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EVALUATION OF SEED FLOW UNIFORMITY DISTRIBUTED BY SEED DRILL INCLINED FLUTED ROLLER AT COMPUTER AIDED INSTALATION

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Abstract: *Seed distribution uniformity on the soil surface is one of the main factors that influence the yield of agricultural crops. Fluted roller metering device used in construction of the seed drill have a coefficient of variation of the space between seeds of more than 70%. The research purpose is to establish the distribution uniformity of dosing device, without researcher involvement, at the computer aided experimental installation. The research process automation, by using microcontroller, allowed setting functional parameters such as rotation speed and air velocity and data acquisition from the piezoelectric sensor. Research results, conducted on computer-aided installation, show that grooves and seed tube inclination angle reduce distribution uniformity coefficient of variation by 20-30%.*
Key words: *seed drill, microcontroller, fluted roller, flutes angle, distribution uniformity, seed.*

1. INTRODUCTION

According to the United Nations, continuing global population growth and urbanization will lead to increases the annual gradual pressure of the demand for agricultural products, by 50% in 2030 and anywhere between 59% to 98% by 2050 higher than in 2005/07. Farmers worldwide will need to increase crop production in deteriorating soil, declining land availability, and growing climate fluctuation.

Gradual pressure of the demand for agricultural products, by 50% in 2030 and anywhere between 59% to 98% by 2050 higher than in 2005/07, imposes new requirements on the agricultural industry, both in terms of the technologies used for the establishment of crops, and in terms of the machines used. The yield of grain crops depends to a large extent on the quality of field work, and the latter depends on machine components construction. The main trends worldwide refer to the gradual adjustment of agricultural machinery to the needs of the agricultural industry 4.0 (Industry 4.0, Agriculture 4.0) [1, 4, 9, 29]. Achieving this goal involves modernizing the machines and equipping them with autonomous electronic systems for monitoring and acting on the technological processes [5, 10, 11], thus creating the possibility of increasing the precision and working speed of the sowing machines without changing the construction of the mechanical devices. Automatic management of distribution systems in planters involves making decisions about how the quantities involved in the operation of that process must evolve and, therefore, issuing commands to ensure the desired evolution. Management decisions can only be made on the basis of information obtained from within the managed process, information that refers to the values of significant parameters for the characterization of the process. The respective information is obtained as a result of some measurement operations.

The uniformity of the seed flow distributed by the fluted roller is a critical aspect in seed drill construction, as it determines how the seed is sown in the field and can therefore affect crop yield. By using a computer-aided control system, the planter can be assured of an even flow of seed and a constant speed of fluted roller so that each flute distributes the same amount of seed [12, 13]. In addition, sensors can be used to detect potential blockages or problems in the seed flow and adjust parameters to maintain uniformity of seed distribution. In this regard, the installation of a computer-aided control system can significantly improve the uniformity of seed distribution.

Despite numerous studies in this field [2, 3, 4, 13, 19, 20], there are still many problems related to ensuring the functional quality of distribution systems. Thus, according to the research carried out within the Laboratory of Agricultural Machinery [6, 7, 8, 21], the non-uniform distribution of seeds along the row in the distribution systems of a seeders for cereal crops can reach up to 70-80% [6, 7, 17, 21]. This state of affairs is mainly caused by the operation process of the dosing devices and the transport systems to the embedding organs. From the moment of exit from the metering device until it is fixed in the soil, the seeds are affected by a series of factors, such as the unevenness of the metering of machines with fluted roller, the chaotic movement of the seeds through the transport system [7, 20], low precision seeds count sensors [13, 14, 15, 16, 18], the flight path of the seeds when exiting the delivery tube, the impact of the seeds with the base of the compacted furrow, the rolling of the seed after contact with the base of the compacted furrow. For these reasons, the mechanical improvement of the distribution system is a current issue and is of increased research interest.

