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การพัฒนาเครื่องหยอดเมล็ดพืชอัตโนมัติด้วยระบบนิวเมติกส์
Development of automatic seed planting machine using pneumatic system

เมืองมล เสนเพ็ง และ ศิวกร แก้วรัตน์*
Muangmol Senpheng and Siwakorn Kaewrat*
คณะเทคโนโลยีอุตสาหกรรม มหาวิทยาลัยราชภัฏเลย จังหวัดเลย 42000
Faculty of Industrial Technology, Loei Rajabhat University, Loei Province, 42000
*Corresponding author E-mail: siwakorn.kae@lru.ac.th
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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนาเครื่องหยอดเมล็ดพืชแบบอัตโนมัติที่ควบคุมด้วยระบบนิวเมติกส์ สำหรับหยอดเมล็ดพืชลงในถาดเพาะเมล็ด เพื่อลดภาระงานของเกษตรกรจากที่ใช้วิธีการหยอดเมล็ดพืชด้วยมือลงในถาดเพาะเมล็ด เป็นทางเลือกใหม่สำหรับผู้ประกอบการหรือเกษตรกร ทำให้ทำงานได้รวดเร็ว และมีประสิทธิภาพมากยิ่งขึ้น ซึ่งจะช่วยลดต้นทุนการผลิต และเพิ่มผลผลิต การพัฒนาเครื่องหยอดเมล็ดพืชแบบอัตโนมัติที่ควบคุมด้วยระบบนิวเมติกส์ มีขนาด กว้าง 50 ซม. ยาว 90 ซม. สูง 60 ซม. ใช้ถาดเพาะเมล็ดพืช ขนาด 34x54 ซม. ที่มีจำนวนช่องเพาะ 50 หลุม ใช้หัวหยอดเมล็ดพืช 3 ขนาด คือ ขนาด 2.5, 1.32, และ 0.84 มม. สำหรับหยอดเมล็ดพืชลงในถาดเพาะเมล็ดจำนวน 5 ชนิด ได้แก่ เมล็ดเมล่อน ผักกาดหอม คะน้า พริก และมะเขือเทศ และควบคุมการทำงานของเครื่องด้วยโปรแกรม Festo FluidSim 4.2 โดยกำหนดให้หยอดเมล็ดพืชลงในถาดเพาะเมล็ด หลุมละ 1-4 เมล็ด มีถาดสำหรับหยอดเมล็ดแต่ละชนิด จำนวน 20 ถาด รวม 100 ถาด ผลการทดลองหยอดเมล็ดพืช 5 ชนิด ที่หัวหยอดเมล็ดพืชขนาดต่าง ๆ พบว่า 1) เมล็ดเมล่อน มีขนาดใหญ่และยาว ต้องใช้หัวหยอดขนาดใหญ่ หัวหยอดที่แม่นยำที่สุดคือ 2.5 มม. 2) เมล็ดคะน้า มีขนาดเล็กและกลม ต้องใช้หัวหยอดขนาดเล็ก หัวหยอดที่แม่นยำที่สุดคือ 1.32 มม. 3) เมล็ดผักกาดหอม มีขนาดเล็กและกลม ต้องใช้หัวหยอดขนาดเล็ก หัวหยอดที่แม่นยำที่สุดคือ 1.32 มม. 4) เมล็ดพริก มีขนาดเล็กและเบา ต้องใช้หัวหยอดขนาดเล็ก หัวหยอดที่แม่นยำที่สุดคือ 0.84 มม. และ 5) เมล็ดมะเขือเทศ มีขนาดเล็กและเบา ต้องใช้หัวหยอดขนาดเล็ก หัวหยดที่แม่นยำที่สุดคือ 0.84 มม. จากการทดลองทั้งหมด 300 ครั้ง พบว่า เครื่องหยอดเมล็ดพืชมีความแม่นยำ 96% และมีค่าความผิดพลาด 4% สามารถหยอดเมล็ดพืชลงถาด 1 ถาด (50 หลุม) ใช้เวลาประมาณ 1 นาที และหากเทียบกับการทำงานของมนุษย์ใช้เวลาประมาณ 15 นาที

