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Study of an electromechanical system for solid fertilizer variable rate planting

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The work aimed to study the behavior of a prototype planted simultaneously three times with solid fertilizers, nitrogen, phosphorus and potassium, of variable rates and desired quantities. For the evaluation of the prototype, a test bench was built where helical doses and their respective direct current electric motors; three tanks for storage of fertilizers were used. Also used were: A source (12 V-DC), three power drivers (MOSFET), acquisition board and control software. The tests were performed with LabVIEW®8.6 to control the rotation of the axes, record data in maps of soil fertility and geographical location. The results showed that application values showed an error of 3:56% at the rate of 45 kg/ha and an error of 1.78% at the rate of 85 kg/ha. However, the slightest mistake was on rotation of 26 to 30 rpm because the ratio flow rates had error <1%. Therefore, the dosing speed became maximum of 35 rpm; making the variation of the theoretical flow rate from 2.6 to 93.7 kg/ha. But with low flow rate, the error was 8.3% to 4 rpm on products of 9.79 kg/ha.

Key words: Data acquisition board, flow rate, helical feeders, varying rates, power drivers.

INTRODUCTION

The use of fertilizers has over time been increasingly important for the evolution of cultures. Through research and experimental procedures, this practice has been associated with soil needs. In correcting the soil, tools and devices have been used that control systems of manure deposition according to the nearest ideal needs of plants. The term precision agriculture is used to describe the use of several advanced technology to reduce costs of production and preserve the environment (Blackmore et al., 2007).

According to several authors, precision agriculture can be divided into three major steps: collecting of data, mapping of spatial and temporal variability of the field; data analysis for decision making and localized application in agriculture. Precision agriculture involves using equipment with capacity to apply accurately inputs at variable rates. The application of fertilizers in variable rate aims to maximize their use and reduce the negative impacts of agriculture on the environment.

In localized treatments, precision agriculture does not involve direct consequence of the use of equipment with sensors, positioning systems and computer

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Figure 1. Design of 3D test bench.

control systems application of supplies, but of other systems in the generation, analysis and use of information that reflects the variation that can be treated in a localized manner (Lamb and Brown, 2001).

One of the main features of modern agriculture and precision is the use of scientific knowledge associated with rigorous control of the application of fertilizer at variable rates. With modern equipment having granular applicators capable of altering the fertilizer distribution rate for small rate and tractor speed of 5-8 km/h, the required rate of application cannot be achieved over the area to be fertilized (Yu et al., 2006).

The various deposition rate of fertilizer through the equipment used is achieved by varying the speed of the machine, e.g., directly without much computational electronic device. However, it is an important resource for the geostatistical analysis of the spatial variability; the sensor systems yield mapping, geographic information system.

The new tools of this technology are being incorporated to manage the variability of soil attributes and support the improvement of soil and crop management. The increase in efficiency is based on different management based on the variability in the area. The integration of computing and electronics is the means to raise levels of control and monitoring of agricultural activity in specific locations of crops.

Through detailed analysis of crops and improvement of management techniques, new levels of quality and quantity of crop production efficiency can be achieved successively (Silva and Azevedo, 2009).

The implementation of control systems for automation can generate increase of 15 to 20% in operating efficiency of agricultural tractor. In addition to greater efficiency in mechanical operation, the implementation of control systems helps reduce the mental effort of the operator, and fatigue.

A large number of traditional concepts of production plant are being reconsidered for developing intelligent machines. In planting on lines which requires a simpler type of machine, the seeds is placed along each line.

If the location of each seed is known and the position of each cultivated plant is estimated, we can identify each plant by its spatial location.

Better information about the characteristics of the plant allows better management and decision making, which in turn brings a number of improvements that can increase the overall efficiency of agricultural production.

MATERIALS AND METHODS

The prototype of the study consists of a reservoir of fertilizer, a helical dosing, an electric motor of 12V - DC for activating the dosing and a hose to lead the fertilizer to the soil. The tests were performed to control two variables directly, e.g., rotation and displacement, and consequently indirect control of flow rate and time. Figure 1 shows the schematic diagram of the electromechanical system supply fertilizer.

This system was designed and constructed in the laboratory to change the mechanical system actuated by gear wheel planter electrical system which is coupled to a variable source (Figure 2). It is used to convert electrical energy alternating continuously to feed motors (12V) and encoders (5V), ICEL Brand: Mod PS - 6100.