Even with new technologies brought to us by agriculture 4.0, technics for testing distribution systems in laboratory are still using 80s, 90s century methods with a sticky conveyor belt test stand [3, 17] and staff implications. In most cases belt type stand is updated with different optical, infrared sensors [3, 18] or expensive high-speed camera and software package to evaluate distribution uniformity of seeds [17], increase precision and reduce labor work.

The research carried out purpose to establish the distribution uniformity of dosing device by changing the constructive parameters and maintaining the uniformity of the flow of seeds provided by the machines with fluted roller without researcher involvement, at the computer aided experimental installation.

The experimental research for determining the seed distribution uniformity aims to analyze the influence of the flutes active working angles, mobile flap posterior angle, in delivery tube air velocity and flow reception and conversion device of the dosing apparatus on the seed distribution uniformity on the soil surface. In this sense, experimental determinations were made with the distribution apparatus and the flow reception and conversion device at the computer-assisted installation.

As part of the experimental research, a computer-assisted installation was developed to carry out tests referring to distribution devices performance characteristic for sowing machines.

2. MATERIAL AND METHODS

2.1 The computer-aided experimental installation

In order to eliminate subjective errors, which can be committed by the researcher, the stand for conducting experiments on the distribution system was organized and automated according to the principle scheme with automatic process of organizing experiments (fig. 1).

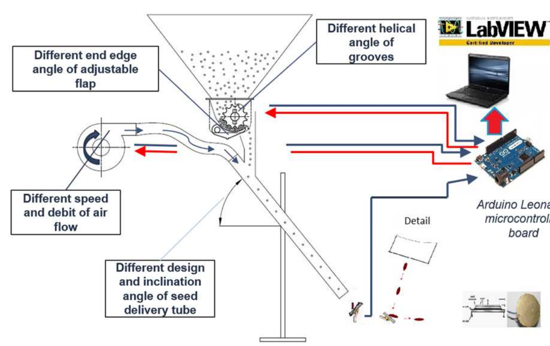


Fig.1. Principle scheme of the organization of experiments and the installation for determining the uniformity of seed distribution under laboratory conditions

The experiments were carried out at the distribution system research installation developed on the basis of the principle scheme of experiments organization within the Agricultural Machinery Testing Laboratory. The monitoring of the experiments was assisted by the computer through the electronic boards (microcontroller) of the Arduino type and the LabVIEW software. With the help of these applications, the entire process of control and data acquisition of experimental research is automated, and human error is excluded.

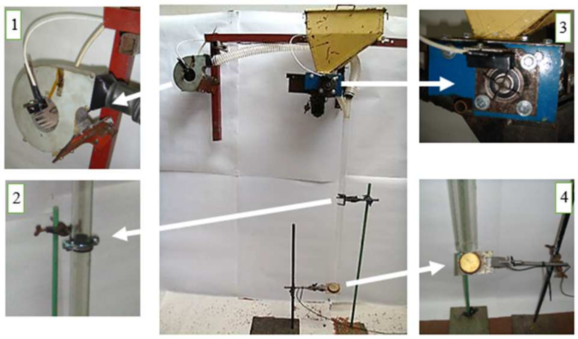


Fig.2. The computer-aided experimental instalation: 1 – fan, 2 – glass delivery tube with fixing device, 3 – device for maintaining and recording the revolutions of the fluted roller drive shaft, 4 – piezoelectric sensor with fixing device

The installation was fixed on a metallic frame (Fig. 2) at a height of 1.5 meters from the floor of the laboratory to ensure the possibility of installing real size delivery tubes, as well as better accessibility and visibility. On the frame was fixed the box with the body of the dosing device, in the sliding bearings of the drive shaft (3), the direct current electric motor with a worm type reducer and the optical transducer. The fan (1) with the optical transducer is fixed on the left side of the frame. The glass delivery tube is held at the bottom of the distributor by the retainer (2). The piezoelectric sensor (3) is located at the seed discharge area. The holder of the guide tube and the piezoelectric sensor provide the ability to adjust both the angle of inclination and the vertical raising or lowering of the sensor.

The Arduino Nano 3.0 type processing board based on the ATMega 328 microcontroller, connected to an HP Probook 6310 notebook via the USB 2.0 plug, was used to drive and regulate the working regimes of the electric motors.

