Research on Energy Saving greenhouse based on Sunlight Environment

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Abstract: This paper combs the current research on the energy-saving greenhouse in a daylight environment. The application and research progress of thermal insulation and energy-saving technology in the solar greenhouse in China are introduced from the aspects of location, type, orientation, front roof, rear roof, wall, multi-layer cover in a greenhouse, cold prevention ditch, cheap energy, utilization and cultivation of energy-saving equipment, operation, and management. Finally, some suggestions are given for the future research of energy-saving greenhouse in the solar environment, to make a certain contribution to the research of energy-saving greenhouse in the solar environment.

Key words: Solar greenhouse; Heat preservation; Energy saving.

1. Introduction
With the development of the market economy, the greenhouse is used more and more. The greenhouse is mainly used for the cultivation or seedling of temperature-loving vegetables, flowers, trees, and other plants in the low-temperature season. Due to the different purposes of use, there are many types of greenhouse. According to the laying of lighting materials, it can be divided into glass greenhouse, plastic greenhouse, onboard greenhouse, etc.; according to roof truss materials, it can be divided into a single-span greenhouse, multi-span greenhouse, single-roofed greenhouse, and double-roofed greenhouse; according to heating conditions, it can be divided into a heating greenhouse, non-heating greenhouse and so on. The greenhouse structure should be sealed and insulated, and it is convenient for ventilation and cooling. Modern greenhouses have the equipment to control temperature, humidity, light, and other conditions, and use computer automatic control to create the best environmental conditions for plants.

The greenhouse must ensure the performance indexes such as light transmittance, heat preservation performance, service life and so on. Light transmittance refers to the percentage of outdoor light into the greenhouse and outdoor light exposure, and its value affects crop growth and the selection of crop varieties. Therefore, the light transmittance of the greenhouse covering material and the shadow size of its skeleton has a direct impact on the greenhouse light transmittance, and with the different solar radiation angles in different seasons, the greenhouse light transmittance is also changing at any time.

The greenhouse has a certain energy consumption, especially in cold areas, which is higher in winter. Heating and energy consumption is the main obstacle to the operation of greenhouse in winter. To improve the thermal insulation performance of greenhouse and reduce energy consumption is the most direct means to improve greenhouse production and economic benefits. The insulation ratio of the
greenhouse is a basic index to measure the thermal insulation performance of the greenhouse. The greenhouse insulation ratio refers to the ratio of the coverage area of the greenhouse transparent material with low thermal resistance, the coverage area of the greenhouse enclosure structure to the ground area. The higher the heat preservation ratio, the better the thermal insulation performance of the greenhouse.

2. The heat preservation and energy saving of the location, type, and orientation of the solar greenhouse.

To further meet the needs of thermal insulation and energy-saving, based on the ordinary solar greenhouse, many new forms have been developed, such as semi-underground type, pit type, integrated type, hillside type, inclined type, connecting pillar type and so on. All of them have better performance of heat preservation and energy-saving than the ordinary solar greenhouse. Besides, properly reducing the height of the ordinary solar greenhouse and prolonging the length of the roof also has an obvious heat preservation effect, but it may limit the types of crops. The thermal insulation principle of these improvements is to reduce the above-ground volume and exothermic surface area of the greenhouse, reduce the influence of airflow on heat loss, thicken the wall in disguised form, increase the heat input of the transparent surface and increase the heat preservation ratio. By comparison, it can be seen that the Anshan type of solar greenhouse has better thermal energy utilization. Nie Hemin studied and analyzed the thermal environment of the greenhouse and put forward various parameters to optimize the structure. Considering the light and temperature index comprehensively, the height-span ratio of an energy-saving solar greenhouse is 0.5-0.6, the azimuth is 7 °~ 8 °from south to west, and some are up to 10 °in alpine areas. 2 thermal insulation and energy saving of structural materials in solar greenhouse

2.1. Front Roof and Thermal Insulation and Energy Saving

The cross-flow heat release through the front roof accounts for about 70% of the total heat loss at night, so the thermal insulation performance of the front roof is the key to heat preservation and energy saving in the solar greenhouse. In recent years, most of the related studies have focused on this.

