened at July 30th in No.2 greenhouse, the weekly harvest tomato total until September 17th as shown in Figure 6.The growth period of tomato across the summer in the experiment process, but the summer is not the best growth period for tomato, in addition there is no cooling equipment in the solar greenhouse, so the temperature is very high (maximum temperature reached 38^{0}C) in the greenhouse that is not conducive to the growth of tomato, then the production is not high. Total yield of tomato is 1913kg in 8 harvest weeks in No.1 greenhouse, and it is 1437kg in No.2 greenhouse. The production of No.1 greenhouse is higher than the production of No.2 greenhouse, which shows that the closed cultivation system is can improve the production of tomato.

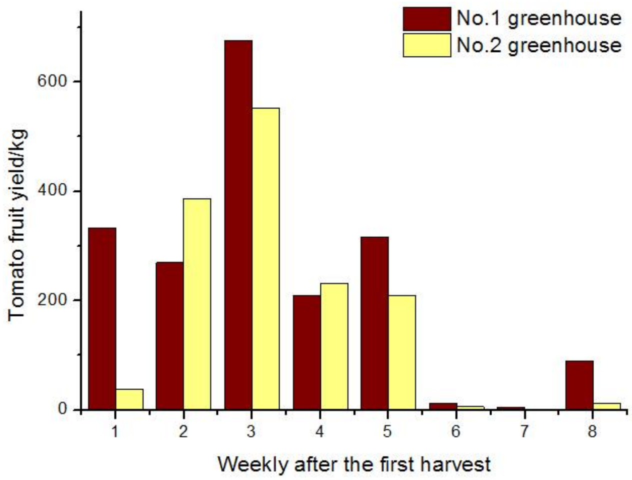


Figure 6: Weekly tomato fruit yield of two experiment greenhouses

4. Conclusion

Water consumption of the closed cultivation system (2380kL/hm^2), it is 69.4% than the water consumption of the traditional soil pattern (3430 kL/hm^2).The current practices of drainage water reuse in No.1 greenhouse has resulted in 30.6% saving of the total potable water for tomato production than the No.2 greenhouse. And the drainage water reuse in closed cultivation system for greenhouse has also prevented the discharge of nutrient rich drainage water into the local environment. In addition, the water productivity of No.1 greenhouse is 1.92 times than water productivity of No.2 greenhouse, this shows that the closed cultivation pattern is better than traditional soil pattern.

The study reveals that there is a significant potential to save water and nutrients and protect the environment by shifting from traditional soil pattern to closed cultivation system pattern in solar greenhouse.

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