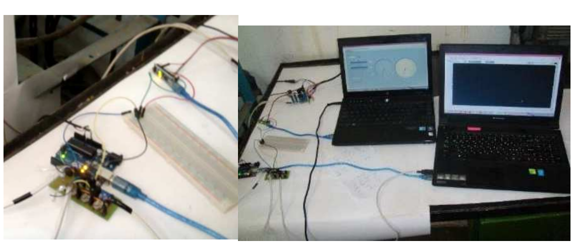


Fig.3. The automated control and acquisition system of the experimental installation

In order to determine the speeds of the fluted roller shaft and fan, infrared optical switches (Fig. 3) were used. For better operation and elimination of parasitic infrared radiation from other sources such as lamps or the sun, were designed and developed covers on 3D printer (Fig. 4) made from black ABS plastic.

The sidewalls of the covers were taller than the electronics to keep interference out, switch pass-through slots, cable slot and mounting bolt holes.

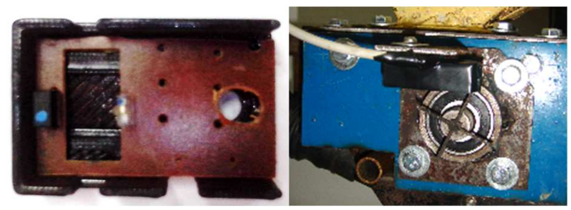


Fig.4. Optical switch and speed transducer assembled from ABS plastic mass housing

The sensors were connected to the elaborated electronic board to provide power to the photoemitter and photodetector from the 5 V source, from the USB port of the computer. The sensitivity adjustment of the speed transducer was carried out by controlling the intensity of the led brightness with the help of the potentiometer through which the power source of the photoemitter passed.


Fig.5. Actuation motor used

For fluted roller shaft actuation, a 24 V DC motor with a worm gear reducer, was used (Fig. 5), while the fan shaft was actuated only by the 24 V DC motor without a reducer.

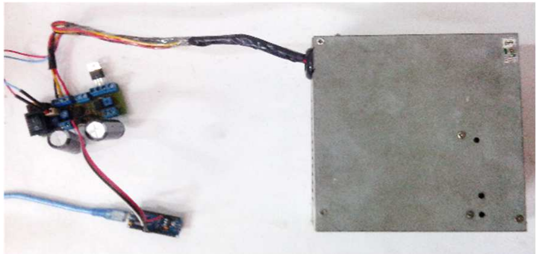


Fig.6. Connection mode of the signal amplifier with the electronic board

The motor was powered and controlled by Pulse Width Modulation (PWM) for DC motors speed with a 5 V signal amplifier from the acquisition board. The voltage was 12-24 V and the current was controlled by an optoisolator of type 4n35 and transmitted to the base of the MOSFET IRF530 transistor through which a DC current of 19 V passed. The transistor modulated the current that passed from source to drain depending on the filling factor of the current applied to the base. The amplifier and electronic board connection are presented in figure 6.
The data acquisition from the piezoelectric sensor was performed through the Arduino Uno R3.0 processing board (Fig. 7) based on the ATMega 328 microcontroller, connected to a Lenovo B5400 notebook via a USB 2.0 port.

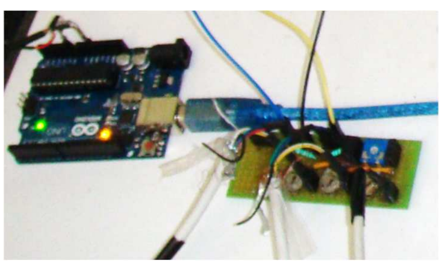


Fig.7. Arduino R3 platform connected to sensors and computer

The piezoelectric sensor was glued with the edges on a plastic mass tube (Fig. 8) to isolate it from vibrations and noises. The plastic mass tube has a length of 10 mm, a diameter of 50 mm, and a wall thickness of 2 mm and was glued to a metal plate. Using a laboratory clamp the plate was attached to the support that allow to be rotated at 360º on XYZ.

