# World trends in the creation of robots for spraying crops

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**Abstract.** The article is devoted to the problem of identifying global trends in the development of robotic sprayers for crop processing. The author distinguishes three groups of spraying robots depending on the area of application. The first group is characterized by the use of technical vision and computer learning technologies for recognition and selective spraying of weeds, the use of spot treatment systems with a micro dose of chemicals, the development of robots with a certain level of versatility, which makes it possible to perform other field works in addition to spraying. The second group is characterized by the installation of high-performance spraying equipment, the use of universal spraying devices to ensure the processing of plants of various heights, the use of laser sensors, gyroscopes, wheel and steering sensors to adjust the movement of the robot in real time. The installation of deployed video surveillance systems on the robot to control movement machine and the quality of the work process is also feature of this group. The third group is characterized by a high degree of automation of all work processes, the installation of a wide range of additional equipment for monitoring the current state of plants and soil, air parameters and illumination.

**Keywords:** plant, spraying, robot, automation, machine.

## 1. Introduction

To ensure competitiveness in the global agro-industrial complex, food producers regularly update their technical base. In turn, machine manufacturers offer more and more advanced energy-saving equipment with significant versatility, providing an increase in productivity and quality of work while respecting environmental safety. The global trend for all types of agricultural machinery is the widespread use of digital technologies, precision crop production systems and robotic machines [1, 2, 3].

One of the types of agricultural machinery where these trends are most pronounced are crop sprayers. Various robotic devices and machines are becoming more and more widespread in this type of plant protection.

The purpose of this study was to identify global trends in the development of robotic systems for efficient spraying of plants.

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## 2. Materials and methods

To achieve this goal, monographic and general scientific research methods were used. Publications of Russian and foreign authors: articles, books, Internet sources were studied.

## 3. Results and discussion

Depending on the area of application, all crop spraying machines can be divided into three groups:

- machines for spraying field crops;
- machines for spraying trees and shrubs in orchards and vineyards;
- machines for spraying plants in greenhouses and other enclosed spaces.

All of the above applies to robotic spraying machines. For each of the identified groups of robots, the main global trends in the development of designs and technologies were identified.

We have conducted a literature review of scientific publications regarding trends in robotic spraying of plants in the fields. The issues of creating modular designs of robots, developing autonomous navigation systems, programming workflows, etc. were studied. [4, 5, 6]. As a result of the analysis of these and other sources, several characteristic designs of robots were identified, in which the main world trends in the development of field spraying robots are visible.

The most representative machine of the first group is the AVO robot sprayer, developed by the Swiss company ecoRobotix, designed for chemical treatment of fields (Figure 1).

**Fig.1** Robot sprayer AVO ecoRobotix

This machine is an autonomous robot that uses advanced machine learning technology to recognize and selectively spray weeds with a micro dose of herbicides. The processing accuracy is up to 1 cm. This reduces the volume of the drug used by more than 90%.

The robot is completely autonomous. Before starting work, the operator sets the parameters of the field boundaries in the software, and the system independently generates a route. For precise navigation and positioning, the robot uses a tracking camera and a GPS RTK module. To ensure safety, the robot is equipped with lidar and ultrasonic obstacle detection sensors.

The mass of the robot is 750 kg, including batteries and a filled 120-liter herbicide container. The robot has 3 kW all-wheel drive with independent control of 4 wheels, which allows it to overcome obstacles and work on slopes up to 10 ° and provides high maneuverability and a small turning radius. Battery life is 8 hours, productivity is up to 0.6 ha/h at a maximum speed of 1 m/s. For additional energy supply, solar panels can be installed.

https://doi.org/10.1051/e3sconf/202338001011

The next characteristic machine is the Trektor hybrid robot, developed by the French company Sitia. It is a highly adaptable robot that can change its track, height and wheelbase to navigate a variety of wide or narrow row crops (Figure 2).


**Fig.1** Hybrid Robot Sitia Trektor

The machine is capable of performing many repetitive tasks (tillage, spraying, etc.). Depending on the working conditions, the 2.7-ton robot is offered in three track widths (from 1.04 to 1.57 m, from 1.37 to 1.90 m and from 1.87 to 2.40 m). Ground clearance varies from 1.10 to 1.50 m.

The robot is equipped with a diesel engine and battery, which can effectively adapt to various types of agricultural soils and crops. The technique uses GNSS RTK navigation. This ensures very high accuracy of the robot movement. At the same time, sensors and bumpers serve as additional security measures. The machine is equipped with a standard three-point linkage. Attachment points are located at the rear and between the wheels.

Another typical design is the ARA robotic sprayer developed by the French company Sitia EcoRobotix (Figure 3).

