

# Analysis and suggestions of greenhouse cleaning machine in China and abroad

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**Abstract.** The light transmittance of greenhouse surface directly affects the illumination of greenhouse, and will eventually affect the indoor ground temperature, temperature, humidity and Photosynthesis of crops, thus affecting the growth of crops. As a modern greenhouse maintenance and cleaning equipment, greenhouse cleaning machine plays an active role in improving the light transmittance of greenhouse and improving the production efficiency of farmers. This paper mainly expounds the structure, principle and method of different kinds of greenhouse cleaning machines in China and abroad, analyzes the current development situation and prospects of greenhouse cleaning equipment, and puts forward some suggestions.

## 1 Introduction

Greenhouse cultivation, as a new direction of modern agriculture development, has gradually changed the traditional planting mode. It plays an irreplaceable role in increasing crop yield, improving quality and easing off-season vegetable supply in China [1-4]. Under artificial intervention, the best growth environment can be provided, but as time goes on, more dust will be deposited on the greenhouse surface, and algae will even grow, which will have a greater impact on the light transmittance in the greenhouse [5-6]. In order to reduce the cost of greenhouse investment, many farmers choose to clean the greenhouse by themselves. However, because of the high height and large span of greenhouse, it is difficult for farmers to use traditional manual cleaning methods, and the cleaning effect is poor. In recent years, domestic and foreign researchers have done a lot of research on greenhouse cleaning device. This paper analyzes the structure and principle of different types of greenhouse cleaning machine, and puts forward the development trend of greenhouse cleaning machine in China.

## 2 Cleaning characteristics of greenhouse roof

### (1) Specificity of greenhouses cleaning machine

At present, there are many kinds of greenhouses, which can be divided into sunlight

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greenhouse, arch greenhouse, multi-span plastic greenhouse and multi-span glass greenhouse according to their shape characteristics. Generally speaking, due to the variety of greenhouse structure and the difference of surface covering materials, most of the greenhouse cleaners developed now have strong specificity. In order to reduce the cost, we should design and manufacture cleaner with high universality in the future.

#### (2) Complexity of clean environment in greenhouses

Because of the difference of greenhouse construction environment location, the differences of greenhouse construction specifications and shading network settings are formed naturally, so the development of greenhouse cleaner must overcome many external facilities. Even in the same kind of greenhouse, the cleaner may not be applicable.

#### (3) Economy of greenhouses cleaning machine

Agricultural developed countries are mostly modern large-scale multi-span greenhouses, which occupy a large area and have a high degree of intelligent management. Therefore, the research and development of cleaning equipment with high scientific and technological content, with advanced automatic control technology, natural products manufacturing costs on the high side[7]; while most of the existing greenhouses in China are arch greenhouses and sunlight greenhouses, which the economic benefit and scientific and technological content of the existing greenhouses still lag behind, compared with the modern large-scale greenhouses in developed countries. Therefore, the cost of greenhouse cleaner developed in China is not easy to be high, otherwise it is difficult for farmers to accept it.

### 3 Research status of greenhouse cleaner abroad

In 2001, the University of Ibadan, Nigeria, proposed a simple hand-held glass greenhouse cleaning device: it adopts a rotary soft brush and is matched with a water spraying device to wipe out the dust on the surface of the glass greenhouse. The cleaning device extends the cleaning area, adopts three-section telescopic mechanism and the maximum cleaning distance is 2.8 meters[8]. The test proves that the cleaning device has ideal cleaning effect, good convenience and can be used as a manual cleaning tool to a certain extent, as shown in Fig. 1 and Fig. 2.