คำสำคัญ : นิวเมติกส์ โปรแกรมจำลอง FluidSIM เครื่องหยอดเมล็ดพืช

ABSTRACT

This research aims to develop an automatic seed planting machine controlled by a pneumatic system for planting seeds into seed trays to reduce the workload of farmers from the method of planting seeds by hand into seed trays. It is a new alternative for entrepreneurs or farmers, allowing them to work faster and more efficiently, which will help reduce production costs and increase productivity. Development of an automatic pneumatic seed planter with dimensions of 50 cm wide, 90 cm long, and 60 cm high. It uses a 34x54 cm seed tray with 50 holes. It uses 3 sizes of seed droppers: 2.5, 1.32, and 0.84 mm to drop seeds into 5 types of seed trays: melon, lettuce, kale, chili, and tomato. The machine is controlled with Festo FluidSim 4.2 program, specifying to drop 1-4 seeds per hole in the seed trays. There are 20 trays for each type of seed, totaling 100 trays. The experiment results of dropping 5 types of seeds with different sizes of seed droppers found that 1) Melon seeds are large and long, require a large dropper head, and the most accurate dropper head is 2.5 mm 2) Kale seeds are small and round, requiring a small dropper head. The most accurate dropper head is 1.32 mm 3) Lettuce seeds are small and round, require a small dropper head, the most accurate dropper head is 1.32 mm 4) Chili seeds are small and light, require a small dropper head, the most accurate dropper head is 0.84 mm 5) Tomato seeds are small and light, require a small dropper head, the most accurate dropper head is 0.84 mm From a total of 300 trials, it was found that the seed dropper has an accuracy of 96% and an error of 4%. It can drop seeds into 1 tray (50 holes) in about 1 minute, and if compared with human work, it takes about 15 minutes.

Keywords: Pneumatic, Festo FluidSim, Seed planter

Introduction

The problem in the current agricultural system is the lack of labor. The method of dropping seeds on seedling trays by hand takes a long time to drop seeds causes fatigue and takes a lot of time to work because the seeds are small. If people are used to drop seeds without expertise there will be a problem of dropping too many seeds into the holes which wastes seeds and results in higher costs. The current technology is a lot of progress and it is easy to find materials and equipment for building agricultural machine. They can be ordered domestically to develop cultivation, save labor for farmers, increase yields, and reduce damage from seedling cultivation.

The researcher has developed system of pneumatically controlled seed planting machine for planting seedlings in seed trays with a width and length of 34x54 cm and 50 holes. This reduce farmers working time and the cost of hiring labor, and to provide fast and efficient work. This will be a new alternative for entrepreneurs or farmers who still use the seed planting method by planting seeds in seedling trays.

There are many research which was shown papers in pneumatically controlled seed sowing machines and the field of work in sowing machine to grow the seeds for this planting tray, followed by:

Kaewrat and Senpheng (2023) proposed that the computer numerical control for automatic seed sowing machine to grow the seeds for this planting tray by TB6560 stepper motor driver board and Arduino Uno and stepping motor for x and z axis. It was concluded that the accuracy of the automatic sowing machine was 89.95%, the error was 10.05%.

Arteaga et al. (2020) proposed that automation of a seed on tray seeder machine to fully automate. It can reduce the number of personnel by 50% compared to the manual method and can drop 87% of the seeds, which is the highest efficiency when using a pressure of 0.2 to 0.3 MPa in the pressure pump.

Wang and Xiong (2023) proposed that low-cost fault diagnosis of pneumatic systems with exergy and machine learning: concept, verification, and interpretation. The result is that multiple downstream cylinder faults can be accurately diagnosed with a single upstream sensor at a low cost compared with pressure and flow data, the xerometer data has high stability and accuracy and is less sensitive to various algorithms.

Szcześniak and Szcześniak (2022) proposed that fast designing ladder diagram of programmable logic controller for a technological process. It presents a method of designing a sequential system, which allows to create a ladder electro-pneumatic system. The ladder diagram consists of two parts: one part is responsible for controlling the valve coils, the other is responsible for the operation of the memory blocks. The signals that control the transition to the next state are the signals described on the boundaries of the graph division. Synthesis of the control system and its verification are carried out using the computer-aided program FluidSim from Festo.

Winarso et al. (2022) proposed that design and fabrication of automatic metal plate cutting machine. The results showed the machine design has several advantages, such as faster production processes, relatively less energy consumption and more efficient use of labor, thus increasing productivity.

Olubunmi et al. (2022) proposed that archetypal model of a breathable air-circuit in an electro-pneumatic ventilator device. It was shown that the pressure platform in the pipe may not appear if the ventilator evacuation time is less than 1.6 s. A 5/2 solenoid valve is considered the best when the flow rate is constant. The prototype model of the pneumatic circuit developed in this research can be effectively applied in the design of patient interface devices, especially in ventilators and neonatal incubators.

