RESEARCH ARTICLE

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Automation of liquid fertilizer application aystem in a direct drill machine

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Abstract

An automation system was designed to measure and monitor the amount of liquid fertilizer sprayed on a direct drill machine with the ability to apply liquid fertilizer. The clogging of spray nozzles is a common problem in liquid fertilizer machines. The objective is to detect clogged spray nozzles during the application of liquid fertilizer and to allow the tractor driver to monitor the amount of liquid fertilizer discharged with this designed automation system. It gives a visual warning to the driver when the flow is zero. Flow sensors are mounted on the spray nozzles of the machine. The machine was operated at 540 rpm PTO speed. A total of 30 measurements were taken from each flow sensor with 3 replications. The actual volume was found from the amount of liquid collected in the scaled vessels that are placed under the spraying nozzles and the measured volume obtained from the flow sensors. The calibration curve of the liquid fertilizer system was created by performing a regression analysis with measurements taken from the sensors and scaled vessels. At the same time, the real volume and the volume measured by the sensor were compared with the t-test and analyzed whether there was a statistically $p< 0.05$ difference between the measurements. As a result of the measurements, the volume measured by the sensor was slightly higher than the actual volume. The mean difference was calculated as 0.17 liters and the standard deviation as 0.08 liters. The regression curve between the actual and the measured volume shows that there is a high linear relationship and the regression coefficient was calculated as R2= 0.947. At the same time, since $p=0.012$ ($p<0.05$) was found as a result of the independent two-way t-test, it was determined that there was no statistical difference between the actual volume and the measured volume.

Keywords: Direct drill, Liquid fertilizer, Automation

INTRODUCTION

The products grown by agricultural production constantly use nutrients from the soil. The source of the nutrients used is mineral building materials and various organic materials. Although some soils are rich in nutrients, they may have a poor amount of nutrients available to the plant. During the transition from primitive agriculture to advanced methods for feeding the increasing population, fertilization was the first adopted method when productivity-enhancing methods were investigated (Ülger et al., 1996).

Fertilizers are substances that increase the productivity of the soil by regaining plant nutrients that are reduced in the soil as a result of agricultural production. Fertilizers are a powerful tool used to increase food quality while increasing agricultural production (Shojaei, et al, 2022). Compared to other agricultural inputs, fertilizers alone provide a yield increase of more than 40%, making very important contributions to world food security, raising living standards, and fighting hunger. The growing number of people in the world is causing an increase in our food needs. The decrease in arable land per person requires more plant production per unit of area. It is already understood that fertilizers will be at an important point in sustainable agriculture in the future as they are today. (Eraslan et al., 2010, Rahman and Zhang, 2018).

Materials such as farm manure, plant residues, animal waste, artificial fertilizers, and green manure are used to increase soil fertility (Gökçebay, 1986; Ülger, 1982, Tekin, 2002)

30-40% of the fertilizer consumed in our country is met through imports (Eraslan et al., 2010). One of the biggest problems for our agricultural producers is the high input costs in production and the fluctuations in prices. Fertilizer is one of the most important cost items in agricultural production and, for these reasons, sufficient fertilizer cannot be used in agriculture. Yield and quality losses are experienced due to insufficient fertilization (Kaplan et al., 2000).

When the fertilizer type suitable for the grown product is used in the right amount, yield and quality increase. For this reason, it is necessary to produce new forms and different types of fertilizers, taking into account the crop and soil to be grown (Taban et al., 2016).

Due to increasing fertilizer prices and increasing environmental awareness, more people are using approaches to reduce the use of chemical inputs in agriculture are used by more people (Şahin, 2016). Liquid fertilization is the subject of attention in this respect (Çelik and Bayhan, 2020).

Liquid fertilization is the delivery of nutrients to the plant dissolved in water. Liquid fertilizer has important benefits in plant nutrition (Halil et al., 2017; Gökçen, 2019):

• prevents toxic effects on the seed;

• Protects the seed against harmful insects and diseases in the seed bed,

• It increases the level of microbiological activity by increasing the density of microorganisms in the soil. Increasing the microbiological activity has a positive effect on the yield.

• Since the fertilizer is in liquid form, it allows plants to absorb plant nutrients more easily

The most important problem encountered in the liquid fertilization machines used is the clogging of the fertilization nozzles. Additionally, monitoring how much fertilizer is sprayed during the fertilization process is important to the success of the application.

In this study, an automation system was developed to measure and monitor the amount of liquid fertilizer sprayed on a direct drill machine used in grain planting after sunflower harvest in the Thrace Region.

