Robot for strip spraying of vegetable crops

Ivan Nesmiyanov[1], *Ivan* Borisenko[1], *Natalia* Vorob'eva[1], *Alexey* Ivanov[1], and *Victor* Dyashkin-Titov[1*]

[1]Volgograd State Agrarian University, 26, University ave., Volgograd, 400002, Russia

Abstract. The article deals with the problem of reducing the use of agrochemicals through the use of strip spraying using robotic tools that increase the uniformity and accuracy of the distribution of pesticides. The proposed design of the strip spraying module is based on the principle of consistent development of unified modular components in order to change the basic characteristics of the robotic complex. The use of a robotic complex for strip spraying of vegetable crops during treatment with pesticides or liquid mineral fertilizers will ensure an improvement in the quality of plant processing, a reduction in the hectare consumption of the working solution and a negative impact on the environment.

1 Introduction

Spraying plants is one of the main way to control pests and diseases, as the introduction of pesticides allows you to control pests and diseases that can cause serious damage to crops. However, the use of pesticides has its drawbacks, consisting in a negative impact on the environment and human health, therefore it is necessary to strive for more gentle spraying methods [1-3].

Reducing the use of agrochemicals in the treatment of crops from diseases and pests, as well as reducing the hectare rate when applying fertilizers, is one of the directions for resource conservation and restoration of natural resources in the agricultural sector, the use of technologies based on band-effect processes can achieve this goal of reducing the use of pesticides [4-9].

When carrying out the technological process of spraying agricultural crops, one of the main requirements is the uniformity and accuracy of the distribution of pesticides, the introduction of liquid forms of pesticides and fertilizers using robotic tools contribute to a more uniform distribution over the treated area and achieve the required accuracy of getting to the processing object [10].

Resource-saving technologies in agriculture provide for the use of highly efficient means of mechanization and robotic systems for cultivating crops [11-12], which increase the level of mechanization and automation of field work and reduce the severity of environmental problems, reduce the anthropogenic burden on the environment.

* Corresponding author: c_43.52.00@mail.ru

2 Materials and methods

The proposed design of the strip spraying module [13] (Figure 1) is based on the principle of consistent development of unified modular components in order to change the main characteristics of the robotic complex. The basic parts of the module are the frame 1, the block 2 with the motor 3 and the drive pump 4 located in it, which is connected at the inlet to the tank for the working solution 5. A horizontal guide rail 6 with two movable carriages 7 connected to the control unit 8 is fixed on the frame 1. The carriages 7 are driven by a stepper motor 9, by means of rollers 10 and a toothed belt 11. Each carriage 7 has a housing with a sprayer 12 connected to the outlet nozzle of the pump 4. The axes of the sprayers 12 are located in the same vertical plane and are directed towards each other at an angle of 450, ensuring that the upper edges of the spray cones merge to form a flow inward, and the lower edges do not extend beyond the outline of the treated plant on the soil. A vision sensor 13 is installed in front of the frame 1 in the center of the movement. The technical vision sensor 13 determines the projection of the contour of the treated plants in the vertical-transverse and vertical-horizontal planes and transmits a signal to the control unit 8. The control unit 8 sets the amount of movement for each housing with a sprayer 12 along the horizontal guide 6, ensuring full coverage of the contour of the treated plants with a working solution.

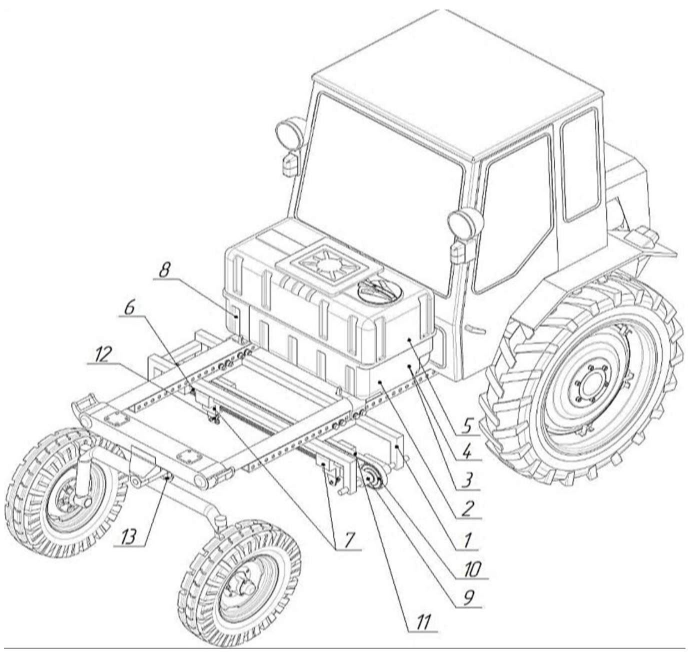
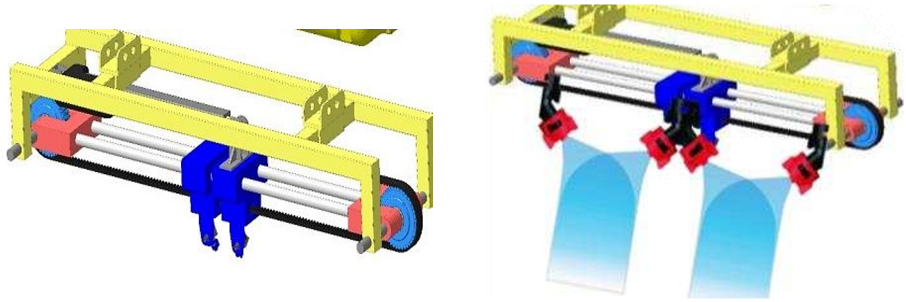