The power voltage supply (Tabile et al., 2011) was done through dragging, which was generated by a computer system with its respective data acquisition via LabView 8.6 (Bishop, 2007). Its function is to control rotation and mass flow. An important issue to be clarified is that the method of applying the variable rate fertilizer was the VRA (Variable-Rate Application) with GPS, based on maps preparation. Map-based VRA adjusts the application rate through an electronic map, also called prescription map. Using the field position from a GPS receiver and a prescription map of desired rate, the concentration of input is changed as the applicator moves through the field.

The control system was generated in closed loop and consisted of comparing the input signal with response, which in this case is the estimated mass flow rate to be released into the soil. This comparison is performed through feedback to the data system reference of supplies suitable for the soil (Figure 3). In general, in

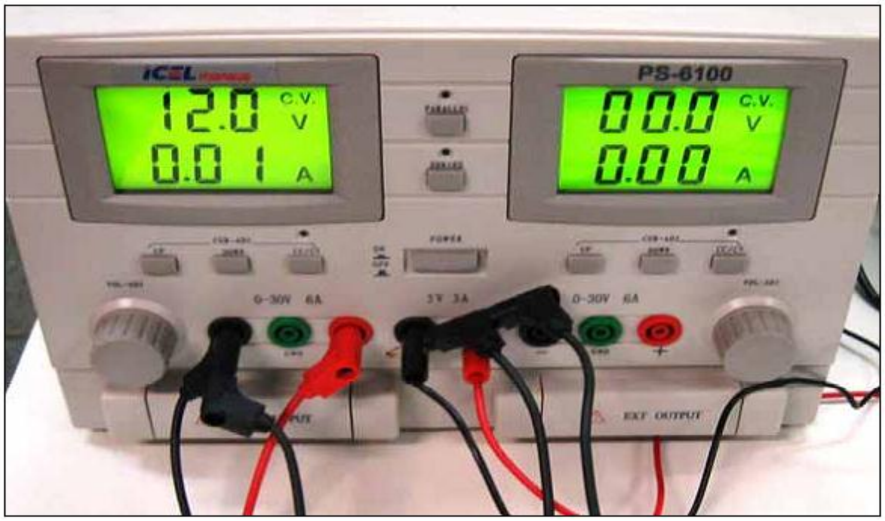

Figure 2. Variable power supply.

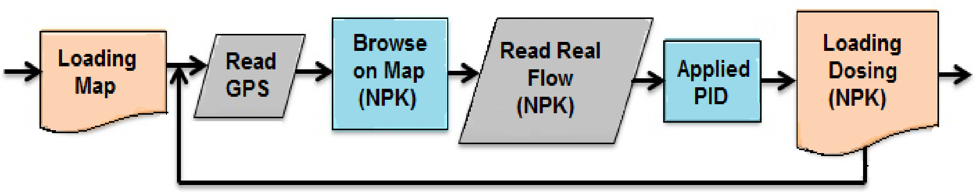

Figure 3. Flowchart of steps for simulating the LabView 8.6 (Lawrence et al., 2007).

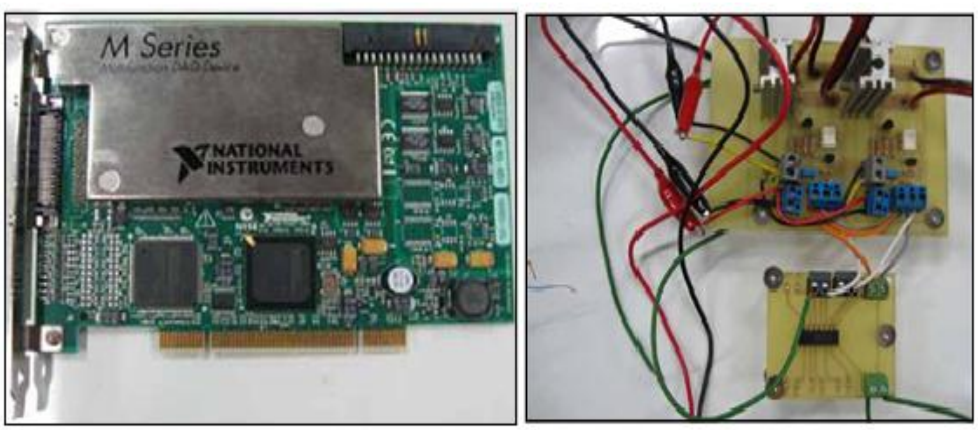

Figure 4. Acquisition board and power drive.

order to make more precise and cause it to respond to external disturbances system, the output signal is compared with a reference signal and the difference between these two signals is used to determine the reference signal. The device that uses the error signal to determine or calculate the control signal to be applied to the plant is called the controller or compensator.