Yang and Li (2021) proposed that the research and development of a novel pneumatic-electric hybrid actuator. The results show that the pneumatic-electric hybrid actuator has satisfactory movement characteristics, including high speed, low overshoot and low load sensitivity. The positioning accuracy is ±0.01 mm with a positioning time of 2 seconds, which is better than the current pneumatic positioning actuator and pneumatic-electric hybrid actuator.

Methodology

1. Pneumatic system

In the structure of any modern automation device, it is easy to see that there are many different elements and components that coexist: electrical, mechanical, pneumatic and hydraulic. Pneumatic systems play a role and have a reason for their development, as each technology has advantages that make it more suitable for certain types of applications than others.

The diagram describes the circuit structure of a pneumatic automation system, from the compressed air supply to the functional connections of the components and the dialogues related to the interconnection of the components. In this structural diagram, all the steps that the fluid takes to start and activate the automated system, machine or equipment are observed as Figure 1.

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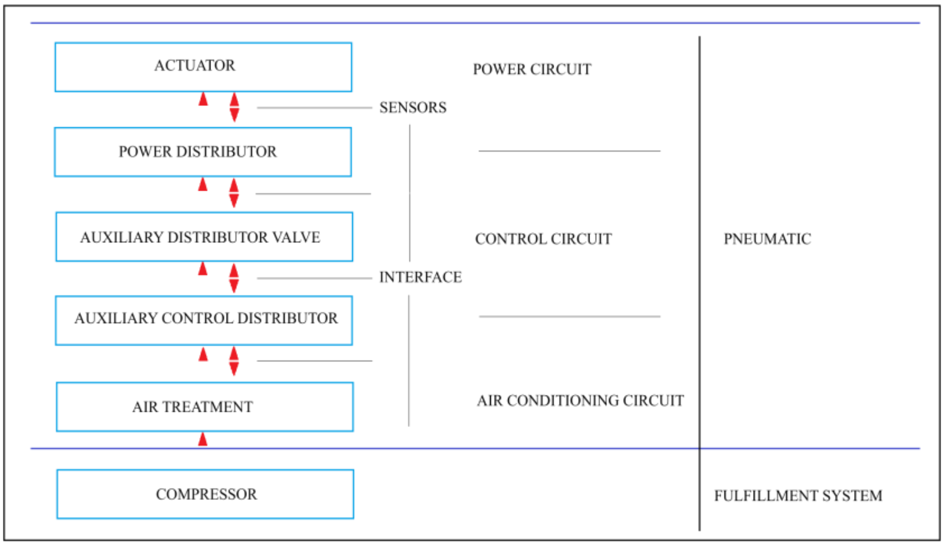

Figure 1 The circuit structure of a pneumatic

Compressed air is an important component for pneumatic run on a compressor. Once the air is compressed, it is sent to the user, the operator involved in the automation system. The power needed to compress a volume of air at the discharge pressure is obtained by means of the following as equation (1).

$$\mathrm{N} = Q \times Pa \times 3.5 \times (r^{2.852} - 1) \tag{1}$$

Pa Suction pressure
Pe Discharge pressure
r Pe/Pa (Pascal) Compression ratio
Q (nm^3/s) Suction flow rate
Ql (m^3/s) Discharge flow rate

Air treatment, the compressed air to be supplied must be treated to remove any foreign particles floating in the air by means of suitable filtration and to reduce and stabilize the pressure, which in the network varies to a lower and constant value than the value in the supply system, and the lubricating mist and oil should be supplied to the moving parts of the equipment. The structure of the air treatment device is as follows: Filter, Regulator and Lubricator.

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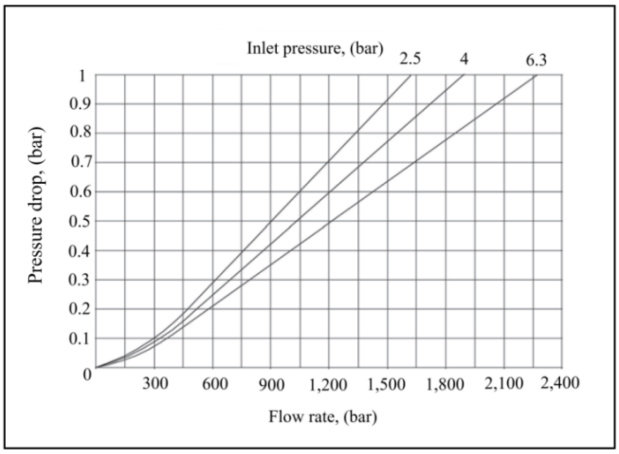

Figure 2 The flow rate diagram

These diagrams are useful in selecting the appropriate filter. If the flow rate requirement may require a standard filter 900 Nl/min with a working pressure of approximately 6 bar, increasing from the flow rate axis up to the curve of 6.3 bar respectively, we can detect a pressure drop of 0.35 bar on the vertical axis respectively. This means that during the absorption of the mentioned flow rate, the downstream filter pressure will decrease to approximately 5.9 bar. Furthermore, the diagram shows that if the air demand increases significantly, the pressure drop also increases and should become unacceptable at a value of approximately 1 bar. In these cases, it is necessary to select a larger device.