For a prototypical visualization of the signal from the speed transducers, as well as those from the piezoelectric transducer, which monitored the seed drop frequency, a two-channel sound card incorporated in the Lenovo B5400 Notebook was used. With the help of the specialized software PowerGraph (Fig. 9), which was adapted to the parameters of the circuits and the signal coming from the transducers, the computer interface was easily transformed into an oscilloscope.

Fig.8. Piezoelectric sensor support device

Thanks to this method it was possible to adjust and test the developed electronic devices in a shorter time.

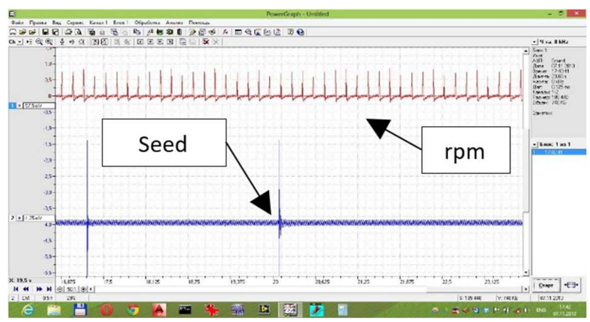


Fig.9. The shape of the signal obtained from the sound card used as an oscilloscope.

2.1 Graphical programming platform

The application developed is intended for data control and acquisition. The block diagram developed (Fig. 10) represents the program nodes, as well as decision structures, mathematical operators, logical processing functions, etc. The code developed for data acquisition and presentation represents the algorithm by which the application will perform the necessary calculations for retrieving and processing information.

The front panel (fig. 11) consists of a control panel with two tabs. The first tab is used to control the speed of the electric motor. Two indicators are placed on it to simulate the fill factor of the slide type with a scale from 0 to 255.

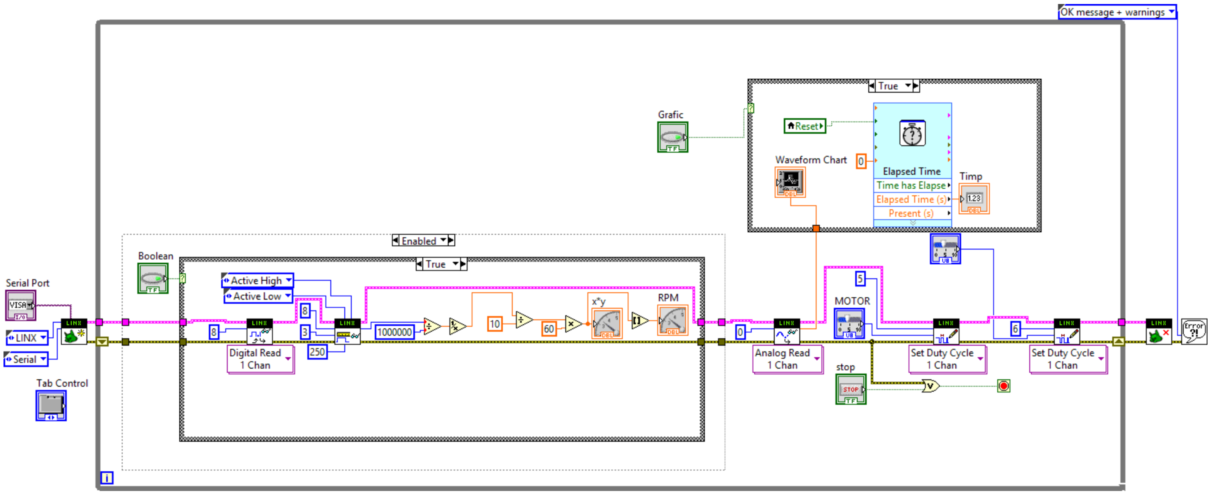


Fig.10. Developed block diagram for data acquisition and presentation

They control the speed of the drive shaft of the grooved cylinder and the speeds of the fan shaft by transmitting a digital PWM signal to pins 5 and 6 of the Arduino UNO control board.