**Fig.3** Robotic sprayer EcoRobotix ARA

The machine can be used to selectively spray crops with insecticides, fungicides or herbicides. The robot has a three-chamber surveillance system in combination with artificial intelligence. This makes it possible to distinguish between weeds and spray them with micro doses of herbicide with an accuracy of one centimeter.

As a result, the volume of used herbal preparations and plant protection products is reduced by up to 95%, while maintaining crops. The principle of operation of the robot is similar to a conventional trailed sprayer. The implement is mounted at the rear of the tractor. The equipment consists of three adjustable rods 2 m long, each of which is equipped with 52 flat fan nozzles, located at a distance of 4 cm from each other. The two outer parts of the system can be lifted up for ease of transport on public roads.

Another machine of this type is the See & Spray robotic sprayer from the American company Blue River Technology, which recognizes weeds and purposefully applies the pesticide, even if there are many germinated plants on the field (Figure 4).

**Fig.4** See & Spray Robotic Sprayer

Blue River Technology is owned by Deere & Company. This weed detection robot uses computer vision and machine learning to detect weeds in crops and uses special automated nozzles to apply the drug while passing the unit.

The last machine from the first group is the robot sprayer Solix Sprayer, developed by the Brazilian-American company Solinftec, designed to detect and spray weeds (Figure 5).


**Fig.5** Robot sprayer Solinftec Solix Sprayer

The robot is equipped with artificial intelligence technologies and performs spot treatment of weeds with liquid preparations based on their identification by a video surveillance system. In addition to spraying, the unit also provides users with differentiated spot application maps for weeds with an analysis of the amount of resources saved compared to traditional full-field treatment. The machine is powered by four solar panels that control the drive system and spraying. Depending on the shape and topography of the field, as well as the condition of the working area, the machine can process up to 40 hectares per day.

The identified trends for the first group of robots are given at the end of the article.

We conducted a literature review of scientific publications regarding trends in robotic spraying of trees and shrubs in orchards and vineyards. The specifics of the technological process of spraying high agricultural plants in the open air, the issues of the spatial orientation of the robot in orchards and vineyards, the problems of ensuring environmental safety during the operation of spraying robots with increased productivity were studied [7, 8, 9, 10, 11]. As a result of the analysis of these and other sources, several designs of robots were identified, in which current trends in the development of robots of the second group can be traced.

Robot sprayer Agbot 2.055W3 Hol Spraying Systems, developed by the Dutch company AgXeed, is designed for intensive continuous work in orchards and vineyards (Figure 6)


**Fig. 6** Robot sprayer AgXeed Agbot 2.055W3 Hol Spraying Systems

The unit is equipped with a CF2000-AB spray structure and has a high performance electrically driven fan and a detachable spray bar with 16 nozzles (8 on each side). The machine is equipped with a four-cylinder water-cooled Deutz diesel engine with a capacity of 156 hp. The unit has an electric transmission and two wide wheels, which increase the permeability and at the same time reduce the pressure on the soil.

The GUSS Automation robot sprayer, developed by California-based Crinklaw Farm Services, is a robotic platform that can move between rows of trees in orchards (Figure 7).

**Fig. 7** GUSS Automation Robot Sprayer

Since GUSS Automation usually works under trees, in addition to GPS, the robot is equipped with a laser sensor, a gyroscope and wheel and steering sensors that transmit information to a computer to correct movement in real time. If an obstacle occurs at a distance of about 1 m or a sudden obstacle touches the front bumper, the machine is immediately stopped. Also, a virtual fence is created around the field in the mapping software, when crossing which the robot automatically turns off.

The robot is equipped with a camera that broadcasts streaming video of the process. Thus, the operator can control up to 10 sprayers at the same time. The speed of the robot is set by the operator using the GUSS software. Processing parameters such as application rate, working pressure are also set. All processing indicators with indication of rates, date and time are automatically saved. A feature of the robot is its relatively low profile, which eliminates damage to tree branches or fruits during processing. The YV01 robot sprayer, developed by the Japanese company Yanmar, is designed to work in orchards and vineyards (Figure 8).


**Fig. 8** Yanmar YV01 Series Robot Sprayer

The machine is equipped with a two-cylinder Honda gasoline engine with a volume of 0.8 liters and a power of 27 hp. The unit is able to climb slopes up to 45%. At the same time, the robot can operate at a maximum speed of up to 4 km / h.

The volume of the working solution hopper is 200 liters. Its vertical position ensures simultaneous spraying of one row in one pass. The robot sprayer has a fuel tank with a capacity of 19 liters, which allows applying fertilizer continuously for 4 hours. You can control the equipment using your smartphone or tablet.

