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Development and Application Prospects of Pneumatic Electrostatic Sprayer in Orchard

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Abstract We firstly introduce existing situations of development of electrostatic spraying technology both at home and abroad. On the basis of such problems as serious drift, loss and deterioration of environment during orchard spraying in Xinjiang, we design and develop a new electrostatic sprayer which can effectively reduce the pesticide, improve the adhesion rate of pesticide in the target, and reduce pollution on human body and environment. Using electrostatic induction principle, this electrostatic sprayer directly sprays charged droplet onto target in the action of electrostatic force and high speed air flow. Besides, this sprayer has outstanding economic and social benefits. For farmers, it can raise the utilization ratio of pesticide to 60%, reduce the pesticide loss by 50%, and reduce prevention cost for 10% to 20%; for enterprises, this investment project has a trial profit-tax rate up to 21.4%; the entire sprayer only needs one person to operate; it is highly efficient and low pollution, conforming to national environmental protection and policy concerning agriculture, farmers and countryside. Therefore, this new pneumatic electrostatic sprayer in orchard will have bright popularization and application prospect.

Key words Pneumatic, Electrostatic, Sprayer, Electrostatic induction

Located in the hinterland of the Eurasian continent, Xinjiang Uygur Autonomous Region has hot and dry climate, great temperature difference between day and night, and long sunlight time. These are favorable to accumulation of fruit drops and nutrients. Fruits produced there have good color, high content of sugar and excellent quality. Therefore, its light, heat and environmental resources endowed by nature are particularly suitable for planting fruits. Recently, along with structural adjustment of planting industry, its characteristic forest and fruit industries develop rapidly and have become pillar industries for optimizing agricultural industrial structure, speeding up economic development of Xinjiang and Construction Corps, and also important approach to increase of workers' income and Corp field efficiency.

Rapid development of fruit industry brings considerable economic benefits to farmers. At the same time, however, it leads to serious pollution of fruits and ecological environment due to excessive use of pesticide and even hypertoxic pesticide. At present, large sprinkler spraying is adopted in plant protection of orchard. One sprinkler covers all crops and sprays all pesticides. Then the utilization effect is greatly reduced, leading to lower utilization ratio, serious waste and loss of pesticide^[1]. The maximum utilization ratio is less than 30%, loss of pesticide is greater than 70%, and nonuniformity of pesticide distribution is up to 46.6%.

Prevention of injury to operator during application of pesticide, and reduction of pollution to environment due to pesticide

loss and drift are important marks of advancement of modern plant protection machinery. At the present stage, most plant protection machines widely applied in orchards of China are manual and small motive power machines. However, these machines have such disadvantages as high labor intensity, low working efficiency, plenty opportunity of poisoning due to exposure to pesticide, and serious environmental pollution. To reduce pollution to the utmost and improve spraying quality of pesticide, we conduct a study on development of pneumatic electrostatic sprayer in orchard.

1 Existing situations of development of electrostatic spraying technology both at home and abroad

As a kind of new technology developed in recent 40 years, the electrostatic spraying technology features unparalleled advantages compared with other spraying types. The advantages include: firstly, particle size of electrostatic spraying is in the range of trace and can be directly sprayed with pesticide liquid, so much dilution water can be saved and low amount and super low amount pesticide spraying can be realized. Secondly, since droplets have the same electric charge, they will repel to each other when spraying and it is not easy to gather together, thus the spraying will be uniform in the target. Thirdly, due to action of electric field force and power line around target, the droplets have high penetration power, strong adhesion and resistant to rain erosion, so it can significantly increase sedimentation of pesticide liquid in middle and lower level leaves, backside of leaves and hidden positions, reduce drift of small droplets and ineffective sedimentation of pesticide on ground, improve pesticide utilization ratio, and alleviate pollution of pesticide to environment and degree of pesticide spraying affected by weather^[2-5].

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1.1 Development of foreign electrostatic spraying Researches started earlier in foreign countries. Since the 1970s, there have been patents about electrostatic spraying. The United States, UK and Canada have carried out series of researches and tests on electrostatic spraying technology. For instance, America developed embedded type electrostatic spraying nozzle; Imperial Chemical Industries Limited (UK) developed rotary electrostatic spraying nozzle; Japan also has researches in contact charging micro-taper rotary electrostatic spraying nozzle and atomizing electrostatic spraying nozzle, but products fail to come out all the time^[6]. Till 1989, Doctor S E Law from University of Georgia (America) invented ESS electrostatic spraying system on the basis of pneumatic electrostatic spraying nozzle. From then on, the application of electrostatic spraying technology in plant protection machine started to make breakthrough. Besides, Imperial Chemical Industries Limited (UK), Institute of Agricultural Machinery (UK), and some scientific research units of Germany, Japan and the former Soviet Union conducted many researches on electrostatic spraying theory, charging mechanism, nozzle structure, charging method and static electricity obtaining ways, and have made great achievements in these fields^[7].