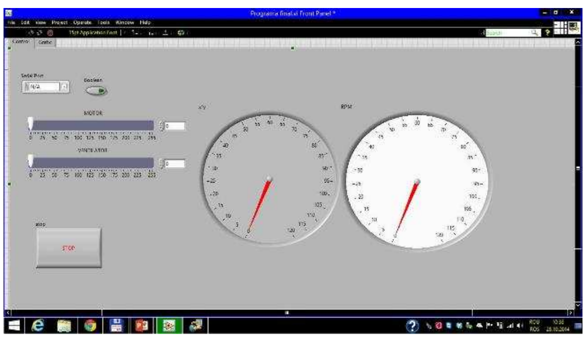


Fig.11. Front panel developed for controlling actuators

The clock-type indicators display the numerical value of the speed of the grooved cylinder drive shaft and the speed of the fan shaft by acquiring data from pins 8 and 9 to which optical switches are connected.

The second panel contains a graphical representation element of the Waveform Chart type (Fig. 12) the voltage value applied to the pin by the piezoelectric sensor are represent by the values of the points after which the straight segment is drawn.

From the graphic element, the data obtained from the piezoelectric sensor acquisition was exported to an .xlsx file, which can later be opened using Microsoft Office Excel.

To ensure communication between LabVIEW and the Arduino electronic board, the Linx source code was compiled and uploaded to the electronic board memory from the LabVIEW MakerHub interface used to interact with common integrated platforms such as Arduino.

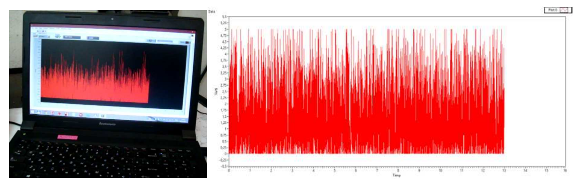


Fig.12. Example of a chart obtained with the Chart element and the Image of the graphic representation exported from the graphic element

The distribution uniformity of the seads at the outlet of the delivery tube was estimated by the coefficient of variation of the time between the impacts applied by seed to piezoelectric sensor. The coefficient of variation was determined as a function of the flutted roler speed, air velocity and inclination angle of the delivery tube. The coefficient of variation was estimated by processing experimental data using the One-Way ANOVA statistical package.

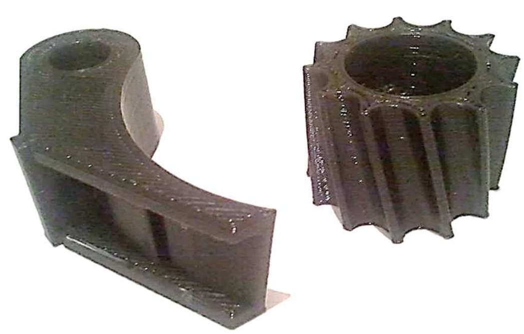


Fig.13. General view of the fluted roller and experimental movable flap

In the dosing devices, an experimental fluted roller was used with a groove twist angle (α_{rc}) of 22º, groove width of 10.6 mm, active groove length (L_{lc}) of 33 mm and working angle of the mobile flap (δ_{lcl}) of 8° (Fig. 13) [6, 7, 8, 21].

The delivery tubes were installed at different inclination angles - 0, 15, 30º (Fig. 14) relative to the vertical axis of seed discharge from the movable flap.

Fig.14. Aspects during experiments with delivery tubes with different inclination angles to the vertical axis of the flow: 1) 0 º; 2) 15º, 3) 30º

For experiments, sorghum seeds with a diameter of 2.5 mm, calibrated with a sieve, and a hectoliter mass of 759.9 g/l were used.

The operating modes of the fan and electric motor of the fluted roller were set by modifying the indices in LabVIEW software. After setting the operating modes, the correctness of the parameters is checked using a digital phototachometer and digital anemometer by performing at least 3 tests.

Data recording was done over a period of 15 seconds, after which an additional check was made on the correctness of the preset operating parameters. The accuracy of the obtained results was ensured by repeating the experiments at least 3 times.