MATERIALS AND METHODS

The research was carried out in the agricultural machinery workshop, Tekirdag Agricultural Faculty, 40°59 ‘30”N latitude and 27°34’55”E longitude, in the years 2021. The altitude is 10 m above sea level. The climate of Tekirdag is characterized by a Mediterranean type with mild and rainy winters and hot and dry summers at the coast, while a continental type prevails inside.

Direct Drill Machine and Nozzles

In the study, a direct drill machine with a liquid fertilizer system manufactured by Altayoglu Agricultural Machinery Food Agriculture and Farmer Ind.Trade.Co.Ltd. was used. General dimensions of the direct drill machine are given in the Table 1.

Table 1. General dimensions of the direct drill machine.

General Dimension	Road Position	Working Position
Length (mm)	2400	2400
Width (mm)	3250	5650
Height (mm)	1750	1500
Weight (kg)	880	
Working width (mm)	2375	
Operation Speed (km/h)	5-7	
Power Requirement	>95	
3 Point Linkage Category	Category-II	
Number of opener seed bed	19	
Opener type	Spring type	
Distance between the seed coulters (mm)	125	
Grain tank capacity (lt)	373	
Fertilizer tank capacity (lt)	393	

TeeJet TG-3 Full Cone Spray Tip nozzles (Figure 1, TEEJET TG-3 FULL CONE SPRAY TIP BRASS. (n.d.)) are used in the liquid fertilization system. The spray nozzles are made of brass material and have a 50 degree spray angle.

Figure 1. TeeJet TG-3 Spray Nozzle

Tractor

New Holland L95 model tractor was used in this experiment. The pump of the liquid fertilizer machine takes its rotation movement from the PTO connection. 540 rpm PTO speed was used in the study.

Arduino Mega

In the developed system, Arduino Mega microcontroller unit was used in order to perform the calculation process by processing the data received from the sensor and to display the results on the user screen. Table 2 shows the technical specifications of Arduino Mega.

Table 2. Technical Specifications of Arduino Mega

Length	101.52 mm
Width	53.3 mm
Weight	37 g
Microcontroller	ATmega2560
Input Voltage	7-12V
Digital I/O Pins	54
Number of Analog Pins	16
DC Current per I/O Pin	20 mA
Flash Memory	256 KB (ATmega2560) 8 KB bootloader
EEPROM	4 KB (ATmega2560)
Clock Speed	16 MHz

Nextion Touch Screen

Nextion is a visualization interface used for ease of use between device/application and human. Because of its own special editor, human-machine interfaces can be created easily. It can be controlled with a microcontroller by UART (Universal Asynchronous Receiver Transmitter). It has been preferred in the study because it is easy to use and works in harmony with Arduino. The technical specifications of the Nextion HMI smart 2.8 inch touch TFT LCD screen are given in Table 3.

Table 3. Touch Screen Specifications

Resolution	320x240
Color Space	RGB 65 K
Screen Size	57.6 mm (Length) x 43.2 mm (Width)
Internal Memory	4 Mb Flash Memory

Liquid Flow Sensor

A water flow sensor with a plastic body, rotor, and hall effect sensor is used. The measurement is made when the water flowing through the sensor rotates the rotor, and the hall sensor generates a signal depending on the rotor rotation speed. It produces 4.5 pulses for every liter of liquid that passes through it. In this way, the flow rate of the fluid passing through it or the total volumetric flow amount is measured. The technical specifications of the YF-S201 liquid flow sensor are given in Table 4.

Table 4. Liquid Flow Sensor Specifications

Operating Voltage	5V-24V DC
Operating Current	15 mA
Output Type	Digital Pulse
Measuring Flow Range	1-30 L/dk
Maximum Operating Pressure	≤1.75MPa

Experiment Setup

Flow sensors are mounted on the spray nozzles of the liquid fertilizer. The experiments were carried out with the tractor at a standstill, at 540 rpm PTO speed. A total of 30 measurements were taken from each flow sensor with 3 replications (Figure 2). To determine the actual amount of liquid fertilizer sprayed by the measured spray nozzles, scaled vessels were placed under each spray nozzle. The calibration curve of the system was created by regression analysis of the measurements taken from the sensors and scaled vessels.

Figure 2. Calibration measurements taken for the designed system

In addition, the real volume and the volumes measured by the sensor were compared with the t-test and it was analyzed whether there was a statistically $p<0.05$ difference between the measurements.