Fig. 1. The design of the module for strip spraying of vegetable crops based on the tractor self-propelled chassis VTZ30SH.

The design of the carriages and sprayers allows them to be quickly rearranged, for example, to change the nozzle of the sprayer or add an additional carriage with a sprayer (Figure 2 a, b). The number of carriages can be increased to three pieces, and the number of sprayers on one carriage can be increased to two pieces (Figure 2, b). These parameters are set depending on the processed vegetable crop and the technological process, which involves a robotic complex with a strip spraying module.

https://doi.org/10.1051/e3sconf/202449404033



a) b)

Fig. 2. 3D model of the spraying module.

A stepper motor is used to move the carriages in a horizontal plane (Figure 3). In the prototype, an engine with a supply voltage of 12 V. The speed of rotation of the stepper motor shaft, as well as the number of steps taken, is regulated using a PWM control signal. The technical characteristics of the stepper motor are shown in Table 1.

Fig. 3. DC Motor.

Table 1. Technical characteristics of the motor.

Parameter	Meaning
Step angle	15 °
Phase resistance	10 ± 7 Om
Voltage	12 V DC
Weight	135 g
Operating temperature range	-10…55 °C
Operating relative humidity	5-95 %
Control mode	Bipolar
Maximum response rate	More than 1300 pulse/s
Insulation level	E

The power supply system of the stepper motor, microcomputer and position controllers of the module for strip spraying consists of a 12V battery with a capacity of 90 Ah.

The kinematic scheme of the module design for strip spraying of vegetable crops is shown in Figure 4.

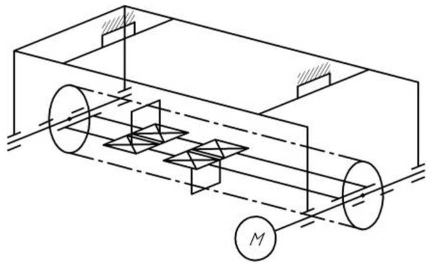
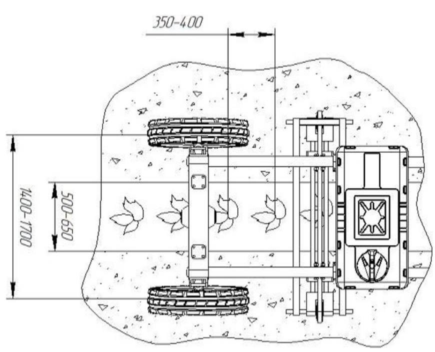


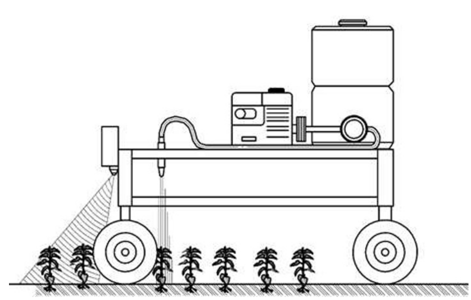
Fig. 4. Kinematic scheme of the module design for strip spraying of vegetable crops.

3 Technological process

The technological process of processing vegetable crops (Figure 5) with a strip spraying module is carried out as follows. In accordance with the program of strip treatment of an agricultural field with pesticides or liquid mineral fertilizers, a robotic complex for strip spraying of vegetable crops is installed on the edge of the field at the point of its commissioning. The robotic complex receives a map and coordinates of the start of work. The software calculates the optimal trajectory of movement along the rows of plants for a complete passage of the field (Figure 5, a). Using a technical vision sensor, the robotic complex detects in real time all the plants in its path and receives information about which vegetation should be treated and where it is located. The projection of the contour of the treated plants in a vertically transverse plane is determined and the signal is transmitted to the control unit 8, which in turn sets the amount of movement of the movable carriages 7, in the lower part of which there are housings with sprayers 12 connected to the outlet nozzle of the pump 4. The axes of the sprayers 12 are located in the same vertical plane and are directed towards each other at an angle that ensures the direction of fusion of the upper edge of the spray cone to form a flow inward, and the lower edges of the spray cone do not extend beyond the outline of the location of the sprayer above the soil. The amount of movement of the carriages 7 ensures complete coverage of the contour of the treated plants with a working solution, taking into account the deviation of the outline of the plants from the axis of movement of the robotic complex (Figures 2, 6).



a)



b)

Fig. 5. The technological process of strip spraying using a module for strip spraying: a) the layout of the robotic complex in a row; b) detection of plants by a vision sensor.