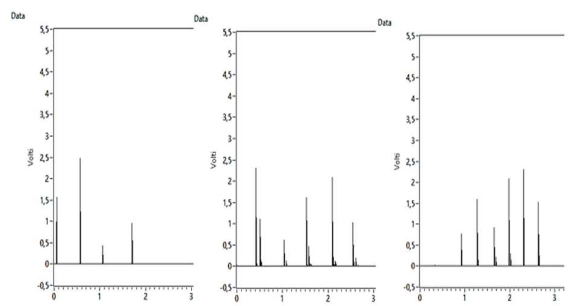
2.1 Calibration of the sensors used in the computer-assisted installation

Calibration aimed to convert the electric signal in the form of an impulse generated by the piezoelectric transducer. The methodology of converting the electric signal consists of establishing the value of the electric signal generated depending on the characteristics of the seed (mass, hardness and shape), which hits the piezoelectric crystal. To establish the level of the signal generated by seed when hitting the plate, through the delivery tube was administered one seed at different time intervals, so that the number of hits in an experiment was not less than 5. The level of signals provided by the transducer can also provide us with information about the number of seeds that hit the transducer.

The simulation of simultaneous impact of two or more seeds was carried out using groups of 2, 3 and 4 seeds glued together (Fig. 15).

Fig.15. The seeds used to calibrate the transducer: a) a seed; b) group of 2 glued seeds; c) group of 3 glued seeds; d) group of 4 glued seeds

The methodology of converting the electric signal with groups of 2, 3 and 4 seeds was similar to that described above for establishing the level of the signal generated by the impact of a seed with the transducer, namely by administering groups of 2, 3 and 4 seeds through delivery tube (Fig. 16).



a) b) c)

Fig.16. The electric signal generated from hitting the piezoelectric transducer with two seeds simultaneously: a) 0º angle of delivery tube; b) 15 º angle of delivery tube; c) 30º angle of delivery tube

To ensure the accuracy of the results obtained, the experiments were repeated at least 3 times for each parameter.

Since the inclination angle of the delivery tube will change in the range from 0 to 30º, thus influencing the impulse force, calibration was performed for each case separately (Fig. 16). Also, to minimize the possibility of multiple seeds hitting the transducer simultaneously, the piezoelectric transducer was placed at an angle of 15…30º relative to the perpendicular to the force of gravity.

In experiments performed with a delivery tube inclination angle of 15, 30º, the piezoelectric transducer was placed perpendicular to the centerline of the tube. The evacuation and rebounding of seeds in the collection box were ensured by the inclination angle of the tube.

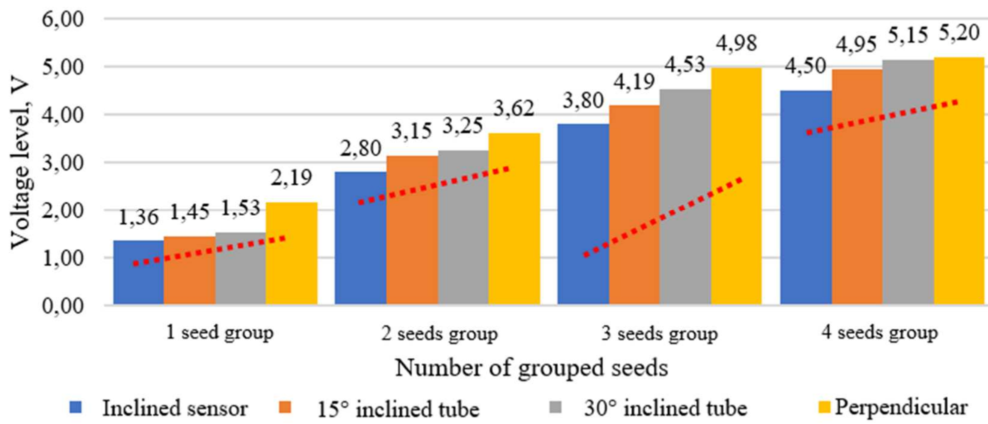


Fig.17. Voltage variation generated by the piezoelectric transducer as a function of the number of seeds and the tube inclination angle.