**Fig. 1.** Simple hand-held cleaning device



**Fig. 2.** Cleaning test



**Fig. 3.** Cleaning machine structure

In 2004, someone in Israel put forward a principle of plastic greenhouse cleaning machine method: the use of a deceleration motor driven by a brush rotating at high speed to erase the dust on the surface of plastic film, and then cooperate with the vacuum way to remove dust[9]. The experimental results show that the principle of the model cleaning machine is feasible and the cleaning effect is obvious, but the development of the model cleaning machine is only at the stage of principle testing. Considering the practical application needs of complicated connecting arm and large input cost, the cleaning principle scheme has not been well popularized, and there is no such cleaning machine in the end, as shown in Fig. 3 and Fig. 4.



Fig. 4. Overall structure



Fig. 5. Glasshouse cleaning operation



Fig. 6. Shift cleaning

As a developed country of facility agriculture, the Netherlands not only has the most developed greenhouse planting technology, but also has carried out earlier research on its related facilities. At present, the Netherlands has developed and put into use the glass greenhouse cleaner and multi-span plastic greenhouse cleaning device. The glass greenhouse cleaning machine includes: walking part, cleaning part and its control part. The walking part uses the adjacent ditches on both sides as the self-running track, and uses the soft non-water-absorbing brush to wash the dust on the greenhouse surface to the ditch with the flushing device. While the machine is running, the cleaning brush in the ditch will wash the dirty water and the sludge to the end of the greenhouse. In addition, the glass greenhouse washer is also equipped with mobile platform which uses computer programming to precisely control the movement state of each part. It realizes automatic shift of cleaning machine, and is convenient for cleaning operation[10], as shown in Fig.5 and Fig.6.

The cleaning equipment for multi-span greenhouse developed by the Netherlands also uses the trench as the walking support. The whole machine adopts the same curved beams as the roof curvature as the brush attachment structure, and the lower end face of the bending beam is equipped with water spraying system and cleaning brush. While the whole equipment is running, the brush rubs the dust through high-speed rotation and cooperates with water spraying to ensure the cleaning effect. Owing to a large amount of dirt deposited into the gutter during the cleaning process, a high-pressure water spraying device is installed to clean the ditch to ensure smooth movement of the whole machine. Therefore, the water consumption and electricity consumption of the whole machine are large, and it is not suitable for the use of multi-span plastic greenhouse with shading net[11], as shown in Fig.7.



Fig. 7. Plastic greenhouse cleaning



Fig. 8. Actual installation and operation

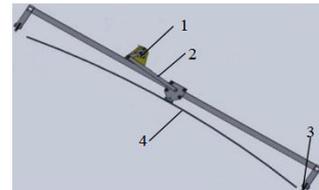


Fig. 9. Principle and structure of greenhouse cleaner

1. motor 2. connecting rod 3. supporting travel wheel 4. scraper

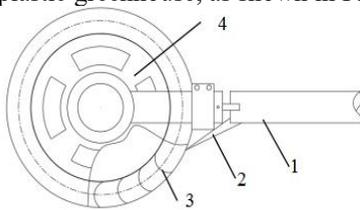
In 2017, Thailand developed a plastic greenhouse cleaning machine: the machine consists of four sets of 1-meter-long cleaning modules and a set of guiding modules; the guiding module uses a set of motors to drive the wheels along the C-shaped guideway laid on the top of the greenhouse through a chain system; and each cleaning module uses a 12V DC motor to drive the scraper to vibration up and down to remove dust, through a linkage mechanism. Besides, in order to ensure good cleaning effect, each scraper installed at the bottom of a soft sponge. Four groups of cleaning modules were assembled with flexible joints to support the bending moment when the cleaning machine moved along the greenhouse roof[12]. The greenhouse cleaner is reasonable in structure, small in volume and portable in movement. However, the contact friction cleaning method is only suitable

for dust removal, and the stubborn (such as tightly attached mosses and bird droppings.)stains on the film surface will be difficult to clean up thoroughly. Moreover, the use of the cleaning machine also needs to change the greenhouse structure beam, so that the light rubber wheels of each cleaning module joint can be installed at both ends of the frame, as shown in Fig.8 and Fig.9.

