ISSN 1454 - 8003
Proceedings of 2022 International Conference on Hydraulics and Pneumatics - HERVEX
November 9-10, Băile Govora, Romania

EXPERIMENTAL RESEARCH ON AN INNOVATIVE HORTICULTURAL TECHNICAL SYSTEM OF ANALYSIS, PREDICTION AND BIODYNAMIC ACTION

Mihai Gabriel MATACHE[1,*], Iuliana GĂGEANU[1], Alexandru IONESCU[1], Ana-Maria TĂBĂRAȘU[1], Andrei Alexandru BENESCU[2]

[1] National Institute of Research – Development for Machines and Installations Designed for Agriculture and Food Industry – INMA Bucharest / Romania, gabimatache@yahoo.com

[2] INOE 2000-IHP Bucharest / Romania

* gabimatache@yahoo.com

Abstract: *The research carried out in this paper aimed to test the operation of an innovative horticultural technical system (intelligent equipment) for analysis, prediction and biodynamical action, which is an electrically driven equipment intended for spraying and applying phyto-sanitary treatments in a various range of crops using an algorithm for weed and diseased plant detection. The experiments conducted focused on testing the autonomy and charging time for the system, verifying the power consumption and testing the volumetric yield, but also on the algorithm. The results showed good functioning for both the hardware and the software parts of the system, encouraging to further the experiments for a larger variety of applications in agricultural crops.*

Keywords: *Intelligent system, electrically driven, detection algorithm, weed detection, crop maintenance*

1. Introduction

The "attack" of weeds, diseases and pests implies the reduction of the quantity and quality of crops, regardless of their nature (agricultural, horticultural and, why not, forestry). To combat diseases, pests and weeds in agricultural crops, pesticides are frequently used, which according to their purpose can be: fungicides, used to combat diseases caused by parasitic fungi; insecticides, used to fight insects and herbicides, used to fight weeds. The timely, fast and effective application of pesticides can save a potentially compromised crop and is crucial in modern agriculture [1,2].
From the complex of works that make up the maintenance technology of agricultural and horticultural crops, the works for combating diseases and pests have a special significance for the quantity and quality of production. It can be estimated that production losses due to diseases and pests can reach up to 35%, and in some cases, production can be completely compromised. Reducing production losses per hectare is possible only within the framework of integrated control, the method in which chemical treatments occupy the most important place [3].
Machines and equipment for the application of treatments ensure the optimal use of protection products, minimize the risks for the crop, man and the environment, intervene quickly where necessary and as often as necessary, they can apply emulsions, solutions or suspensions of chemical products, the application is made in the form of drops small for maximum coverage effectiveness can be applied before, during or after sowing [4].
Currently, hydraulic sprayers, pneumatic sprayers, mechanical sprayers and hydro-pneumatic combined sprayers are used. In general, a spraying machine consists of: the frame of the machine; liquid tank; hoses and liquid transport pipes; the filtration system; liquid pump(s); liquid agitators (homogenizers); the command group with control, dosing and distribution equipment; the spraying boom with the spraying equipment; various auxiliary equipment (for washing, preparation of solutions, etc.) [5].
Agricultural machines can be equipped with different equipment that allows them to be automated, and they can be handled as easily as possible. Such equipment can be the GIS localization

systems and the machine vision systems that promote efficient coordination and guidance of machines [5,6,7].
Also, new technologies are based on the use of modern sensors that remotely transmit valuable information that can prevent the appearance of diseases of agricultural crops. An important application in this regard are unmanned aircraft systems (UAS) that can be equipped with optical sensors (e.g., multispectral, thermal, hyperspectral cameras, etc.), which provide high-precision data about the field of interest (identification of plant diseases, weed recognition, terrain mapping, etc.) [8].
Automatic intelligence (machine learning) is an essential element in precision agriculture, it is used in the processing of data generated by detection systems, using different statistical and mathematical models. The fields of application of automatic intelligence in agriculture are diverse, it can be used in crop prediction, species identification, pest recognition, soil moisture and temperature estimation, etc. [9,10,11].
The paper presents the experimental research conducted on innovative horticultural technical system of analysis, prediction and biodynamic action, both from a mechanical point of view and for its the capacity to analyse crops and distinguish weeds from plant crops in order to perform treatments.