Obtained data, during transducer calibration, were entered into an Excel program and processed by establishing the arithmetic mean. The results used later in processing data obtained from laboratory experiments are presented in diagram form (Fig. 17).

3. REZULTS AND DISCUSION

In order to have a view of the time coefficient of variation dependence between seeds, the sample of data obtained at the computer-assisted experimental installation was classified and statistically analyzed according to the type of tube inclination angle. The obtained result is presented in figure 18.

From diagram of the delivery tube inclination angle influence on the coefficient of variation of the time between seeds depending on the type of device used (Fig. 18), it can be observed that the polynomial function has a slow descending character at delivery tube inclination angle values ε at 0 - 15° and acquires an abrupt descending character in the interval 15 - 30° of the delivery tube inclination angle. The highest value of the coefficient of variation of the time between seeds (68.97%) is at the inclined delivery tube at an angle ε = 0°.

It can be seen from the diagram that with the increase of the tube inclination angle ε = 15, 30° of the experimental distribution device, the coefficient of variation of time decreases from 68,25 % to 53,48 %, with a difference of 15 percentage points.

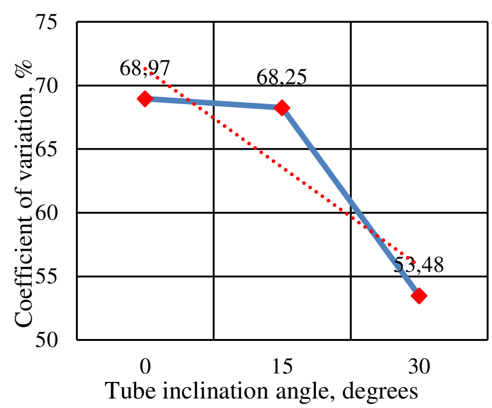


Fig.18. Influence of the tube inclination angle on the coefficient of variation of the time between the seeds

The smallest time coefficient of variation is at the delivery tube which is made at an angle ε = 30°. The value of the coefficient of variation for this type of distribution is 53,48 %. Compared to the standard distribution system, the value of the time coefficient of variation between seeds is 77,83 %.

From the diagram analysis of the delivery tube inclination angle influence on the coefficient of variation of the time between seeds depending on the type of device used, depending on the type of device used (Fig. 19), it is observed that the lowest time coefficient of variation is in the experimental distribution system, in the composition of which also includes the device for receiving and converting the seed flow which is carried out under an angle ε = 30°, and the diameter of the cross-section of the tube at the outlet from the receiving and converting device was ≤20 mm.

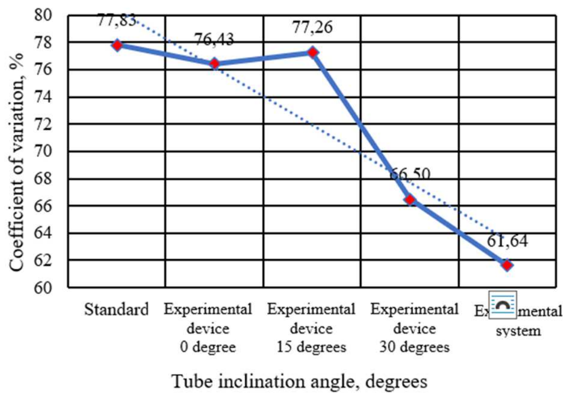


Fig.19. The influence of the tube inclination angle on the coefficient of variation of the time between seeds depending on the type of device used

The coefficient of variation value for this type of distribution is 61.4 %. Compared to the standard distribution system, where the coefficient of variation value is the highest (77.83%), the experimental distribution system has a 16.43 % lower distribution uniformity variation.

The experimental distribution device, which includes the fluted roller and the experimental flapped valve, with the standard guide tube located at an angle ε = 0° to the vertical of the seed flow, the time variation coefficient is a percentage lower than the standard one, i.e. 76.43%.