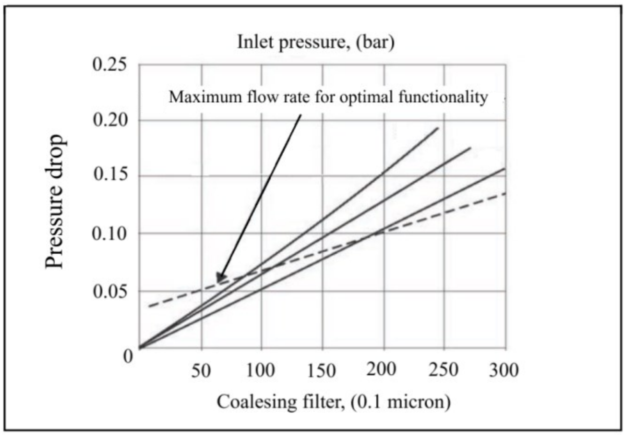

Figure 3 The coalesing filter

For a Coalesing filter of the same size, the flow rate will be lower due to the porosity of the filter cartridge. Therefore, the indications described in the relevant diagram should be observed. For optimum operation, the total flow rate and pressure drop values included in the area below the dashed line are considered valid.

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Actuator, pneumatic components are the final part of the system that performs mechanical functions and performs various operations. The actuators that perform other types of movement or rotation are called cylinders. It is linear and moves in a straight line about its own axis, from the retracted (-) axis position to the extended (+) axis position. The cylinder performs mechanical work by applying a force appropriate to the point of application. The force exerted by a pneumatic cylinder is given by means of the following as equation (2).

$$F = P \times A \tag{2}$$

F (T, kg, N) = Force
P (kg/cm^2) = Pressure
A (cm^2) = Piston Area

Another type of actuator is called run on produced when the pressure value is lower than the atmospheric value and absolute vacuum is produced when there is no atmospheric pressure. Vacuum is defined as the condition of a space free of matter or which contains only rarefied gases. The earth's atmosphere exercises on the planet surface at the sea level pressure equal to 101kPa (1.013bars). The value of this pressure is influenced by altitude for example at a height of 3,000 m the pressure is equal to 70kPa. Atmospheric pressure is strictly correlated with vacuum.

The table below describes the conversions between different units of measurement and the equivalent values for different values as Table 1.

Table 1 The conversions between different units of measurement

Vacuum mbar	Vacuum %	Vacuun kPa	Vacuum mHg	Vacuum torr
0	0	0	0	0
-100	10	-10	-75	-75
-133	13.3	-13.3	-100	-100
-200	20	-20	-150	-150
-267	26.7	-26.7	-200	-200
-300	30	-30	-225	-225
-400	40	-40	-300	-300
-500	50	-50	-375	-375
-533	53.3	-53.3	-400	-400
-600	60	-60	-450	-450
-667	66.7	-66.7	-500	-500
-700	70	-70	-525	-525
-800	80	-80	-600	-600
-900	90	-90	-675	-675
-920	92	-90	-690	-690

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For example, if the air compressor uses 2 Nl/sec of fuel when fed at 6 bar, the compressor must be able to deliver at least 2 x 6 = 12 Nl/min. The energy delivered by pumps is the product of the suction flow rate and the vacuum level as equation (3).

$$\text{Power} = \text{flow rate} \times \text{vacuum level} \tag{3}$$

Vacuum level (bar) = vacuum level
Power (Nl/min) = compressor power
Energy delivered (Nl/sec) = flow rate

We can calculate the efficiency as equation (4).

$$\text{Efficiency} = \frac{\text{Supplied flow rate}}{\text{Consumed flow rate}} \tag{4}$$

Table 2 The power is product of the flow rate and the vacuum level

Flow rate [Nl/s]	Vacuum degree % [-K Pa]	Supplied power [Nl/min]
10.9	0	0
5.7	10	57
3.8	20	76
2.5	30	75
1.4	40	56
1.1	50	55
0.8	60	48
0.48	70	33.6
0	80	0

2. Methods

The methods of pneumatically controlled seeds sowing machines for planting seeds consists of the process of simulating the movement and control of the pneumatic using the fluid simulation software (FluidSim). The fluid simulation software (FluidSim) is one of the computer software for the demonstration of the simulation of fluid flow, especially the flow of air. Festo Didactic, Germany, has developed this pneumatic fluid simulation software. This software is a support program for the demonstration of the simulation of fluid (air), especially in the pneumatic circuit system.

