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Automation of greenhouse pesticide application: design and construction

Automatización de la aplicación de plaguicida para invernadero: diseño y construcción

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RESUMEN

Como parte del proyecto del Sistema General de Regalías titulado: Fortalecimiento de la competitividad del sector floricultor colombiano mediante el uso de la ciencia, tecnología e innovación aplicadas en Cundinamarca, fue desarrollado un Sistema automático de aplicación de plaguicidas para cultivos en invernadero buscando obtener un mejor tratamiento sobre el cultivo y una mayor velocidad de aplicación frente a los métodos tradicionales, debido a los riesgos que estos implican para la salud, entre otros, de los operarios. Considerando esta aplicación, el sistema automático se mueve dentro del invernadero y aplica plaguicidas sobre el cultivo mediante aspersión. El sistema fue diseñado y construido para descansar sobre una estructura de rieles, se mueve a una altura mayor a la de las flores cultivadas, y es independiente de la estructura de soporte del invernadero. La aspersión se realiza con seis aguilones soportados en la estructura móvil, de manera que se ejecuta la aplicación simultánea sobre todas las plantas con una sola pasada. Se obtiene una aplicación tanto en operación manual como automática y en uno, dos o los tres tercios, con respecto a la altura de las plantas, según las necesidades de riego y la fase fenológica de estas.

ABSTRACT:

As part of the General Royalty System project entitled: Strengthening the competitiveness of the Colombian floricultural sector through the use of science, technology and innovation applied in Cundinamarca, an automatic pesticide application system for greenhouse crops was developed seeking to obtain a better treatment on the crop with greater speed of application compared to traditional methods, due to the risks that they imply for the health, among others, of the operators. Considering this application, the automatic system moves inside the greenhouse and applies pesticides on a crop using a sprinkler system. The system was designed and constructed to rest on a rail structure, it moves at a height greater than height of the cultivated flowers, and is independent of the greenhouse's support structure. Spraying is carried out with six booms, supported in the mobile structure, to execute the simultaneous application on all the plants with a single pass. This system allows to make the application, both in manual and automatic operation and in one, two or three thirds, with respect to the height of the plants, according to the needs of irrigation and the phenological phase of the plants.

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1. Introduction

Floriculture is one of the most competitive sectors worldwide, as it is associated with the economic development of many countries and with the demands of mass consumers. In Colombia, the flower, and particularly the rose, is considered one of the most economically important products, exporting 228,045 tons for US $ 1306 million in 2017, where 70% of the production was made in the savanna of Bogotá, 27% in Rionegro and the rest, in the coffee region, according to Asocolflores, [1].

Currently, the production of flowers presents several problems and challenges, one of the most relevant being the manual application of pesticides, due to the health conditions and the times and quantity of personnel that demand for export. This situation requires maintaining and improving quality due to the commercial competition of increasingly technician companies in the world. Therefore, it is necessary to improve the efficiency of processes and production per square meter. This justifies the automation of pesticide application to maintain the trend and commercial competitiveness in floriculture.

In intensive agriculture, it is sought to obtain the maximum benefit with minimum cost, best use of resources and the intervention of the soil and the environment as little as possible. For this, the application of new technologies for planning, production and automatic crop management is required. That is called today as "Precision Farming" [2] and allows us to obtain the maximum soil potential per hectare with less fertilizer use, less soil degradation and higher yield; using automatic equipment with sensors [3], detection systems, global positioning systems (GPS) and geographic information systems (GIS) [4] with robotic applications for planting, dosing and / or application of fertilizers, collection of harvest, irrigation and weeding [5], among others. These systems are based on technologies according to physical, chemical and geographical conditions; with computer optimized travel paths [6]; that allow a better use of the area available for planting; higher productivity and with variable dosage of fertilizers in a localized way. Nowadays, robotics also focuses on the development of automatic vehicles and systems applied in the field, [7]. Among the health risks to which a person working in the floricultural sector is exposed, the most significant currently are: ergonomic risks, chemical risks, physical risks, biological risks and psychosocial risks, which can be mitigated through the system developed of automatic application of pesticides.

On the other hand, the purpose in this project, carried out by the AVARC Group of the Automation Engineering program at La Salle University, was to respond to two main needs: 1) make the application of pesticides more uniform, with better coverage and greater speed, being adaptable to the different forms of application required for roses; and 2) optimize the pesticide spray process to reduce the use of chemical products, with greater application efficiency.

The process was carried out in the next stages describes in this paper: 1. Design of component subsystems, for which a greenhouse located in Agrosavia (before Corpoica) was taken as a reference and a CAE engineering program was used to determine stresses, deformations and displacements. 2. Construction of component subsystems, developing a support structure and another one for transporting the booms for pesticide spraying, assembling the hydraulic and control system for moving the booms and regulating the fluid to be dosed. 3. Validation and optimization the operation system, which included: type of nozzle, speed of the mobile car and manometric pressure of injection to the application system; 4. Results, finding a reduction in time and quantity of application pesticide with respect to the manual system. 5. Conclusions, where the obtained achievements are mentioned and, another possible application for the designed system.

2. Design of component subsystems

Based on the dimensions of a greenhouse provided for the project by Corpoica (now Agrosavia), located on lot 5 of the Tibaitatá Research Center at kilometer 14, via Bogotá - Mosquera, Cundinamarca (4°41'24.62 "N; -74° 12 '6.62 "W); the main support structure was designed, without using the greenhouse structure as support, but it can be adapted to fix it to its structure.
Applied engineering design concepts, the operating conditions were defined, and using engineering design

software (CAE) the forces, deformations and displacements were determined as shown in Figure 1. With the defined structural system, the hydraulic distribution system of the pesticide and the booms (spray nozzle support assembly) was designed, considering the versatility required in the positioning and orientation of the sprinklers, for use on the plants according to application needs.