2. Material and methods

The experimental model of innovative horticultural technical system (intelligent equipment) for analysis, prediction and biodynamical action is an electrically powered equipment intended for the distribution of phyto-pathological treatments for onion, carrot, potato, parsley, parsnip, and celery crops. Being powered by electricity, it can be used without restrictions both in closed spaces and in open spaces. The drive wheels are placed on the rear axle.
The experimental model of innovative horticultural technical system (intelligent equipment) for analysis – Figure 1, prediction and biodynamical action if composed of:
1. SME electrically operated mobile structure;
2. DSP dosage system and biological protection of plants.
The system it is equipped with a KIT of hardware-software system, neural network for automatic control of its functionality.

Fig. 1. Experimental model of innovative horticultural technical system (intelligent equipment) for analysis, prediction and biodynamical action

The main technical characteristics of the experimental model of the innovative horticultural technical system (intelligent equipment) for analysis, prediction and biodynamical action are:

Table 1: Main system characteristics

Characteristic	M.U.	Value / characterization
Rear wheel track	mm	1320
Wheelbase	mm	2600
Electric drive motor	kW	12
li-ion battery	Vcc	96
Solution tank capacity	l	400 l
Tank material	-	glass fiber reinforced resin
Pump motor	kW	3
Maximum flow rate of the pump	l /min	86 l/min
Maximum working pressure	bar	20 bar
Line filter	-	with self-cleaning and discharge based on hydraulic agitator
Agitation system	-	with hydraulic agitator
Boom length	m	8
No. boom sections	-	3
Nr. Port-nozzles	-	31
Pressure and flow regulator	-	3-way
Clean water tank capacity for the human operator	l	10
Solution indicator	-	through transparency
Platform structure	-	steel, galvanized

The tests for the innovative horticultural technical system (intelligent equipment) of analysis, prediction and biodynamic action, were carried out under the following conditions:
- the land used was cultivated agricultural land and the test track which is a flat surface covered with concrete,
- air temperature: 23.1 °C;
- air humidity: 45%;
- wind speed 0.6 m/s.

The charging time of the batteries was measured with the help of a multimeter and a timer but also with the help of the communication interface with the PC connected to the BMS. The charging times corresponding to the three power regimes were determined.
The movement speed is determined by calculation, timing the time required to cover the distance of 50 m. Three measurements were made, reporting the average of the measured data. The speed is calculated with the formula:

$$V = (3.6 \ x \ d)/t \text{ [km/h]} \quad (1)$$

where: *V* – movement speed [km/h];
d - travelled distance [km];
t - travel time [s].

Determination of electricity consumption from the network

The power absorbed (*P*) from the network is measured, then the electrical energy consumed (*W*) is calculated with the formula:

$$W = (P \ x \ t)/3600 \text{ [kWh]} \quad (2)$$

where: *P* - is the power absorbed from the network [kW];
t - operating time [s].

The charging energy that ends up being stored in the battery is determined by a charger efficiency coefficient (μ).

$$\boldsymbol{Pb} = W \ x \ \mu \tag{3}$$

where: Pb - is the energy with which the battery is charged;
W – consumed energy, [kW];
µ - the efficiency coefficient of the charger [0.93].

The flow rate of the pump was determined by the volumetric method at the input speed of 540 rpm. The liquid discharged by the pump was captured through the hoses that lead it to the boom for 1 minute in a vessel and was measured with capacity units from the laboratory's equipment. The tests were performed at a pressure of 2 bar.
The volumetric yield of the pump was determined by calculation using the relation:

$$\boldsymbol{\eta_v} = Q_r / Q_t \ \ x \ 100 \ [\%] \tag{4}$$

where: Q_t = the real flow rate of the pump [l/min];
Q_r = the theoretical flow [l/min];
$Q_t = \pi ø^2 / 4 \ s \cdot n \cdot i$ – where:
Ø = (interior) pump cylinder diameter [dm];
s = piston stroke [dm];
n = pump crankshaft speed [rot/min];
i = number of pump cylinders (i=3).

Image classification is a key component in the field of artificial vision algorithms to develop applications such as: surveillance, traffic monitoring, collision avoidance, face recognition, augmented reality, eye tracking, medical imaging, agricultural industry, etc. The evolution of cameras on the market and the emergence of new cameras requires the development of new algorithms that produce similar results, regardless of camera brand, in the same quality class. The artificial vision algorithm testing procedure must take into account testing on different cameras but also in specific situations that appear in reality.
The algorithm proposed for the intelligent system is running on the laptop which processes the data from the camera. Depending on whether weeds are detected, the command is sent to the Arduino control board, which controls the relays to operate the spray heads.
The recognition process takes about 100 - 50 ms per image (or 10 - 20 fps) to detect a weed target before a new image is captured and is ready for processing, which allows the data to be processed to enable command in real time for real situations.
To test the robustness of the algorithm, 4 cameras were tested, one of them - Eboda Sj6100, being the adventure camera with angle of view. The camera used is a LOGITECH HD Pro C920 Web camera, but to test the robustness of the developed algorithm, the Eboda Sj6100, VHD J1702C and Microsoft LifeCam HD-3000 Web cameras were also used, only for a limited set of tests.

