Digital technology for the disposal of the non-cereal portion of the crop as fertilizer

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Abstract. The possibility of using digital technology in the utilization of the non-cereal part of the crop as fertilizer is being considered. The algorithm of the analytical unit of the machine for utilization of the non-cereal part of the crop (AdU NCHU) as a fertilizer is presented, on the basis of which a software module was developed. This machine allows one to perform a set of operations in one pass, converting plant residues lying in the swath into organic fertilizer. The performance of the analytical unit and software in the field was assessed. Based on the obtained data, models of straw rolls were built, which were compared and the total deviation in the indicators did not exceed 3.8%. The range of pressure values varied from 0.18 to 0.26 MPa. Field tests of the software module of the analytical unit AdU NChU showed reliable and adequate operation.

1. Introduction

Currently, the population of our planet is increasingly worried about the environmental situation, since the quality of our life depends on it. We live on earth and it is no secret that all the products we consume in food, both plant and animal origin, go through a closed cycle, starting and ending in soil. Therefore, soil pollution directly affects the quality of food we consume, and therefore our health. One of the directions for greening agricultural production is organic farming, which involves the use of organic fertilizers) \cite{1-4}.

We will consider the technology of growing crops. So, when harvesting, we notice that more than half of the harvested biological crop falls on the by-products of crop production, its non-grain part. At the same time, the soil, for the formation of the crop, has given nutrients and needs to be compensated. When using crop residues as fertilizer, a number of difficulties arise. So, for example, the process of decomposition of plant residues takes a long time (up to several years), together with putrefactive processes and the release of phenolic compounds, which inhibit the development of subsequent cultures. Thus, the non-cereal part of the yield (NPY) used as fertilizer, on the one hand, is a source of elements and organic matter lost by the soil, and on the other, it “throws out” the field from the crop rotation at least one year. To accelerate the decomposition process, various fertilizers and biological products are introduced, but in view of the prevailing environmental requirements, biological products and products are of more interest.
The use of digital technologies in agricultural production is expressed by the use of many different sensors that allow you to monitor the process, the condition of plants, animals, soil, various external factors. The entire amount of information received implies the use of high computing power for their analysis and further decision-making. At present, in the agro-industrial complex, digital technologies are actively introduced in the field of animal husbandry, when using the sensors to track the location of animals, their vital indicators, etc., however, in the field of crop production, these technologies are used much less.

We will consider the use of digital technology in crop production when disposing of the non-cereal part of the crop as fertilizer.

2. Materials and methods

At Ryazan State Agrotechnological University named after P.A. Kostychev a machine for utilization of the non-cereal part of the crop (AdU NCHU) was developed as a fertilizer, which is a serial shredder-mulcher intended for work on straw felling [5]. It is additionally equipped with a complex for preparing for the use of nanoparticles as a fertilizer (it is a system for supplying a working solution of a drug that accelerates the decomposition of plant material, and made in the form of an injector ramp with sprays), a module for differential application of a working solution (includes a scanning device, analytical unit and actuator for adjusting the working pressure) and a complex for embedding finished fertilizer in the soil (made in the form of a disk implement and installed optionally). In the field experiments, MTZ-82.1 + AdU NCHU (figure 1) was used without a complex for embedding finished fertilizer in the soil (made on the basis of the Kverneland fx 230 serial shredder-mulcher), the embedding was carried out by an additional machine and tractor unit (MTA) K-744 + BDP6x4.

![Figure 1. A machine for utilization of the non-cereal part of the crop (AdU NChU) as fertilizer, the numbers indicate: 1 - scanning device; 2 - signal converter; 3 - analytical unit; 4 - actuator; 5 - injector ramp.](image)

Let us consider in more detail the operation of the module for differentiated application of the working solution, since it is this element that uses digital technologies in its work [6].