In Figure 2, the initial design of the spray systems is shown, looking for the total coverage of the plants with the product applied with only one pass. The configuration of the pesticide application hydraulic system is also shown, from the tank where the solution is prepared until sprinkler system.

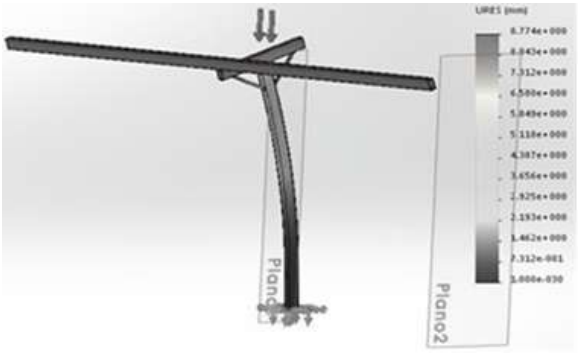

Figure 1. Calculation of displacements the support column of the structural system, using the SolidWorks Software. Source: own.

In the same way, the electrical power systems with their protection systems, the mechanical transmission systems from the geared motor and the electronic and control systems, required for the automatic operation of the system, were calculated.

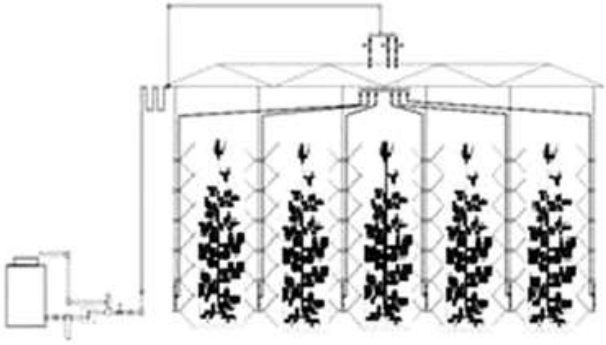

Figure 2. Spray system and hydraulic distribution system of the pesticide from the preparation tank of solution to be applied. Source: own.

3. Construction of automatic pesticide application system in the greenhouse.

Once the main structure of the system was designed, it was constructed, as shown in Figure 3. After assembling the columns (a) and aligning the travel rails (b), the main carriage (c) was built and mounted, and it is responsible for supporting and transporting the booms on the mobile system, shown in the same Figure 3.

Figure 3. Mobile carriage and support structure of the booms mounted on the travel rails. Source: own.

Figure 4 shows the boom prototype designed and constructed with the sprinkler assembly installed, which allows adjusting the distance between sprinklers and their orientation, according to required application direction.

Figure 4. Detail of the boom construction with the sprinkler assembly installed. Source: own.

Finally, the entire hydraulic distribution system was mounted with the hoses supported on the main structure, as shown in Figure 5, and the hydraulic and electrical distribution and connection system (d) for the solenoid valves and boom sprinklers, shown in Figure 3.

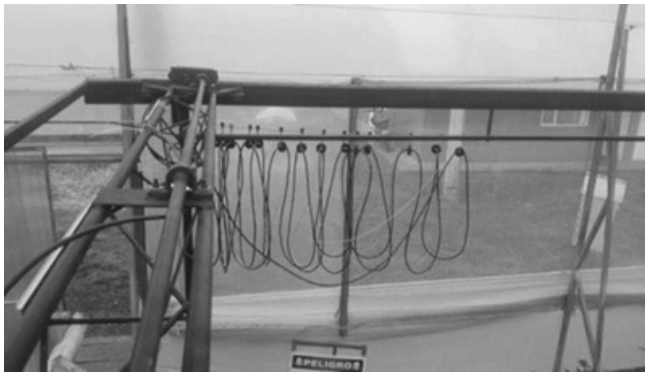

Figure 5. Installation of hoses and hydraulic distribution system, on the main support structure. Source: own.

To put the system into operation, all wiring and electrical connection from the control and control panels was carried out. Figure 6 shows the power panels for the motors of the displacement car (left) and the motion control system (right) respectively.

Figure 7. Manual and automatic operation tests of the spray system. Source: own.

5. Results

After completing the research project, the following results were obtained:

- Design and construction of an automatic system for application of pesticides in greenhouses.
- Reduction of the operator's contact with chemical products.
- Lower pesticide consumption due to controlled dosage and homogeneous application on the crop, complying with the requirements of green flower version 7.0.
- Reduction of pesticide application time on the crop.
- Adjustable application speeds and easy orientation and positioning of the nozzles.
- Pesticide application in the low, medium or high third of the crop controlling the application volume.
- Appropriation of technological knowledge for development of the sector through human resource training, with the skills required for floriculture.

6. Conclusions

The following achievements can be highlighted:

- Construction of an automatic system for applying pesticides to roses in greenhouses.
- The automatic control system allowed the homogeneous application of pesticides by means of adequate positioning of the spray nozzles, guaranteeing the coverage for all plants; in addition to a lower consumption of pesticides due to the control dosage system, by means of regulation the pressure of hydraulic system and displacement speed.
- Shorter time of application pesticide than using manual means, due to the use of a system that can maintain a preset speed, and with enough power to transfer all the elements responsible for pesticide dosage and supply.
- Because this system was designed with materials used in agriculture, it can also be used for irrigation and / or fertilizer as a complement to the work done on the crop.

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