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Results and Discussions

1. Design and results process

The design process of the automatic pneumatically controlled seeds planting machine, the team has divided the operation steps and methods into 9 steps as follows:

1. Start pressing the S3 Start switch to start the operation of the solenoid valve Z3, cylinder B, moving the seeds drop head into the seeds box for 1 second.

2. Vacuum generator, Solenoid valve C sucks up the seeds.

3. Solenoid valve Z3, cylinder B, moves the seeds drop head up for 1 second.

4. Solenoid valve Z4, cylinder A, moves the seeds drop head to the seeds drop pipe for 1 second.

5. Solenoid valve Z2, cylinder C, Vacuum generator releases the seeds into the seedling tray.

6. Motor Z5 moves forward for 1 second to move the seeds drop head to the 2nd row.

7. Solenoid valve Z3, cylinder 1, moves the seeds drop head into the seeds box for 1 second and sucks the seeds into the seedling tray in each row and repeat the operation 10 times.

8. The seeds box will hit the limit switch, input S2, which is attached to the end of the track, to reverse the motor rotation and move to the starting point.

9. When the motor rotates back, it will hit the limit switch, input S1, which is attached to the head of the rail. The motor will stop working and is ready to start a new start tray.

The results of design pneumatically controlled seeds sowing machines for planting seeds using fluid simulation software are shown in Figure 4.

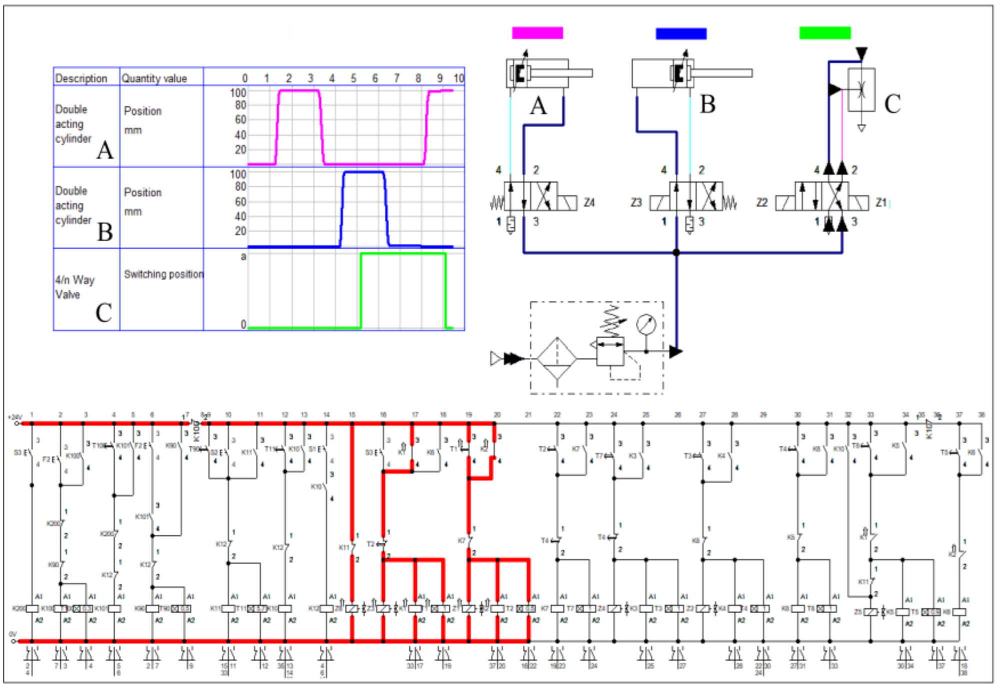

Figure 4 The results of design

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The manufacturing process of this pneumatically controlled seed sowing machines for planting seeds is as follows:

1. Making frame
2. Making the cylinder holders
3. Installation of a tube and fitting
4. Setup the cylinder
5. Assembly process
6. Testing process
7. Finishing

The result of the manufacturing process and the prototype of automatic pneumatically controlled seeds planting machine is shown in Figure 5 and Figure 6.