The Sensor Ion Selective Field Effect Transistors (ISFETs) was used to measure phosphate level, temperature and humidity of the environment in agricultural experiment (Ramdas and Galande, 2014). The NPK Micro-sensor used is accurate to assist in the collection of spatial data in the variable rate technology (automated fertilizers). All this control was performed by LabView 8.6 software. It operates based on a graphical platform that enables both simulations and controls data acquisition through acquisition board from NATIONAL INSTRUMENTS. For this case is the NI-PCI6251 plate (Figure 4), that allows the interface between the engine and

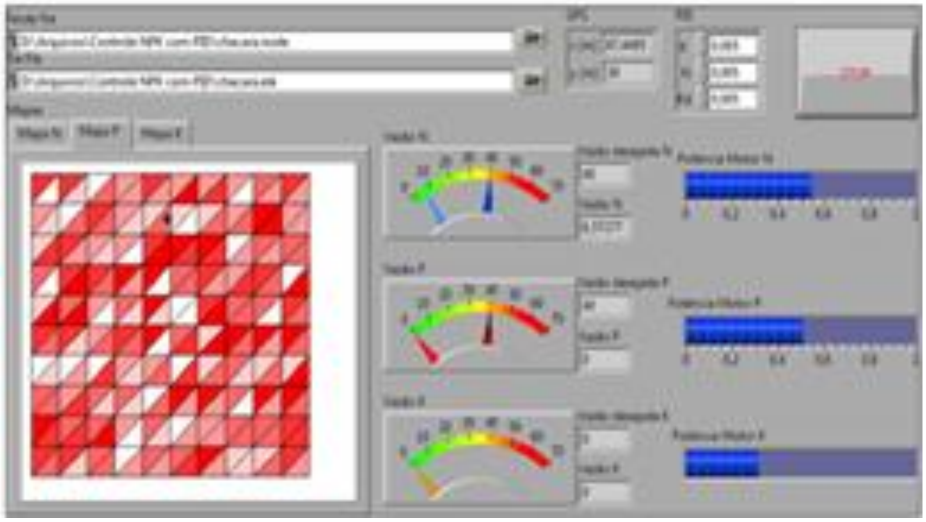

Figure 5. Interface/Control Panel of the rate of nitrogen (N), phosphorus (P) and potassium (P) with closed mesh.

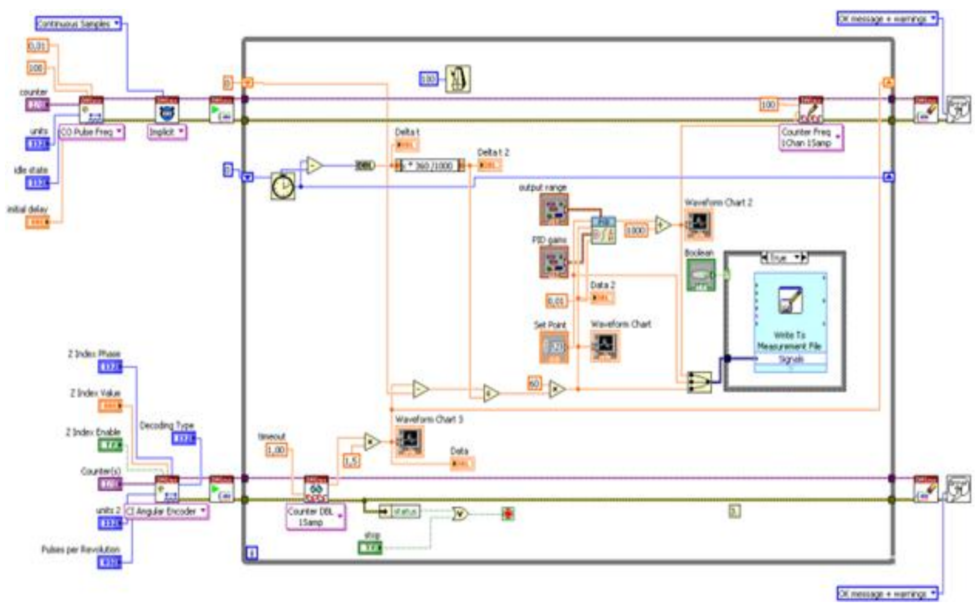

Figure 6. Motor simulation with PID control (Block Diagram).

the virtual simulation software. For the simulation it was constructed a map with cells of 50 by 50 m according to the information of references soil. Therefore, we used the method of Delaunay triangulation for mesh creation and their respective geographic map and doses of N, P and K.