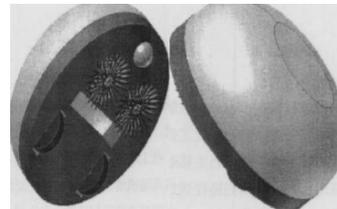
#### 4 Research status of greenhouse cleaner in China

The introduction and development of modern greenhouse facilities in China is relatively late, so the research and development of its supporting facilities is relatively slow at this stage. In recent years, with the increase of investment in agricultural development, China's modern greenhouse has developed rapidly, and its supporting facilities are constantly improving. Domestic universities and research institutes have made some achievements in the development of greenhouse cleaning equipment, and there are also some greenhouse cleaning machines with ideal experimental results.

A portable plastic greenhouse cleaner has been developed by Guangxi University and Yangtze University in China. Its principle is to use high-pressure pump to inject high-pressure water into the blade of the turbine, so that the wheel with brush on the blade surface can rotate at high speed to remove dust. Because the local pressure of the contact position between the brush and the film decreases when the water wheel rotates at high speed, the brush can be close to the film and the cleaning efficiency can be improved to a certain extent[13-17]. The cleaning effect is good, but the cleaning efficiency is low, only suitable for the use of low plastic shed, not suitable for large-scale, high-altitude, large-span modern plastic greenhouse, as shown in Fig.10.



**Fig. 10.** Portable cleaner.  
1. handle 2. nozzle 3. turbine blade 4. runner



**Fig. 11.** Physical structure.

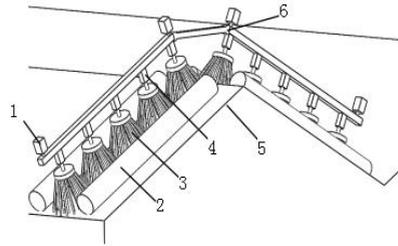
In 2007, Hebei Agricultural University developed a plastic greenhouse cleaning machine, which can realize the whole machine independent movement and cleaning operations. The working principle of the cleaning machine is that the dust attached to the film surface is separated by the high-speed rotation of the cleaning brush, and then the dust is sucked into the dust suction port by the local negative pressure formed by the high-speed rotation of the fan at the bottom of the cleaning machine so as to complete the cleaning operation. In order to improve the coverage rate of the whole machine, the cleaning machine also embedded traversing cleaning path domestication algorithm[18]. The cleaning device has a high degree of automation and can realize long-distance control, but the cleaning effect of the whole machine is general, inefficient, and the stability is not enough to ensure that the cleaning operation does not fall.

In recent years, Professor He Peixiang of Southwest University and Professor Li Qingdong's research team have designed and developed a plastic greenhouse cleaning device and a glass greenhouse roof cleaning device, which has solved the cleaning problems of plastic arch shed and glass greenhouse. The developed cleaning device for plastic greenhouse uses a plurality of cleaning motors to drive the disc cleaning brush to rotate, which is naturally bonded to the plastic film by an elastic coupling; besides, each cleaning device is also equipped with a set of walking support drums to provide the driving

force of the whole machine and ensure the walking stability[11, 19-20]. The developed cleaning device can be used for cleaning single arch shed and multi-arch shed with high cleaning efficiency and good automation. It can also be used for plastic greenhouse with shading net, as shown in Fig.12.



**Fig. 12.** Cleaning device for plastic greenhouse.



**Fig. 13.** Cleaning device for glass greenhouse.  
1. lifting motor 2. moving drum 3. cleaning brush 4. cleaning motor 5. glass greenhouse roof 6. hinges