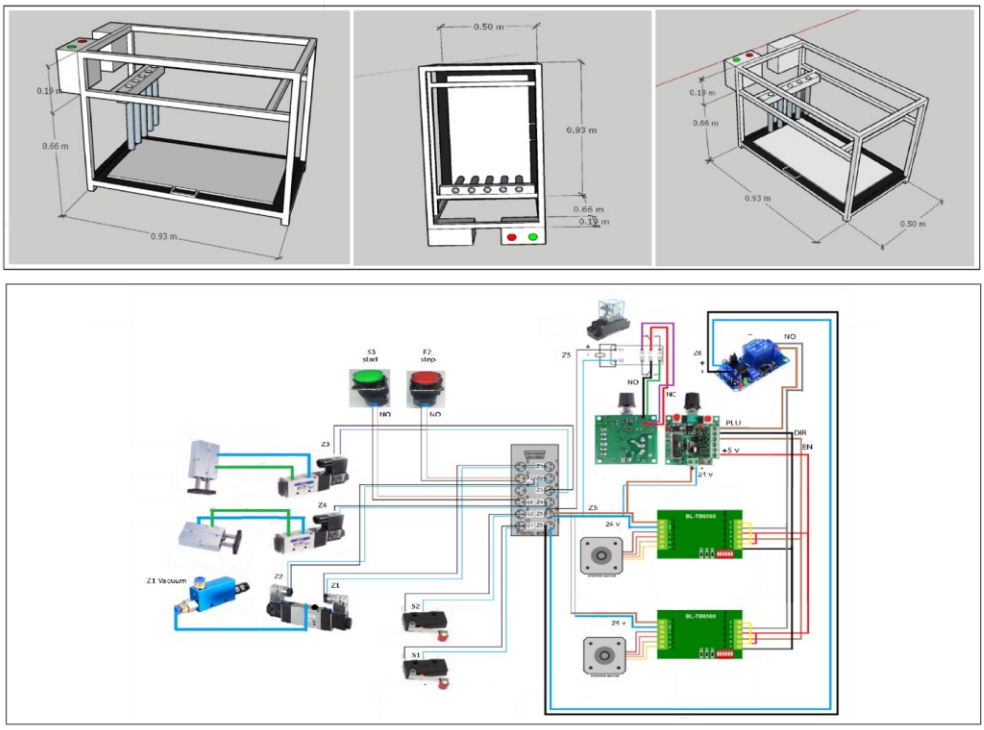

Figure 5 The results of manufacturing process

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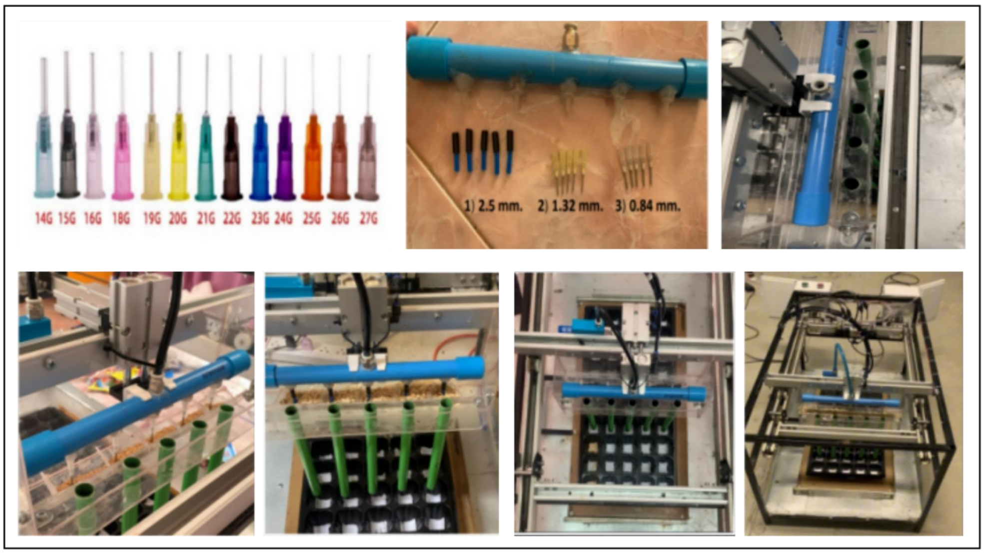

Figure 6 The prototype of automatic seed planting machine using pneumatic system

The result of percentage of seeds planting experiments with a dropper head size of 2.5 mm in Figure 7.