1.2 Development of domestic electrostatic spraying technology The research of electrostatic spraying in China started from the end of the 1970s. Some units, including Shanghai Guangming Instrument Factory, Jiangsu Taicang Electrostatic Equipment, Danyang Institute of Electronics, and Beijing Agricultural University, developed hand-held rotary electrostatic sprayer. Hebei Handan Machinery Research Institute developed electric field smashing hand-held electrostatic sprayer. Beijing Plant Protection Machinery Factory developed Dongfanghong-18 knapsack power electrostatic sprayer. Jiangsu University of Science and Technology (now Jiangsu University) developed handheld and rotary electrostatic trace sprayer, pneumatic cage electrostatic sprayer, and handheld smashing hydraulic sprayer from the 1980s on the basis of researches on electrostatic spraying theories and testing technologies. Electrostatic sprayers developed by China have problems of short spraying range, electricity leakage, inverse ionization, difficult control of spraying range due to centrifugal or hydraulic atomizing and contact charging method. Besides, Jiangsu University and China Agricultural University designed and developed electrostatic spraying machines for locust elimination and disease and pest control in orchards on the basis of sprayer principle and contact-charging method.

2 Development of pneumatic electrostatic sprayer in orchard

2.1 Research contents The pneumatic electrostatic sprayer is a kind of modern plant protection machine developed along with low amount, super-low amount and anti-drift spraying technologies. It is called as the most advanced spraying machine since the 1990s. To improve effective utilization ratio of pesticide, reduce pollution of pesticide to ecological environment due to pesticide loss and drift and expand applicable range of

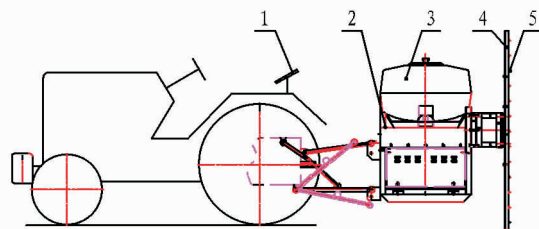
machinery, we develop pneumatic electrostatic sprayer on the basis of electrostatic induction principle. Specifically, after pesticide liquid passes pneumatic electrostatic sprayer embedded with electrode, droplets will be charged, move in fixed direction and absorbed onto targets. General structure of this machine is shown in Fig. 1.

2.1.1 Design of pneumatic electrostatic sprayer. In practical application, there are three methods for liquid charging: contact charging, induction charging and corona charging. For agricultural plant protection machinery, there shall be low operating voltage and current, and the structure should be compact, simple and have excellent insulating property. Among these three charging methods, the droplet charging of contact charging method has the highest effect, and the next is induction charging method. However, in the practical application, these two charging methods will show some problems, such as droplets return to insulating surface and leak electricity and breakdown insulating barrier. Therefore, it is hoped to reduce charging voltage as much as possible.

2.1.2 Design of frame and lance boom truss. It adopts rear suspension attaching to connect with tractor. The frame bears pesticide box. The drive shaft transmits tractor power to hydraulic pump and pneumatic pump. It mainly includes suspension rack and lance boom truss. The lance boom truss adopts changeable mechanism. In line with different plating type of orchards and different planting models, we can adjust the truss to flat type, H type and V type just through adjusting rotary angle on the frame.

2.1.3 Design of control system. Most loops of control system are multiple actuating element control loop. The power supply adopts tractor battery and this machine uses 12V power. It separately performs two functions. Firstly, open the liquid loop. Secondly, control high voltage module. The liquid loop connecting sprayer is controlled through a two-way electromagnetic valve, while high-voltage circuit on the sprayer will be controlled charging control switch of control system.

2.1.4 Design of electrostatic sprayer. High-voltage static generator is a central element of electrostatic sprayer. It can output 1.2 kV direct current through oscillation, boost, voltage multiplying and rectification of 12 VDC battery. In the research and development, we select high voltage static-resistant materials and determine small solid state high voltage static module for practical pneumatic electrostatic sprayer.