The robot sprayer Arbus 4000 JAV, developed by the Japanese company Jatco, is designed to process trees and tall shrubs (Figure 9)

**Fig. 9** Robot sprayer Arbus 4000 JAV

The innovative component of the robot is that the machine uses laser scanning to measure the size and proportions of plants. This information is used for optimal analysis of the environment and spray patterns. The liquid tank holds 4000 liters. The robot is equipped with a 132 hp diesel engine, independent suspension, which allows it to work at high speeds, as well as an intelligent control system that detects obstacles and stops the machine if necessary.

The identified trends for a group of robots for spraying trees and shrubs are given at the end of the article.

We have conducted a literature review of scientific publications regarding trends in robotic spraying of plants in greenhouses. The issues of evaluating the performance of greenhouse spraying robots, various aspects of precision spot spraying, the creation of robotic systems with environmental sensors in greenhouses were studied. [12, 13, 14, 15, 16]. As a result of the analysis of these and other sources, several characteristic designs of robots were identified, in which the main world trends in the development of spraying robots for greenhouses are visible. The first typical design is the Qii-Jet robot sprayer developed by the British company Bogaerts (Figure 10).

**Fig. 10** Qii-Jet Robot Sprayer

The robot works in greenhouses, has a tank of 300 liters and a spray boom. Almost all operations in this machine are automated. The operator programs the robot using the touch panel. Horizontal and frontal nozzles are installed on the boom. This allows spraying plants more efficiently. The robot has wheels and moves along concrete paths and tubular rails.

The second characteristic machine is a robotic platform developed at Michurinsk State University (Moscow), designed for the environmental protection of greenhouse plants from diseases (Figure 11).


**Fig. 11** Robotic platform for the protection of greenhouse plants

In addition to spraying, the robot irradiates greenhouse plants with coherent laser light at night for plant resistance to diseases and useful productivity increase. In addition, laser irradiation significantly increases the activity of protective biopreparations based on live cultures. The robotic platform uses 28 laser modules that irradiate plants.

The robotic platform is completely autonomous. The unit independently moves along the same tubular rails along which other technological equipment moves. Built-in sensors help the unit to recognize and avoid obstacles in its path by stopping and moving in the opposite direction.

The device is also equipped with sensors for measuring light, temperature, humidity and carbon dioxide. The solar battery located above the control unit allows receiving light energy and recharge the battery. An important property of the robotic device is the automatic increase in the height of the working bodies and sensors in the process of plant growth.

## 4. Conclusions

Based on the results of the research, characteristic global trends were identified for each of the three identified groups of robots.

The following development trends have been identified for robotic sprayers of field crops:

- use of technical vision and computer learning technologies in the robot for recognition and selective spraying of weeds;

- application of point treatment systems with a micro dose of chemicals;

- the ability of the robot to independently form a route of movement due to a complex of systems and devices, such as navigation, security cameras, lidars and ultrasonic obstacle sensors;

- providing significant battery life in the field (over 8 hours);

- development of a robot design with the possibility of changing the track width, wheelbase length, ground clearance for working in fields with various crops;

- development of robots with a certain level of versatility, providing the ability to perform other field work (tillage, fertilization, sowing) in addition to spraying;
- the possibility of aggregation with a tractor as a trailed machine to increase productivity and perform a significant amount of work in a limited agrotechnical time frame;
- compact design and low weight of the robot to ensure loading into a vehicle upon delivery to the field;
- availability of special software for compiling electronic maps based on the results of field work.

For robotic sprayers of trees and shrubs in orchards and vineyards, the following development trends have been identified:

- installation of high-performance spraying equipment;
- the use of universal spraying devices to ensure the treatment of plants of various heights;
- the use of movers that reduce pressure on the soil and increase cross-country ability;
- the use of highly economical internal combustion engines;
- installation of catalysts and other devices to reduce harmful emissions into the atmosphere;
- use of laser sensors, gyroscopes, wheel and steering sensors to correct the movement of the robot in real time;
- the use of innovative software that allows controlling several spraying robots at the same time;
- installation of deployed video surveillance systems on the robot to control the movement of the machine and the quality of the work process;
- use of special software for automatic recording of the results of work performed.

For robotic sprayers of plants in greenhouses and other enclosed spaces, the following development trends have been identified:

- high degree of automation of all work processes;
- installation of a wide range of additional equipment for monitoring the current state of plants and soil, air parameters and illumination;
- the use of touch control panels and an intuitive interface for robot operators;
- installation of universal spraying devices for changing the direction and shape of the working fluid jet in a wide range;
- the use of systems for automated adaptation of the geometric dimensions of the robot to the shape of the processed plants;
- the use of solar panels for additional power supply of the robot.

In general, the world's major manufacturers of agricultural machinery and small innovative enterprises have made significant progress in the creation of robotic sprayers. It can be hoped that further adherence to the identified trends will allow this type of machine to successfully evolve and increase the efficiency of agricultural production.

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