This was done to synchronize the GPS machine control system with fertilization (Lawrence and Yule, 2007), with the need to move the machine in accordance with the predetermined geographical coordinates in programming the array. The offset is shown by a point (black) in the map (Figure 5), giving the exact position of the machine on the map, with the flow desired and actual flow rate.

This system could be significantly used for variable-rate applications with overall system errors in the range of ±5% (Tola et al., 2008). The PID control type (Birkus, 2012), as shown in Figure 6, is used in closed-loop systems. It takes into account the behavior of the engine speed, controlling it through a rotation sensor (ENCODER); its function is to measure the frequency by rotating shaft engine with the feedback system. It adjusts the engine speed according to the required reference (Malik et al., 2014).

Only the automation of fertilization systems is not enough, as there is a need for a whole set of interrelated and interdependent systems. However, currently there is a well-founded and consolidated technological apparatus (GPS technologies best, better development of information technologies, maps for soil fertility, etc.) that enables and supports the development of the project. So for the tests were also used: centesimal balancing with precision, digital thermo-hygrometer, a computer and all electronic device to control motor rotation, stopwatch to time the manure deposition in their respective rotations. The time was estimated based on the speed of 1.6 m/s; 31.25 s is hypothetically the

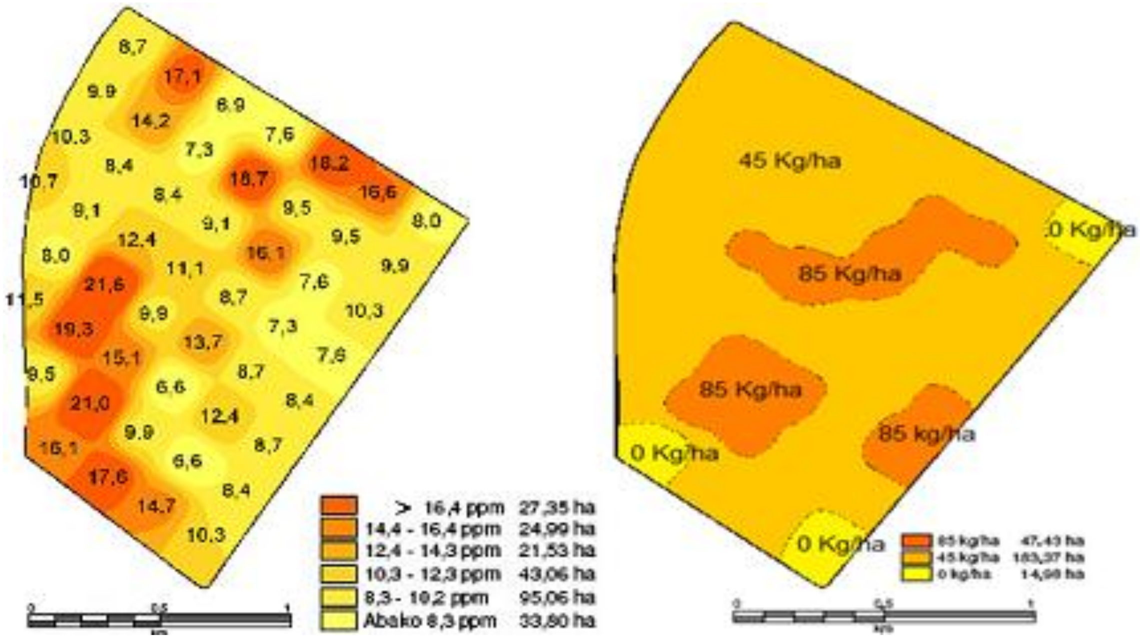

Figure 7. Map of application and fertility in the distribution of fertilizer (Potter et al., 2010).

time which it takes to traverse fifty meters (50 m) and pounds (5 kg); fertilizer (potassium - P) reused as the experimental system was a fertilizer tank just below dose.

During the test, the mass flow rate with the fertilizer was monitored at room temperature (21.9ºC), and relative humidity of 81.5%, since they interfere in the management of fertilizer because of its hygroscopic nature. A map with a range of 0-85 kg/ha potassium (Figure 7) was used in the planned route for moving the machine and going through eight sample cells. These were followed with constant speed of 1.6 m/s for product application with spacing between rows in 0.7 m.