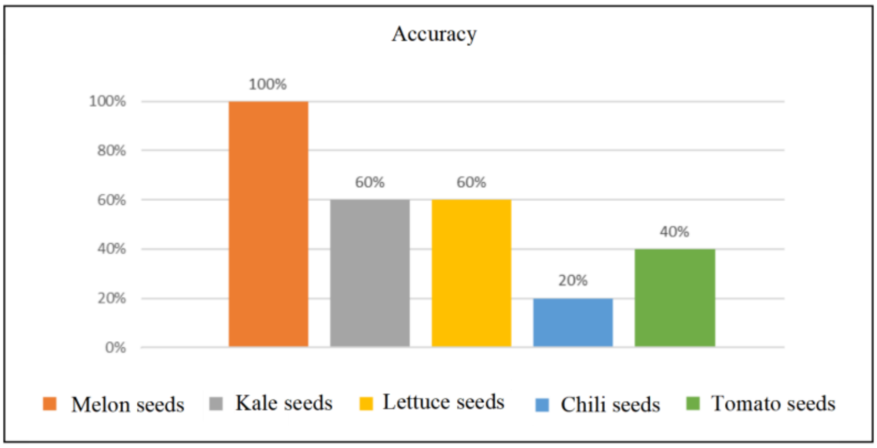

Figure 7 The percentage of seeds planting experiments with a dropper head size of 2.5 mm.

Results of the experiment on dropping seeds of all 5 types, the size of the seeds drop head used for dropping seeds is 2.5 mm Melon seeds are the most suitable and have a high accuracy of 100% because melon seeds are large and long in shape, so a large drop head of 2.5 mm is required.

The result of percentage of seeds planting experiments with a dropper head size of 1.32 mm in Figure 8.

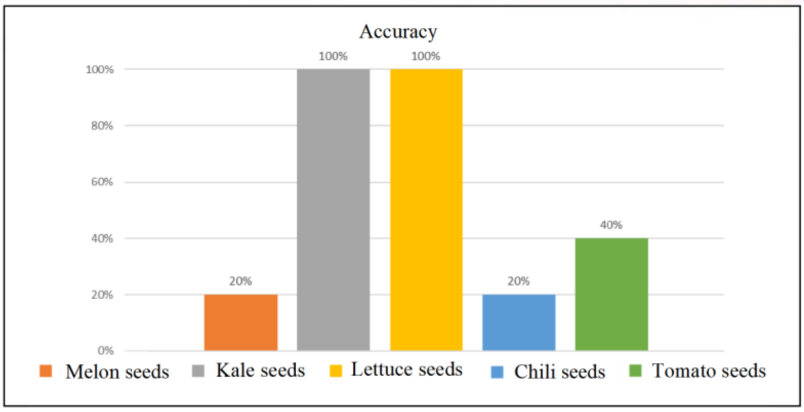

Figure 8 The percentage of seeds planting experiments with a dropper head size of 1.32 mm

The results of the experiment on dropping seeds of all 5 types, kale and lettuce seeds were the most suitable and high accuracy of 100% because of kale and lettuce seeds are small, round, and light, they must use a dropper head is 1.32 mm

The result of percentage of seeds planting experiments with a dropper head size of 0.84 mm in Figure 9.

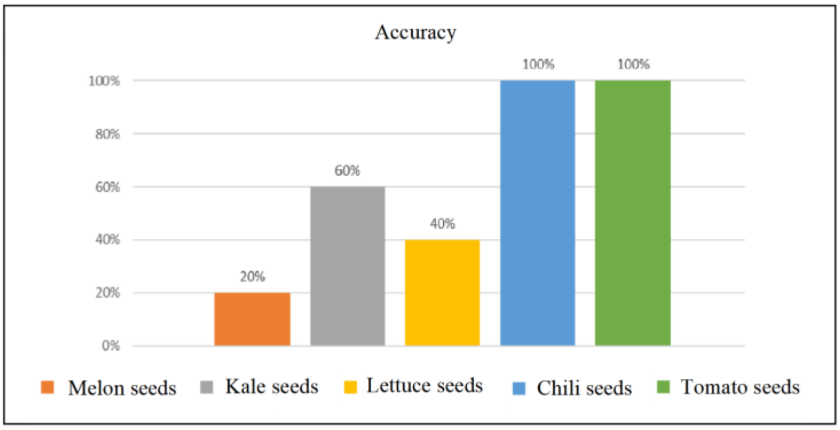

Figure 9 The percentage of seeds planting experiments with a dropper head size of 0.84 mm

The results of the experiment on dropping seeds of all 5 types, kale and lettuce seeds were the most suitable and high accuracy of 100% because of chili and tomato seeds are small, round size and light weight. They must use a dropper head is 0.84 mm

Percentage suitability of each type of seeds to which size of dropper head is illustrated in Figure 10.