The dosage of the amount of pesticides or liquid fertilizers is determined depending on the size of the outline of the treated plants in a given area [14-15].

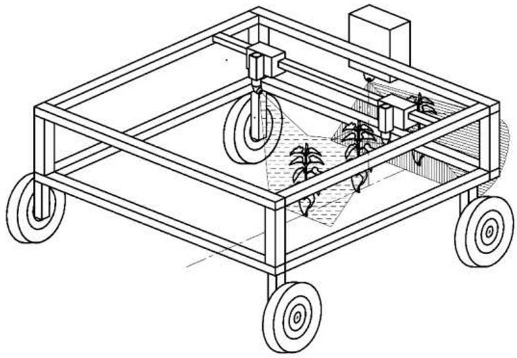


Fig. 6. Full coverage of the contour of the treated plants with a working solution.

4 Conclusion

The use of a robotic complex for strip spraying of vegetable crops during treatment with pesticides or liquid mineral fertilizers will ensure an improvement in the quality of plant processing, a reduction in the hectare consumption of the working solution and a negative impact on the environment.

Acknowledgement

The work was carried out within the framework of Research and Development of the Ministry of Education and Science of the Russian Federation No. FESR-2023-0009 "Development of technology for cultivating vegetable crops based on the use of modern methods of breeding, primary seed production with elements of robotization".

References

1. K.O Fuglie, Conservation Tillage and Pesticide Use in the Cornbelt. Journal of Agricultural and Applied Economics, **31**(**1**), 133–147 (1999)
2. A.V. Palapin, S.V. Belousov, Modern approach to chemical protection of plants. British Journal of Innovation in Science and Technology, **3**, 13-24 (2016)
3. S.V. Belousov, Y.V. Khanin, V.V. Zhadko, *Methods and means of concentrated fertilizers plication*, IOP Conf. Series: Materials Science and Engineering, **971** (2020) 052050
4. A.Y. Nesmiyan, V.A. Chernovolov, A.M. Semenihin, V.P. Zabrodin and S.L. Nikitchenko, Research on Crops **3**(**19**), 560-7 (2018)
5. S.I. Kambulov, V.P. Maksimov, Yu.A. Tsarev and E.M. Zubrilina, Scientific life **2**, 19-26 (2019)
6. V.N. Churzin, A.O. Dubovchenko, Proc. of the Lower Volga Agro-University Comp **1** (**57**), 158-67 (2020)
7. A.I. Zavrazhnov, A.V. Balashov, S.V. Dyachkov, A.N. Omarov, S.P. Strykin, Achievements of science and technology in the AIC, **1**, 52-5 (2017)

8. E. Canales, J. Bergtold, J. Williams, Agricultural and Resource Economics Review **47**(**1**) 90-117 (2018)
9. E.L. Lipkovich, A.Y. Nesmiyan, S.L. Nikitchenko, V.V. Shchirov, Y.G. Kormiltsev, Scientia Iranica **2**(**27**) 745-56 (2020)
10. M.V. Meznikova, I. B. Borisenko, O. G. Chamurliev, E. I. Ulybina, O. N. Romenskaya. *Innovative method of strip-till 3-D spraying in chemical treatment of crops to implement resource-saving approaches in strip-till technology,* Conference Series: Earth and Environmental Science, Volume 839, Biological Technologies in Agriculture: from Molecules to Ecosystems, 042043 (2021)
11. A.G. Ivanov, N.S. Vorob'yeva, V.V. Dyashkin-Titov, V.V. Zhoga, A dynamic algorithm for stabilization of the working body of a mobile robot weeding for the future of agriculture. IOP Conference Series: Earth and Environmental Science, Volgograd, 012050 (2022)
12. N.S. Vorob'yeva, I.A. Nesmiyanov, A.G. Ivanov, Mobile robotic complex for cultivating row crops. XVI All-Russian Multi-conference on management problems (MCPU-2023) Volgograd State Technical University, 65-268 (2023)
13. I.B. Borisenko, D.V. Skripkin, M.V. Meznikova A.N. Sidorov, A.A. Shabunina, A.V. Sorokin, N.S. Vorob’eva, A.G. Ivanov, A.V. Dyashkin, V.V. Dyashkin-titov, RU Patent 2796491 (2023)
14. I.B. Borisenko, M.V. Meznikova, E. I. Ulybina, Scientific aspects of technical modernization of sprayers for chemical protection sunflower Proc. of the Nizhnevolzhsky Agrouniversity Complex: Science and Higher Professional Education **4**, 193-197 (2020)
15. I.B. Borisenko, A.S. Ovchinnikov, M.V. Meznikova, S.D. Fomin, V.S. Bocharnikov, A.F. Rogachev, E.I. Ulybina, Resource-saving method of chemical treatment of tilled crops Conference on Innovations in Agricultural and Rural development IOP Conf. Series: Earth and Environmental Science, 341 (2019)