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RESEARCH ARTICLE

Pre-sowing inoculation system and its associated expenses

Mykola Shelest, Vladyslav Zubko, Andrii Butenko*, Dmytro Zhyhylii, Oksana Datsko

Sumy National Agrarian University, H. Kondratieva Street, 160, Sumy, 40021, Ukraine

***Corresponding author:** Andrii Butenko, Sumy National Agrarian University, H. Kondratieva Street, 160, Sumy, 40021, Ukraine
E-mail: andb201727@ukr.net

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Abstract

Recently, the issue of using bio fertilizers has been raised more and more frequently in Ukraine. But the process of inoculation is quite energy-consuming. Therefore, a model of mechanism for inoculation during sowing was created and coasts for its creation was counted. Modeling of seeding device was created in the program SolidWorks and printed on the Fling Bear Ghost 5. Arduino Nano and sensors were used for creating electronic control of the system model. A model of the pre-sowing inoculation system was created, total amount of expenses was 237, 5 €. The use of 3D modeling and 3D printing are quite convenient technologies for agricultural engineers, as it allows create cheap models of inventions and thus immediately correct possible errors or inaccuracies on full-scale inventions.

Keywords: Seed inoculation, Seeder, Organic farming, Coating, Energy conservation

Introduction

Modern efforts to improve global environmental sustainability and reduce chemical use in agriculture have emphasized the importance of seed inoculation. Although, before the start of the full-scale invasion, Ukrainian farmers did not use bio fertilizers so often (Dobrovolska et al., 2023; Datsko et al., 2024). Inoculants are powerful agents for boosting crop yields and improving agricultural quality, have gained significant recognition. Producers of inoculants usually using effective microorganisms that engage in interactions with plants and establish a symbiotic relationship with them. A concise summary of the influence of microorganisms on plants can be found in the study of (Zakharchenko et al. 2024). Moreover, many authors have demonstrated the effectiveness of using inoculation (Zakharchenko et al., 2023; de Sousa et al., 2021; Azeem et al., 2022).

However, the challenge with inoculation lies in the absence of adequate technical support capable of streamlining this process and ensuring optimal effectiveness in the application of these treatments to seeds. Although some scientists have already attempted to simplify this process for example, Manae (2009) developed a similar system its primary distinction lies in the fact that while Manae's system directly applies bio fertilizer to the soil, the system devised at Sumy National Agrarian University is designed to apply the inoculant directly onto the seeds (Shelest et al. 2022). A comparable system that applies bio fertilizer to the soil was developed by a Serbian scientist; however, the study did not encompass an examination of the system's parameters, particularly regarding the optimal choice of nozzles and the appropriate pressure to employ (Drazic et al. 2017). That is why the system of inoculation was developed and patented. Due to the arrangement of the inoculation system, certain data have already been acquired, offering insights into its capabilities.

Materials and Methods

In order to create the prototype, a vacuum-type seed dispenser was initially designed in Solid Works software. The prototype's casing and mounting components were also designed to ensure stability during operation. Once the design was finalized, it was converted into STL files for 3D printing.

The STL files were employed for 3D printing the prototype components, including enclosures intended to safeguard sensitive elements from environmental factors such as a display or an encoder. The printing process was conducted using the Fling Bear Ghost 5 3D printer. The 3D-printed parts were inspected for accuracy and quality, and any necessary adjustments were made.

The electronic control system was built using an Arduino Nano microcontroller. Various components, including motors, sensors, and solenoid valves, were connected to the Arduino to control the seed treatment process. The Arduino program was developed to regulate the period of nozzle work (treatment occurs solely upon receiving a signal from the sensor indicating the presence of seeds within the sowing tube), pressure, and timing for optimal inoculant dispersion. Wiring and connections were carefully arranged to ensure proper functionality. The code for controlling the sensors and microprocessor was developed using the Arduino IDE (Fig 1).

More detailed information about the system is described in the work (Shelest et al. 2023).

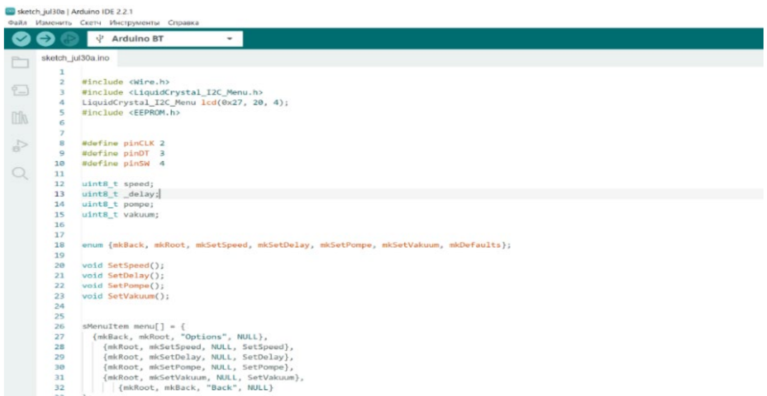

Figure 1. The code segment responsible for controlling the operation of the computer for the pre-sowing inoculation system.

Only the cost of materials and technological expenses were taken into account to establish the prototype's value. The cost of labor, depreciation, and other expenses were not considered. Microsoft Excel was used for calculations.

Results and Discussion

The issue of covering seeds with bio fertilizers is quite relevant (Sohail et al., 2022). So, the outcome of the work resulted in a prototype of pre-sowing inoculation system, that emulates the functioning of a planter, providing valuable support for the exploration of essential parameters destined for a forthcoming configuration (Fig 2). Created prototype has the potential for scalability, as similar models addressing slightly different tasks have already been developed by (Yu et al. 2023, Mirzakhaninafchi et al. 2021, Zhou et al., 2023).