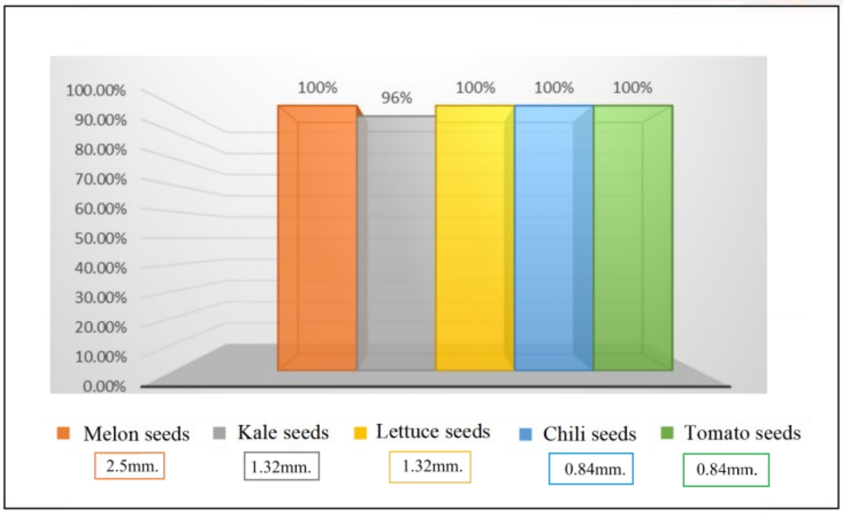

Figure 10 The percentage suitability of each type of seeds to which size of dropper head

The results of the experiment on dropping 5 types of seeds at 3 sizes of dropper heads, namely 2.5 mm, 1.32 mm and 0.84 mm were as follows: 1) Melon seeds are large and long, they require large size droppers. The most accurate dropper head is 2.5 mm. 2) Kale seeds are small and round, they require small size droppers. The most accurate dropper head is 1.32 mm 3) Lettuce seeds are small and round, they require small size droppers. The most accurate dropper head is 1.32 mm 4) Chili seeds, because chili seeds are small and light, they require small size droppers. The most accurate dropper head is 0.84 mm and 5) Tomato seeds are small and light, they require small size droppers. The most accurate dropper head is 0.84 mm.

The experimental results are consistent with the work of Kaewrat and Senpheng (2023) who proposed a computer numerical control system for an automatic seeding machine for sowing seeds in seed trays, using a TB6560 stepper motor control board, Arduino Uno, and stepping motors for X and Z axes. It can be concluded that the automatic seeding machine has an accuracy of 89.95%, a tolerance of 10.05%, and can reduce the number of personnel by 50% compared to the manual method, and the number of seeds can be reduced by 87%, which is consistent with Arteaga et al. (2020) The automatic seeding machine has high stability and accuracy, similar to Wang and Xiong (2023) ; Yang and Li (2021) and the validation is performed using Festo's FluidSim computer-aided program, similar to SzczeŚniak and SzczeŚniak (2022)

Conclusions

The development of automatic seeds planter for seedling trays with pneumatic system, the researcher has tested the automatic seeds planter for seedling trays which can work according to the intended objectives as follows: 1) The results of the experiment of planting all types of seeds 60 times from a total of 300 tests. The operation of the solenoid valve and the movement of the stepper motor moved to the correct position 100%. 2) The machine operation in planting seeds from a total of 300 tests. The accuracy of this automatic seeds planter is 96%.

In conclusion, the results of the experiment on dropping 5 types of seeds at 3 sizes of dropper heads, namely 2.5 mm, 1.32 mm and 0.84 mm were as follows:

1. Melon seeds are large and long, they require large size droppers. The most accurate dropper head is 2.5 mm.

2. Kale seeds are small andround, they require small size droppers. The most accurate dropper head is 1.32 mm.

3. Lettuce seeds are small andround, they require small size droppers. The most accurate dropper head is 1.32 mm.

4. Chili seeds, because chili seeds are small andlight, they require small size droppers. The most accurate dropper head is 0.84 mm.

5. Tomato seeds are small andlight, they require small size droppers. The most accurate dropper head is 0.84 mm.

The most accurate dropper head is 0.84 mm, from a total of 300 tests, the accuracy of this seeds planter is 96% and the error is 4%. It can drop seeds in 1 tray (50 holes) in 1 minutes, when compared to human work, it takes about 15 minutes.

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