2.1.1. Shape of the front roof. The research of Sha Jibo et al shows that the front roof is arc-shaped, and the horizontal angle from the back of the roof to the front is 33 °, and the horizontal angle from top to bottom is 5 °~ 70 °, which is beneficial to greenhouse heat preservation at night and is suitable for Urumqi, Xinjiang. The better isometric roof shapes are arc shape, arc-parabola combination shape, cycloid shape and so on. Through the computer program, the mathematical model of the front roof is designed. Under the condition that the wall, height, span, and other conditions are the same, the optimal front roof increases the light flux 100~500kJ per meter length greenhouse compared with the conventional empirical design.

2.1.2. Skeleton of the front roof. The thicker building materials such as bamboo and concrete are cheap and easy to obtain, but the shade is large, the light transmittance is reduced, and the light and heat utilization rate of the greenhouse is reduced. Steel and reinforced fiber synthetic materials have the advantages of small size and high strength, which can be used to build a non-pillar greenhouse and have a tendency to replace traditional materials.

2.1.3. Transparent materials for front roofs. Modern solar greenhouse mostly uses a variety of plastic films as transparent materials, a small amount of glass, double-layer inflatable film, PVC board and so on. The thermal insulation performance of the latter kind of transparent surface is improved, but the light transmittance is decreased. Generally speaking, all kinds of PVC, PE and EVA films in plastic films have good thermal insulation. The new covering material modified polyethylene terephthalate (PETP) film has higher thermal insulation performance. Generally speaking, the thermal insulation greenhouse film in our country can not meet the agronomic requirements. Because at present, the heat preservation agents used for processing thermal insulation greenhouse film in our country are almost inorganic, and the particle size of the powder is on the high side, which reduces the transmittance of
direct light and affects the warming effect, which is disadvantageous to the production of fruits and vegetables in an energy-saving greenhouse in winter and spring.

2.1.4. External covering thermal insulation material. The requirements of external thermal insulation materials for facility horticulture are high heat preservation, non-moisture absorption, lightweight, sturdiness and durability, and reasonable price. The traditional outer covering thermal insulation material of solar greenhouse in our country is grass (1.2cm 2.0m × (810m, thick 4~5cm). Its heat preservation effect is 40.6 ℃, the maximum is 10 ℃, it is cheap and easy to get, but it is easy to absorb moisture, heavyweight, inconvenient to operate, easy to pollute greenhouse film, and is not durable. Wang Anke and others have conducted comparative experiments on a variety of new types of thermal insulation materials and grass for many years. It is proved that the temperature of the composite paper quilt, lead foil quilt, aluminized film quilt, bumper harvest quilt, rain-proof non-woven cloth (double layer), rock wool quilt, asbestos quilt, and the short cotton quilt is 0.03-0.43 ℃ and 0.17-0.54 ℃ higher than that of grass quilt, respectively. The low temperature in the shed appears later and lasts shorter at night. The thermal insulation material with PE closed-cell foaming self-waterproof material as core and polyester cloth as the surface has good waterproof, thermal insulation, and high strength, and its thermal insulation property is 1 ~ 2 ℃ higher than that of grass. The addition of the PVA long-wave reflective layer also has a certain thermal insulation effect. Xue Yulin and Chen Duansheng have also done a lot of research on thermal insulation quilts and thermal insulation measures. The new thermal insulation quilt not only has good thermal insulation performance but also has the characteristics of lightweight, low cost, wide source, easy to popularize, durable, suitable for mechanized operation, factory production and so on. The heat preservation effect will be better when the new lightweight external thermal insulation material is used in conjunction with the transparent roof, or two or more kinds of external covering materials are used at the same time. Such as paper quilt, straw quilt, double air flushing film, thermal insulation quilt, etc., can increase the temperature by 1 ℃ to 3 ℃ compared with one layer of thermal insulation material. The indoor thermal environment has been steadily improved with the improvement of the thermal insulation capacity of the greenhouse. The two-in-one material (PHF) can create a better indoor thermal environment. For example, the transparent honeycomb structure covering material has both transparent and transparent covering properties, which can increase the night temperature by 5 ℃ compared with the ordinary solar greenhouse without external covering material. The heat release at night is reduced by 40%, but to ensure overwintering, it is also necessary to cooperate with external thermal insulation materials.