When the ADC of the low-frequency control unit moves along the roll, the scanning device measures the distance to the roll at its extreme points and at the top (the low-frequency roll is represented as a half of an elliptical cylinder with a large base radius equal to half the width of the roll - \( B_B/2 \), smaller than the height of the roll - \( H \), and a height of form of the aggregate path traveled \( S = V_p*t \)). The received signal is converted (using a signal converter, which is based on the Arduino Uno R3 board) and transmitted to the analytical unit (can be presented in the form of a laptop), where the height of the roll is determined:

Более детально рассмотрим работу модуля для дифференцированного внесения рабочего раствора, так как именно этот элемент в своей работе использует цифровые технологии [6].
where $H_1$, $H_2$ – distance from the range finder to the soil along the edge of the roll, m; $H_u$ – distance from the range finder to the central part of the roll, m.

Next, the working pressure is calculated to meet the application rate of the working solution based on the volume of incoming plant material:

$$P_p = \frac{N^2 \cdot m_{phy}^2 \cdot \rho_p \cdot f_p - p}{2 \cdot \mu^2 \cdot s_c \cdot n_f \cdot t^2}$$

where $\mu$ – nozzle flow rate, $\mu = 0.05...0.8$; $n_f$ – the number of nozzles installed on AdU NCHU, pcs; $S_c$ – nozzle nozzle area, m$^2$; $P_{p}$ – pressure of the working solution in the nozzle at the time of spraying, Pa; $t$ – time, s; $m_{NCHU}$ – NCHU weight, coming to AdU NCHU, kg; $N$ – the rate of application of the working solution, kg/ha; $\rho_p$ – density of working solution, kg/m$^3$.

The software module of the analytical unit of the unit for utilization of the non-grain part of the crop as fertilizer is written in the C++ programming language, the program window is shown in figure 2, and figure 3 shows the algorithm for its operation. The program program code includes more than 1,500 lines of code and consists of three main blocks: a block for obtaining source data from the device and/or water manually by the operator; processing unit according to the algorithm shown in figure 3; block output and/or transmission of information.

![Figure 2. Window of the software module of the analytical module AdU NCHU.](image)

In August 2019, on the experimental field of the URC “Agrotehnopark” of the Federal State Budget Educational Institution of Higher Education and Research, there were conducted production tests of AdU NCHU (in the configuration shown in figure 1, the termination was carried out by an additional MTA K-744 + BDP6x4). Spring barley straw, grade “Vladimir”, was used as fertilizer, the rolls were formed by an Acros 595 plus combine harvester on a field of 4.5 ha and a head length of 400-450 meters (roll width 1.5 m). Several types of biological preparations were used to prepare the working solution: Agrinos 1, Sternifag, Ekorost, and BTU Biocomplex. The control plot was crushed without treatment with a working solution.
Figure 3. The algorithm of the analytical unit.

The performance of the analytical unit and software was evaluated by comparing the obtained roll models. First, the rolls were measured “manually” with a profilometer, measurements were taken every 10 meters, then with the help of a scanning device and a program (AdNU NCHU moved at a speed of 8.5 km/h (obviously higher for testing equipment in difficult conditions), every 10 seconds indicators were read). The profiler was a rectangular contour with 9-dimensional rails, which are located after 0.2 m (figure 4). The analysis of the obtained data and the construction of models was carried out in Microsoft Excel. The working fluid supply pressure was set manually, and the working pressure values obtained in the analytical unit were recorded in a file for further evaluation.
3. Results
Models of harvested rolls were obtained (figure 5). Figure 6 shows the roll profile obtained from averaged data using a scanning device (i.e. digital technology) and a profilometer (“manual” method). Areas in which deviations have been identified are highlighted in red.
4. Discussion
As it can be seen from figure 5, no significant deviations (not more than 3.8%) are observed at the edges of the roll, which does not affect the accuracy of the scanning device, since the main geometry of the roll profile is determined by its height at the top.

5. Conclusion
During field tests of the software module of the analytical unit AdU NCHU it was found that the scanning device is working properly and interacts with the analytical unit. General deviations do not exceed 3.8%. The software module of the analytical unit is working properly, and the obtained values of the working pressure correspond to reality, the range of variation of the pressure values was 0.18 - 0.26 MPa. Due to the preliminary filtration of the working solution before refueling the technological capacity, it was possible to avoid clogging of the main filter (this problem arose in tests in 2018).

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