RESULTS AND DISCUSSION

The flowmeter sensor used in the designed automation system produces 4.5 pulses per lt/min. In the software, the flow rate of the liquid flowing through the sensor and the total volume of liquid sprayed are calculated according to these pulse numbers received from the sensors. These calculated values are shown to the user on a screen. When the flow is interrupted, the indicator corresponding to that spray nozzle turns red, visually showing the blockage in the spray nozzle to the user (Figure 3.).

This study showed automation system is enhancing the ergonomy and simplfying the application as the other researchers also point out (Sharma and Sonwane, 2017).

A total of 30 measurements were taken from the spray nozzles, and the volume data measured from the sensor and the actual volume data measured from the scaled vessels are given in Figure 4. Figure 5 shows the regression curve for these measurements. The volume measured by the sensor appears to be slightly higher than the actual volume. The minimum difference between the actual volume and the measured volume was found to be 0, and the maximum difference was 0.31 lt. The mean difference was calculated as 0.17 lt and the standard deviation as 0.08 lt.

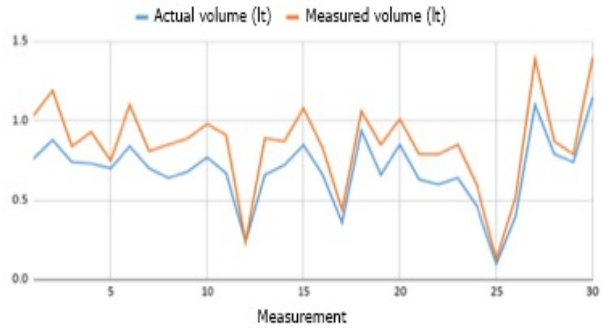

Figure 4. Graph of measured volume versus actual volume

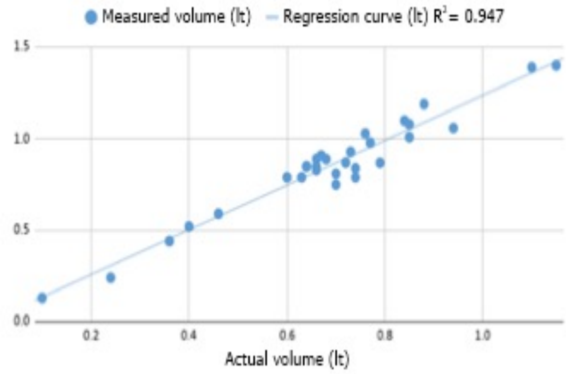

Figure 5. Regression curve between actual volume and measured volume

The actual volume taken from the collection vessels and the volumes measured by the sensor were compared with the t-test and it was analyzed whether there was a statistically $p<0.05$ difference between the measurements. Since $p = 0.02$ ($p<0.05$) was found as a result of the independent two-way t-test, it was revealed that there was no statistical difference between the two measurements.

CONCLUSION

In the Thrace Region, an automation system has been developed to measure and monitor the amount of liquid fertilizer sprayed in a direct drill machine, which has the feature of both direct drill and liquid fertilizer application in grain planting after the sunflower harvest. It has been determined that this developed automation system works within reliable limits, that the clogging of the nozzles gives a visual warning and that the tractor driver can easily monitor the amount of fertilizer sprayed during the fertilization and that this system can be used in practice. The most important limitation of deploying automation systems in agriculture is the cost (Rehman et al., 2022). This low-cost system addresses the need of a low-cost but useful automation solution.

We can summarize the results of the study as follows:

It detects clogged fertilizing nozzles during liquid fertilization. (Visual warning when flow is zero at the spray nozzle)

It allows the tractor driver to monitor the amount of fertilizer sprayed during fertilization.

There is a strong linear relationship of $R2=0.947$ between the values measured by the designed system and the amount of fertilizer actually sprayed.

The independent two-way t-test performed reveals that there is no statistically significant ($p<0.05$ significance level) difference between the actual measurements and the measurements made by the sensor.

Suggestions on what can be done in future studies on the designed system can be grouped under the following headings:

The flow measurement sensors used in the study are plastic. Liquid fertilizer has a high corrosion effect. For long-term operation, sensors made of corrosion-resistant materials can be preferred.

The sensors used in the study are in turbine structure. Solid material in liquid fertilizer can cause clogging in the sensors. For this reason, in future studies, a comparison can be made by testing flow meters that measure by magnetic method.

In order to test the mechanical durability of the designed system, longer field use and testing is needed.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Ethics committee approval is not required.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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