2.2. Rear Roof and Thermal Insulation and Energy Saving

One of the functions of the rear roof of the solar greenhouse is to support the storage of things such as grass, etc. and is suitable for personnel operation. Another function is to store heat. Heat release at night, the rear roof is too short, too long, the elevation is too small, too much is not conducive to thermal insulation or road construction is not feasible. After comprehensive optimization, the elevation angle of the rear roof should not be less than the local solar height angle of the Winter Solstice at noon, and it should be 7 °~ 8 °larger than it, and the projection of the rear roof should be 1.0 ~ 1.5m. During the construction of the rear roof, several kinds of materials (wheat straw, rice straw, soil, linoleum, etc.) are usually covered with more than 40cm (taking into account the load capacity of the rear roof truss, not overweight), which can reduce the night heat release through the rear roof.

2.3. Wall and thermal insulation and energy saving

Chen Duansheng laid the temperature sensor into different walls and found that the earth walls with thick 50cm were heat absorbers during the day and night. Zou Zhirong and others have similar studies and divide the standard wall into the thermal storage layer, thermal insulation layer, and thermal insulation layer according to the change of temperature from the inside to the outside. According to the calculation of the principle of physical thermal resistance, the ideal thermal insulation effect can be obtained only when the thickness of the traditional simple soil wall reaches 1.04 to 2.16m. Such walls
not only take up a lot of arable lands but also inconvenient to build, time-consuming and time-consuming. Recently, it is proposed that the wall structure model should be developed to a heterogeneous composite wall with a certain thickness. That is, the inside is composed of materials with strong heat absorption and heat storage capacity, the outside is composed of materials with poor heat conduction and heat dissipation capacity, and the middle is a light, dry and porous thermal insulation layer with poor thermal conductivity. The study shows that perlite and furnace ash are better thermal insulation materials. Zou Zhirong et al show that the thermal insulation and heat storage performance of 120mm thick slag brick + 60mm thick polystyrene foam board (external insulation material) is better than that of 1m thick earth wall. Guo Huiqing and others simulated the temperature environment in 20 solar greenhouses with different structures and found that the north wall with 120 bricks-120 perlite-240 aerated concrete structure was the optimal combination. Guo Huiqing and others simulated the temperature environment in 20 solar greenhouses with different structures and found that the north wall with 120 bricks-120 perlite-240 aerated concrete structure was the optimal combination. Chen Ruisheng and others proved that the heat storage and exothermic performance of the 480mm hollow brick sandwich wall are better than that of a 500mm thick earth wall. The double-wall solar greenhouse designed by Lei Runtian et al has a five-layer structure of 120 bricks-70 muri 120 bricks-70 Mel 120 bricks, with a plastic film hanging on each side of the middle 2-story 70mm space, which is 33.5 °C higher than that of the control room temperature. The three-story structure wall of 200 aerated concrete blocks + 100 polystyrene board + 200 aerated concrete block has a higher economy. At present, most of the heterogeneous composite walls commonly used in production are hollow walls or sandwich walls. The double-layer inflatable rolling curtain and the single-layer film cover the sidewall, the former reduces the heat loss of the sidewall by about 85%.

2.4. Multi-layer mulching and heat preservation and energy saving in greenhouse
The use of plastic film, non-woven cloth (floating cover), small arch shed, middle shed, reflective film and movable thermal insulation screen in a solar greenhouse all have a certain heat preservation effect. Generally speaking, the temperature of three-layer mulch is about 3 °C higher than that of two-layer mulch, and the air temperature of two-layer mulch is about 2.5 °C higher than that of single-layer mulch. Take cucumber planting as an example, the output value increased by 20% and 10% respectively. Each layer of indoor covering can be used flexibly, such as plastic film + small arch shed (+ grass), plastic film + movable insulation curtain, floating cover + two-layer insulation curtain and so on. Qingliang and cotton cloth as internal thermal insulation materials have better thermal insulation and dehumidification properties than commonly used aluminum foil. Generally speaking, the effect of single insulation curtain or floating cover is better than that of plastic film, small arch shed and middle shed. The reason is that the former is integral thermal insulation, while the latter is local thermal insulation. With the non-woven cloth of 20g/m2 as a floating cover, the indoor temperature can be increased by 2.7 ~ 5.7°C. Hanging a 1m high reflective screen (1m in front of the back wall) can increase the indoor air temperature by 23.5 °C and the ground temperature by 1m.