So to meet the needs of the data raised by the maps of soil fertility implies varying the rotation of the dose. However, we calculated the theoretical values of the mass flow rate, according to Equation 1 to the desired amount of fertilizer per area to be worked with the dose rotating at 1 rpm. This is necessary for calculation and determination of the:

1. Amount of fertilizer per line qF/L = 18.75 g/line in 100 m,
2. Number of lines,
3. The dose of fertilizer applied per rotation, 18 g/min.

According to the reference value of 45 kg/ha of fertilizer raised in the map application, the rotation was 17 rpm, because it is not interesting to study with fractions rotation operation of the dose.

$$q_L = \frac{W_A}{e_L}$$

$$q_{Fd} = \frac{q_{F/L} \cdot q_L}{1000} = \frac{q_{F/L}.W_A}{1000 e_L} = 2{,}6786 \frac{kg}{rpm.ha} \quad (1)$$

where: q_L = number of lines; q_{Fd} = required quantity of fertilizer of an area to be fertilized/rpm; $q_{F/L}$ = quantity of fertilizer/line; W_A = width of the area to be fertilized [m]; e_L = line spacing [m].

This amount of fertilizer was defined with the aid of q_{Fd} required quantity of fertilizer/area/rpm = 2.6786 kg/ha.rpm at 17 rpm. Reference was made to 85 kg/ha of fertilizer application map. Theoretical value of 85.72 kg/ha.rpm was obtained at the place where the map marked the initial value (zero), the starting point without rotation. These values were obtained for an engine which used helical dose with 1” of pass.

RESULTS AND DISCUSSION

The values of the rotation, the required amount of product in accordance with map application, the theoretical and actual amount of product applied by doses used are listed in Table 1; they were obtained by the application of fertilizer map by Equation 1 and the performance of the experimental tests in the laboratory (Rambas et al., 2014; Sivasoundari and Kalaimani, 2013). The legend of the table is based on:

i. Cell - the cell number in soil fertility map;
ii. Reference - Need of the map required in kg/ha in the respective cell of the map;
iii. Theory - Product desired in kg/ha;
iv. Real - Product obtained from doses in kg/ha;
v. Rotation - Rotation of the axis (rpm).

Analyzing the values in Table 1 it can be noticed that the error associated to the theoretical values with respect to reference values occurs because of the approximations in the use of rotations; e.g., considering only entire rotations.

In the comparison of reference values relative to the experimental values, it is shown that the error for the application of fertilizer is around 3.56% compared to the reference value of 45 kg/ha, which has an error of 1.78%, (Figure 8); for more on fertilizer application for the

Table 1. Values of the mass flow rate helical dosing.

Cell	Reference (kg/ha)	Theory (kg/ha)	Real (kg/ha)	Rotation (rpm)
1	0	0	0	0
2	45	45.54	43.40	17
3	45	45.54	43.40	17
4	45	45.54	43.40	17
5	85	85.72	86.51	32
6	85	85.72	86.51	32
7	45	45.74	43.40	17
8	0	0	0	0