It can be seen from the diagram that with the increase of the angle of inclination of the tube ε = 0, 15, 30° of the experimental distribution device, the time coefficient of variation decreases from 77.26% to 66.50%.

In order to have a clear picture of the time coefficient of variation dependence between seeds, the sample of data obtained at the computer-assisted experimental installation was classified and statistically analyzed according to the type of distribution device used. The obtained result is presented in figure 20. From the analysis of the diagram, it can be seen that the highest value of the time coefficient of variation between seeds is in the standard device, 77.83%. A lower value of the time coefficient of variation between seeds of 73.25% is in the experimental distribution device with different inclination angles of the delivery tube.

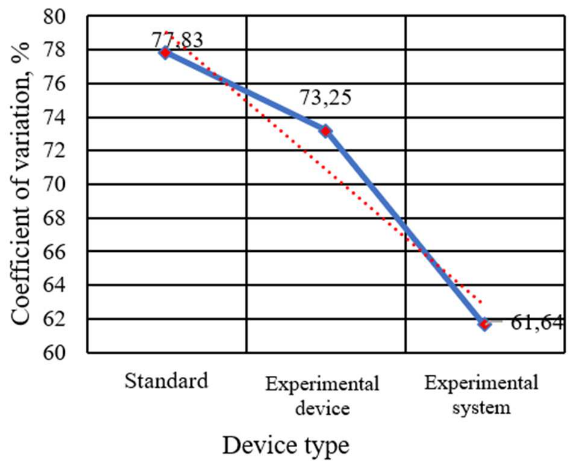


Fig.20. Dependence of the time coefficient of variation between seeds depending on the type of distribution device used

The experimental distribution system in which the seed flow receiving and converting device is also included has the lowest value of 61.64 % of the time coefficient of variation between seeds. The difference between the experimental distribution system and the standard distribution device is 16.22%, and from the experimental distribution apparatus 11.61%.

4. CONCLUSION

The laboratory experiments results demonstrate that the flutes inclination angle of the experimental apparatus fluted roller transforms the seed flow mode from pulsating flow to uniform flow with a significant decrease in the coefficient of variation of time 53.48%, in the experimental distribution system (αrc =22°, δlcl = 8°), with a difference of 16.22% compared to the standard dosing device.

The delivery tube inclination angle against vertical axis of seed discharge from the movable flap in the experimental distribution system has a significant influence on the seed distribution uniformity at the delivery tube exit. The lowest coefficient of variation of time, of 53.48%, was obtained at the delivery tube inclination angle ε = 30° with 24.35 % compared to the standard distribution system where the coefficient of variation of time between seeds is 77.83%.

Forced air flow transport of seeds through the delivery tube to soil embedding area will ensure uniform distribution at sowing, eliminating the phenomenon of chaotic collisions, and will significantly reduce the seeds movement time through the tube. As a consequence, it will be possible to increase the aggregate movement speed to at least 12 km/h, with strict compliance with the agrotechnical requirements for sowing cereal crops.

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Evaluarea uniformității fluxului de semințe distribuit de cilindrul cu caneluri înclinate al mașinilor de semănat la instalația asistată de calculator

Uniformitatea repartizării semințelor pe suprafața solului este unul dintre factorii cei mai principali care influențează recolta culturilor agricole. Aparatele cu cilindru canelat din construcția mașinii de semănat culturi cerealiere are un coeficient de variație a spațiului dintre semințe de peste 70%. Scopul cercetărilor este stabilirea uniformității distribuției aparatului de dozat, fără implicarea cercetătorului, la instalația experimentală asistată de calculator. Automatizarea procesului de cercetare prin utilizarea microcontrolerului a permis setarea parametrilor funcționali ca turația și viteza aerului și achiziția datelor de la senzorul piezoelectric. Rezultatele cercetărilor, efectuate la instalația asistată de calculator, arată că înclinarea sub un unghi a canelurile cilindrului și a tubului de conducere reduce coeficientul de variație a uniformității distribuției cu 20-30%.

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