Fig. 2. Cameras used

3. Results

The results obtained from the measurements performed for the charging times are presented in table 2.

Table 2: Charging time of the system

No.	Characteristic	M.U.	The value of the parameters determined during testing the 96 Vdc battery of the mobile structure electrically operated		
1.	220V 6A power supply	hours	5.6	5.8	5.6
2.	220V 16A power supply	hours	2.07	2.09	2.05
3.	220V 32A power supply	minutes	59	58	58
No.	**Characteristic**	**U.M.**	**The value of the parameters determined during testing the 48 Vdc battery of the dosing system and biological protection of plants**		
1.	220V 6A power supply	hours	2.8	2.7	2.8
2.	220V 16A power supply	minutes	63	61	63
3.	220V 32A power supply	minutes	33	32	33

The results obtained from the determination of the travel speed are presented in table 3.

Table 3: Movement speed results

No.	Characteristic	M.U.	Maximum speed	Average speed
1.	Calculated speed	km/h	25.3	24.6

The results obtained from the determinations for the consumed energy and for the stored energy are presented in table 4.

Table 4: Consumed energy and the stored energy registered for the system

No.	Characteristic 96 Vdc battery of the mobile structure electrically operated	M.U.	Consumed energy [W]	Stored energy [W* µ]
1.	Energy consumed at 220V 6 A	kWh	1320	1227
2.	Energy consumed at 220V 16A	kWh	3520	3273
3.	Energy consumed at 220 V 32 A	kWh	7040	6547
No.	**Characteristic 48 Vdc battery of the dosing system and biological protection of plants**	**M.U.**	**Consumed energy [W]**	**Stored energy [W* µ]**
1.	Energy consumed at 220V 6 A	kWh	1320	1227
2.	Energy consumed at 220V 16A	kWh	3520	3273
3.	Energy consumed at 220 V 32 A	kWh	3612	3360

The innovative horticultural technical system (intelligent equipment) of analysis, prediction and biodynamic action was also tested in the field (figure 3), with all the microvalves turned on in the MANUAL working mode, being equipped with foliar fertilization nozzles and being used for the application of ecological fertilizer in a green crop. The purpose of the experiments was to verify the machine's functionality in the field, its autonomy and its behaviour under maximum load.

Fig. 3. Innovative system - field experiments with fertilization nozzles

Table 5 shows the data corresponding to the autonomy of the intelligent system with a single battery charge of 6.7 kWh. The productivity of the spraying work was calculated using actual working speeds measured during the experiments and the 8 m working width of the machine. Also, the total area was calculated as the productivity of the spraying work multiplied by the autonomy of the machine, considering the assumption of working in a straight line, without taking into account the time required to turn the machine at the end of the field.

Table 5: Autonomy of the intelligent system

Work	Autonomy of the electrically operated mobile structure, *h*	Autonomy of the dosing system and biological protection of plants, *h*
Movement	3.00	-
Foliar fertilization/phytosanitary treatments	2.5	2.5

The results obtained from the determinations for the volumetric yield are presented in table 6.

Table 6: Autonomy of the experimental model

Pressure (bar)	Flow at the pump (l/min)				Measurement uncertainty	Volumetric yield (%)	Measurement uncertainty
2	R1	R2	R3	Average			
	28.3	28.1	27.6	28	0.42 l/min	17.85	0.42 %

The hardware system together with the software system and the developed neural network form a hardware-software system - KIT, neural network for the experimental model of innovative horticultural technical system (intelligent equipment) of analysis, prediction and biodynamic action which has the role of monitoring, analysis and control for the experimental model of innovative horticultural technical system (intelligent equipment) of analysis, prediction and biodynamic action of dosage and biological protection of plants.