Note: 1. Control system; 2. Suspension frame; 3. Pesticide liquid box; 4 lance boom; 5. Electrostatic sprayer.

Fig. 1 Structure of pneumatic electrostatic sprayer in orchard

2.2 Technical indicators Main technical indicators of the sprayer: PTO rotational speed: 720 r/min; spraying rate of single nozzle: 151 ml/min; reliability: greater than 96%; and productivity ratio: 1.81 hm²/h.

3 Analysis on benefits of pneumatic electrostatic sprayer in orchard

3.1 Economic benefits

3.1.1 Economic benefits for farmers. The electrostatic sprayer can effectively improve pesticide sedimentation and distribution of droplets on surface of corps, significantly increase pesticide sedimentation in backside and hidden positions, and greatly reduce ineffective sedimentation due to drift of small droplets. In the aspects of improving utilization ratio of pesticide, reducing pesticide cost and reducing environmental pollution, compared with conventional plant protection machinery, this sprayer has better advantages and it can increase the pesticide utilization ratio to 60% (at present, it is only 20 to 30% in China), reduce pesticide loss for 50%, reduce costs for prevention by 10 to 20% and save pesticide about 25%. Planting farmers can save costs for 10 to 20% for prevention of diseases and pests. In one and half year, farmers can obtain investment in purchasing the machine. Therefore, planting farmers will receive considerable economic benefits.

3.1.2 Economic benefits of production enterprises. According to existing price level and market prospect, we analyze benefits of production enterprises as follows:

(1) Cost for single unit: totally 33 000 yuan, including costs for raw materials, standard parts, general part purchasing, processing, management, and after-sale service, etc.

(2) Selling price: 42 000 yuan.

(3) Profit and tax of single unit: 42 000 – 33 000 = 9 000 yuan.

(4) Analysis of annual benefit (calculated at annual output of 100 units):

Annual output value: 42 000 × 100 = 4.2 million yuan.

Annual profit and tax: 9 000 × 100 = 900 000 yuan.

Rate of profit and tax: 900 000 / 4 200 000 = 21.4%.

It is shown that this sprayer has excellent economic benefits for production enterprises.

3.2 Social benefits This sprayer adopts automatic control, and the entire machine only needs one person to operate. It reduces numbers of workers and labor intensity, as well as operating costs. The newly developed product is favorable to expanding per capita management norm, and energetically promoting industrialized and large-scale production of orchards. With great increase of production efficiency, it is able to obtain farming season in time, which is extremely helpful to safe production and surviving the winter for fruit trees. The development of pneumatic electrostatic sprayer can solve problems of Xinjiang and the whole China's plant protection in orchards. Speeding up application of this technology is favorable to improving fruit quality, developing forest and fruit economy, increasing farms' benefits and workers' income, as well as promoting sustainable development of fruit and forest industry and social prosperity and stability.

4 Prospect of pneumatic electrostatic sprayer in orchard

The development of pneumatic electrostatic sprayer in orchard conforms to requirements for large-scale and industrialization of characteristic forest and fruit production in Xinjiang and Construction Corps. It will play a significant role in promoting scientific and technological advance of fruit and forest industries, speeding up development of fruit and forest industries, and improving mechanical level of fruit and forest industries.

Characteristic forest and fruit industries take up an important position in structural adjustment of planting industry in Xinjiang. The planting area of characteristic forest and fruit expands gradually in Xinjiang. By 2009, the fruit planting area reaches 839 291 hm²^[8], becoming the largest fruit production base in China. However, the existing utilization ratio of plant protection machines and pesticides is low and serious harms ecological environment. Increase of residues of pesticides leads to constant reduction of crop quality, lifts drug resistance of diseases and pests, and causes increase of pesticide use, forming a vicious circle. Nevertheless, at the same time of raising economic benefits, use of chemical pesticides makes chemical substances accumulated in ecological environment and residues of pesticides in agricultural products create great danger to environment. Along with urgent need of fruit industrialization, mechanization and green and pollution-free requirements for high efficient and low pollution plant protection machines, the pneumatic electrostatic sprayer has huge enormous potential.

As a kind of advanced, practical, highly efficient and low pollution plant protection machine, the pneumatic electrostatic sprayer conforms to environmental protection policy and policies concerning agriculture, farmers and countryside. It will become one of leading directions especially for development of national and international advanced pesticide spraying machines, and its popularization and application will bring substantial economic and social benefits.

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