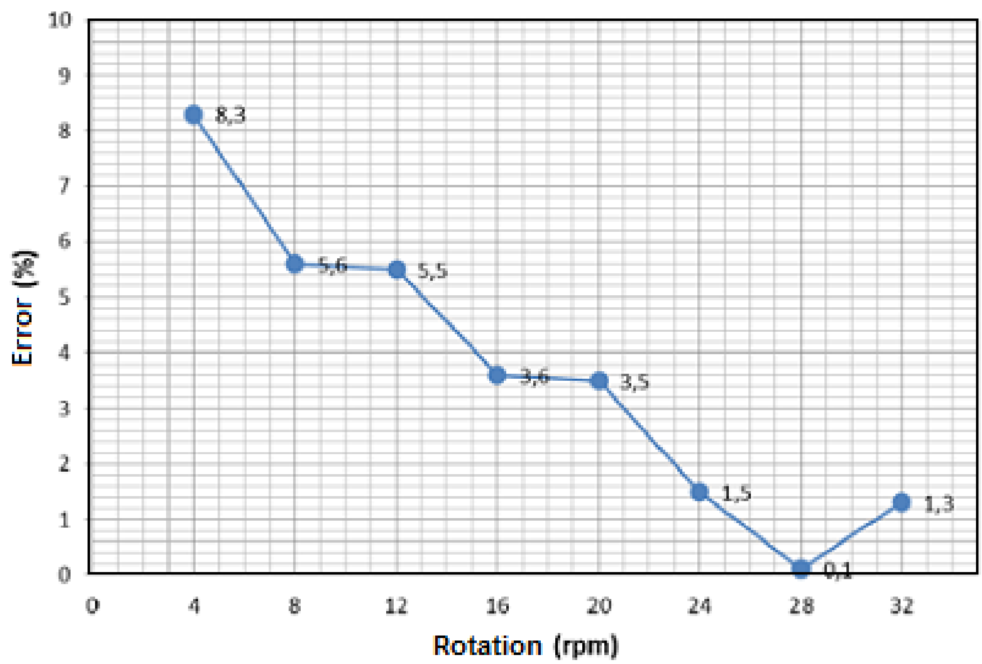

Figure 8. Application error versus rotation of the doses.

reference value of 85 kg/ha, which is quite acceptable in relation to the precision employed in agriculture today.

The survey of theoretical curve by varying the rotation at rpm versus q_{Fd} (theoretical) was made together with the experimental results; it verified the amount of fertilizer applied to the system during 31.25 s in order to verify the behavior of the system in controlling the amount of fertilizer at variable rates (Scarlett, 2001).

Thus, it can be seen in Figure 9 that the system presents the greatest errors for low speed (4 rpm presents an error of 8.3%). This suggests (Yuan et al., 2010) that when the helical type dose operates at higher rotations, graphic displays a decrease in the interval between the peak maximum and minimum amounts used. This indicates that helical dosing projects operating at higher speeds of rotation may have more uniformity.

However in Figure 9, the theoretical curve rotation has a range of q_{Fd} versus rpm at the same time with the experimental results of varied rotation at four rpm.

Conclusion

The values of mass flow rate determined by time were compared with the fertilizer mass values given in the application map.

In the tests, the results for high, medium and low flow were achieved with little variation around the reference values. The computational application developed could, within a range considered acceptable for the practice of precision agriculture machine; control for variation in dosage of fertilizer, as proposed in early labor and that could be confirmed in the tests.

The LabVIEW®8.6 software proved sufficient for the

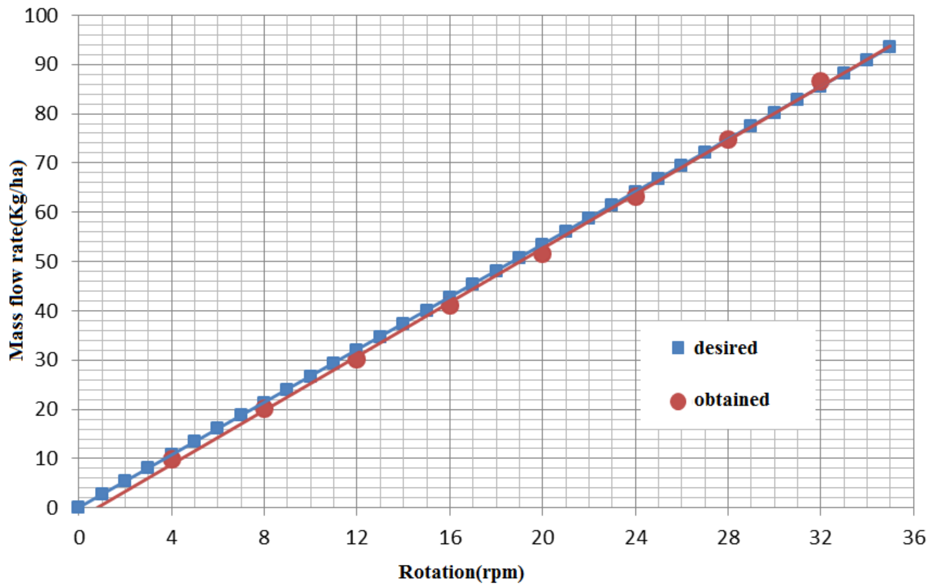

Figure 9. Chart rotation of the doses versus mass flow rate.

general control equipment, being a very fast and accurate tool, allowing simulation that reproduces situation close to the actual situation of the equipment.

The prototype tested was efficient in the dose range, as the results showed that application values present an error of 3:56% at the rate of 45 kg/ha and an error of 1.78% at the rate of 85 kg/ha. However, the slightest mistake was in rotation of 26 to 30 rpm because the ratio flow rates had error <1%.

Therefore, the dosing speed became maximum 35 rpm, so that the variation of the theoretical flow rate is from 2.6 to 93.7 kg/ha.

Conflict of Interests

The authors have not declared any conflict of interests.

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