The verification of the system functionality was done in the manual operating mode, starting and stopping each microvalve individually through the graphical user interface. The continuity of the electrical control circuits, the hydraulic circuits of the sprinkler system, the functionality of the microvalves, as well as the communication between the PLC and the touchscreen operating terminal were thus verified.
After testing, in laboratory conditions, (constant brightness) the false-positive detection situation for the cultivated plant, at different rotations, the result was that the algorithm has 100% accuracy for the same plant. 10 different plants were tested for 12 rotations for each plant. It shows from here that the positioning does not lead to false-positive cases.

Fig. 4. a) Placement of the scene in laboratory conditions   b) scene filmed by the camera

The algorithm tested for weeds recognition showed a similar precision, with very small differences, which is considered to be due to the positioning of the plants due to natural wind conditions and due to the appearance of the focusing phenomenon when the cultivated plant is very close to the camera. The Eboda Sj6100 type camera presented a lower detective rate because of the distortion errors, due to the large viewing angle, but this case really shows the robustness of the algorithm.

4. Conclusions

From the tests carried out, the following can be stated:
- the system registered good charging times for power supplies of 220V 16A and 220V 32A both for the 96 Vdc battery and for the 48 Vdc battery;
- the system has similarly good autonomy, that can be translated into good crop coverage in one pass with one battery charge;
- the detection algorithm works even if the camera takes information above the plant or above the interval between crop rows, in different situation, the results being less conclusive during night-time, due to the different characteristics of artificial lighting.
- the volumetric yield registered good values, similar to those of conventional spraying machines;
- the system is a viable ecological solution for crop maintenance in terms of fertilization and treatment application, being suitable both for conventional and organic crops.

Acknowledgments

This work was financed by The Ministry of Research, Innovation and Digitalization through Program 1 - Development of the national research-development system, Subprogram 1.2 - Institutional performance - Projects for financing excellence in RDI, Contract no. 1PFE/30.12.2021.

References

[1] Mogârzan, Aglaia. *Phytotechnics / Fitotehnie*. Iași, Ion Ionescu de la Brad Publishing House, 2012.

[2] Berar, Viorel, and Gheorghe Poșta. *Vegetable cropping / Legumicultură*. Timișoara, USAMV Timișoara, 2005.

[3] Jianshu, Chen, Wang Jianlun, Wang Shuting, and Liu Hao. “The Matching Research of Strawberry Diseases Image Features Based on KD-Tree Search Method”. Paper presented at Computer and Computing Technologies in Agriculture VII. 7th IFIP WG 5.14 International Conference, CCTA 2013, Beijing, China, September 18-20, 2013.

[4] Rees, S.J., C.L. McCarthy, X.P.B. Artizzu, C.P. Baillie, and M.T. Dunn. “Development of a prototype precision spot spray system using image analysis and plant identification technology.” Paper presented at Agricultural Technologies in a Changing Climate: The 2009 CIGR International Symposium of the Australian Society for Engineering in Agriculture, September 13-16, 2009, Brisbane, Australia.

[5] Persu, Catalin et al. “Intelligent system for the active control of phytosanitary treatment works in field crops, depending on their degree of weed infestation / Sistem inteligent pentru controlul activ al lucrărilor de realizare a tratamentelor fitosanitare in culturile de câmp, funcție de gradul de infestare cu buruieni al acestora.” Contract PN 16 24 01 05, 2016.

[6] Latha, Mrs., A. Poojith, B. V. Amarnath Reddy, and G. Vittal Kumar. “Image Processing In Agriculture.” *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering* 2, no. 6 (June 2014): 1562- 1565.

[7] Wang, Jianlun, Jianlei He, Yu Han, Changqi Ouyang, and Daoliang Li. “An Adaptive Thresholding algorithm of field leaf image.” *Computers and Electronics in Agriculture* 96 (2013): 23-39.

[8] Jain, A.K., R.P.W. Duin, and J. Mao. “Statistical pattern recognition: a review”. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 22, no. 1 (January 2000): 4–37.

[9] Mustafa, M., A. Hussain, K. Ghazali, and S. Riyadi. “Implementation of Image Processing Technique in Real Time Vision System for Automatic Weeding Strategy.” Paper presented at IEEE International Symposium on Signal Processing and Information Technology, Giza, Egypt, December 15-18, 2007.

[10] Shinde, A., and M. Shukla. “Crop detection by machine vision for weed management.” *International Journal of Advances in Engineering & Technology* 7 (2014): 818- 826.

[11] Perez, A., F. Lopez, J. Benlloch, and S. Christensen. “Colour and shape analysis techniques for weed detection in cereal fields.” *Computers and Electronics in Agriculture* 25 (2000): 197-212.