3. The utilization of cheap energy and energy-saving equipment
It is a new technology concerned by many people at present that the solar energy device is used to heat the water body to make it circulate in the heat pipe in the greenhouse or the soil layer, and the stored heat is released slowly at night. or the technology of heat exchange in the ground, which circulates the gases in the greenhouse through pipes and underground, effectively keeps the temperature in the greenhouse constant, and the energy-saving effect is obvious. The average annual temperature in the underground solar storage solar greenhouse designed by Zhang Hailian is 12.2 °C higher than that in the open ground, saving about 30 tons of coal a year. Li Dengshun and others fix the round plastic pipe blackened on the sunny side to the north wall, inject ice into it, absorb heat during the day and morning, and the water temperature can rise to 40 °C. Heat is released at night in the afternoon. Using this kind of warm water to irrigate the ground, the ground temperature can be increased by 5.3 °C. Ma Chengwei and other studies show that the ground heat exchange system in the multi-span greenhouse can effectively ensure that the room temperature at night is above 11 °C higher than that outside. The results showed that the average ground temperature could be increased by 2.7°C with 1 layer of 15cm thick horse manure, 2.5C with wheat straw mixed with chicken manure and 1.5C with wheat straw mixed
with urea. The HOPE-2000 high-efficiency and energy-saving hot air stove, developed and produced by the Horticultural equipment Research Institute of Anshan City, Liaoning Province, saves more than 50% of the cost than steam and water heating boilers. Besides, the utilization of waste heat in the factory and the development of underground heat sources can reduce the cost of manual heating or not.

4. Cultivation, Operation Management, and Energy Saving
Keep the front roof clean and increase the light transmittance; scientifically determine the release time of thermal insulation cover materials; scientific ventilation to reduce sensible heat loss. Plowing frequently, loosening topsoil, reducing soil surface water content, reducing soil evaporation, and promoting heat absorption and temperature increase of deep soil. Variable temperature management. The special shed is used for a special purpose and varies with crops. Different shed types are selected to avoid meaningless energy consumption. The selection and cultivation of low-temperature tolerant crop varieties can significantly reduce the energy demand. The construction of ecological greenhouse or three-dimensional cultivation, making full use of heat energy and space, can significantly reduce energy consumption. The application of matching technologies of the energy-saving solar greenhouse, such as soil warming agent, CO$_2$ gas fertilization, water-saving irrigation, and cold hardening, can enhance the stress resistance of crops, especially the tolerance to low temperature. It can be seen that the further development of high-efficiency and the energy-saving solar greenhouse is not only a problem of horticultural science but also related to material science, architecture, mathematics, mechanics, chemistry, physics, biology, economics, and other disciplines. The research of thermal insulation and energy-saving has changed from empirical estimation to mathematical calculation, qualitative analysis to quantitative research.

5. Summary
To sum up, the urgent problems to be solved in high-efficiency and energy-saving solar greenhouse are as follows: (1) at present, there is no greenhouse thermal insulation covering material which can meet the requirements of thermal insulation, waterproof, wind resistance, aging resistance, mechanical property and a better economy in the market of our country. Therefore, the research and development of new energy-saving mulching materials, it plays an important role in promoting the development of facility horticulture in northern China. (2) further study on the thermal environment and influencing factors of solar greenhouse and the interaction with crop growth. (3) to speed up the breeding process, energy-saving cultivation mode and management methods of new low-temperature-tolerant crop varieties suitable for solar greenhouse growth. (4) the development and popularization of solar energy and ground heat exchange system with simple and low cost.

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