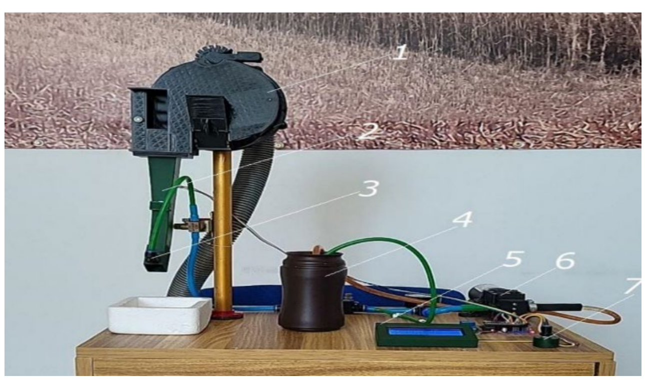

Figure 2. Model of pre-sowing seed inoculation system, where 1 seeding device; 2 sowing tube; 3 nozzle; 4 container for working fluid; 5 monitor; 6 water pump; 7 encoder.

Therefore, the operational principle of the prototype is as follows: once the device is linked to the electrical grid, the researcher triggers the program and configures parameters via the model's computer interface. Paramount among the adaptable variables are the internally generated pressure levels within the system and the temporal extent of nozzle engagement for seed treatment. Additionally, it is worth noting that the nozzle itself can be substituted before the initiation of the prototype's operational phase. By the way, the operation of the nozzles under different pressures was investigated by (Pathan et al. 2019, Han et al. 2020, Butts et al, 2019). These scientists obtained similar results during the investigation of the pressure's impact on the amount of liquid that the nozzle can pass. An outstanding feature of the sowing tube is that it was equipped with a special opening that allows positioning the nozzle at a sharp angle. This design ensures that during operation, the working solution, when sprayed, ricochets off the opposite wall of the dispensing tube, thereby enabling comprehensive seed treatment from all sides (Fig 3). It has to be mentioned that (Wang et al. 2022) also created a sorting tube with an integrated nozzle. However, it was located in a different position and performed different functions.

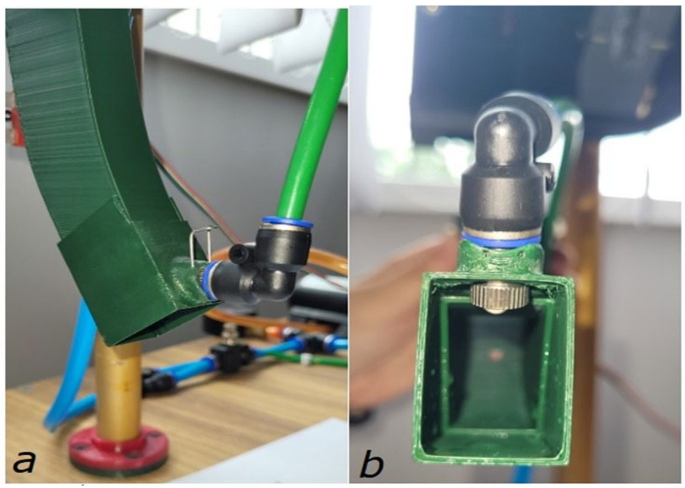

Figure 3. Model of the pre-sowing inoculation system; where a) view from side, b) view from inside.

Following the verification of all adjustments, the activation of a pump comes into play, instating a build-up of pressure within the fluidic framework. At this juncture, the seeding mechanism initiates its course of action; a sensor designed to identify obstacles detects the seeds, consequently transmitting a signal to the computer system signifying the green light for the nozzle to commence its duty. Subsequently, the nozzle unfurls for the designated duration, bestowing its nurturing touch upon the seeds in a carefully orchestrated procedure.

The costs of developing the pre-sowing seed inoculation prototype are provided in (Tab 1).

Table 1. Manufacturing costs of the pre-sowing seed inoculation prototype.

Name	Price, €[1]
Arduino Nano	29.7
Arduino sensors	6.7
LCD display	7.7
High-pressure diaphragm pump	16.2
Mist forming nozzles	40.2
Pressure gauge	5
Quick-release connections	5
Hoses	5
Tap	2.5
Digital pressure sensor	18
Actuator valve	6.7
Tank	7.4

Plastic for a 3D printer	17.5
Motor	15
Wires	5
Vacuum pump	37.4
Power supply	12.5
Total	**237.5**

According to the National Bank of Ukraine currency exchange rate

As can be seen from the table above, the production of the model did not require a large budget, provided that all other necessary equipment was available, such as a 3D printer.

Conclusions

In conclusion, the study's focus on seed coverage with bio fertilizers has led to the development of a pre-sowing inoculation prototype that emulates planter functionality. This innovative system offers valuable insights into essential parameters for future configurations. Its scalability potential is evident, with similar models addressing related tasks previously introduced by other researchers.

The prototype's operational principle involves configuring parameters through a computer interface, including pressure levels and nozzle engagement duration. The design's unique sowing tube, featuring a specialized opening for nozzle positioning, ensures comprehensive seed treatment from all angles. Notably, the study aligns with prior research on nozzle performance under varying pressures.

The manufacturing cost breakdown underscores the affordability of creating the prototype, especially with essential equipment available. Overall, this work advances pre-sowing seed treatment, paving the way for further research and development in the field.

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