The cleaning device for glass greenhouse is designed with the same structure shape as the glass greenhouse roof. In order to ensure its natural adhesion to the roof, hinge connection is adopted between the two supporting frames on both sides of the roof. The cleaning device is mainly composed of two parts: the walking part and the cleaning part. The cleaning part is driven by a separate drive motor to wipe the dust from the surface of the glass greenhouse by a disc cleaning brush at high speed. At the same time, the water spraying device will synchronously spray water to ensure the effect of stain cleaning. The walking part provides a driving force by the walking motor to drive the moving drum to realize the whole machine moving. In addition, a lifting motor is used to control the positive pressure of the cleaning brush on the roof of the glass roof[21-24]. The developed glass greenhouse cleaning device has better cleaning effect and higher cleaning efficiency, and can be applied to the glass greenhouse with sunshade net cleaning, but the whole machine is inconvenient to disassemble, changing the roof for cleaning operation is more difficult, as shown in Fig.13.

## 5 Existing problems

In view of the current development of greenhouse cleaning equipment, the developed countries abroad, taking Holland as an example, have developed relatively mature greenhouse cleaning equipment with high stability and automation level.

(1) Lack of attention and standardization.

For a long time, most farmers think that the greenhouse cleaning is unnecessary, and they are unwilling to invest more costs and accept the greenhouse mechanical cleaning; at the present stage, crop yields continue to decline as environmental damage increases greenhouse surface pollution, farmers' willingness to greenhouse cleaning has been strengthened. In addition, greenhouse cleaning has higher requirements for the structure size of greenhouse itself, external facilities (such as shading nets) and so on. However, in China, greenhouse materials selection, planning and design, as well as the extensive process of actual construction, which puts forward higher requirements for greenhouse cleaning equipment adaptability.

(2) Simple equipment and poor cleaning effect.

At present, most of the greenhouse cleaning equipments developed in China are relatively simple, automation and stability is not high, still need to consume more manpower to complete the greenhouse cleaning, the cleaning effect is not satisfactory.

(3) Exist in research gaps, need to be perfected.

Sunlight greenhouse is a traditional mainstream greenhouse type in northern China.

Compared with glass greenhouse and plastic arch shed, sunlight greenhouse has the characteristics of low cost, light weight, no additional heating in winter, and good environmental regulation and control[25], which is generally accepted by farmers, and accounted for a considerable proportion of the total greenhouse area in China. However, most of the research on cleaning equipment of solar greenhouse is only in the patent stage, and there is no research team or cleaning equipment for solar greenhouse.

## 6 Developing research directions and solutions

In view of the above problems, China needs to improve the development of greenhouse cleaning equipment suitable for our country on the basis of introducing foreign advanced greenhouse cleaning technology, improve the cleaning efficiency of glass greenhouse, plastic arch shed and multi-span plastic greenhouse cleaning device, reduce the cleaning cost, so that farmers can afford to use. And in the future research and development, we need to focus on sunlight greenhouse cleaning device research to apply to China's sunlight greenhouse, and we can focus on the following aspects of research work:

### (1) Study on physical properties of covering materials

The research on physical characteristics of different cover materials is the basic link to solve the greenhouse cleaning. Through the study on the tensile, compressive and surface adhesion of the covering materials, it can provide a theoretical basis for the research and development of greenhouse cleaning equipment and the setting of key parts.

### (2) Research on generality

Finding the best structure size for greenhouse construction: only when the greenhouse structure is reasonable and the composition is determined, can the greenhouse cleaning device be developed. In addition, discovering the commonness of different types of greenhouses: by changing the parameters of different parts or components to achieve a multi-purpose machine, as far as possible to solve the problem of greenhouse cleaning versatility.

### (3) Structural optimization of mechanical devices

Greenhouse roof generally has the characteristics of high height, easy scratch and small load. According to the special working environment of greenhouse cleaning device, it should have the characteristics of light weight and compact structure. On the premise of satisfying the cleaning effect, it should optimize and improve the equipment continuously, reduce the production cost, and get the approval of farmers.

### (4) Automation Research

With the rapid development of science and technology, intelligent control technology and information transfer technology have been applied rapidly. Combining existing technology with greenhouse cleaning equipment can further enhance the controllability and stability of greenhouse cleaning equipment.

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