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DEVELOPMENT AND ANALYSIS OF A PROTOTYPE FOR FORMULATION, DOSAGE AND APPLICATION OF SOLID FERTILIZERS (N, P AND K) AT VARIABLE TAXES IN A LOCATED WAY IN EQUIPMENT OF DIRECT PLANTING.

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Abstract: *The growing demand for food in the world with the same farm area and increasingly scarcer financial resources for fertilizer manufacturing makes the use of new technologies inevitable in order to confront this new reality, because through them it is possible to produce more food with fewer fertilizers. The search for new technologies that make the production process more efficient leads us to so-called "Precision farming", which even though not being a new concept, has been occupying space in developed countries as an alternative to improve the agricultural production process. The actions which lead to the so-called precision agriculture demand several stages for implementation. However, one of the most important is related to the formulation, dosage and application of agriculture fertilizers at variable rates in a localized and accurate manner. For such, it is necessary to develop equipment capable of carrying out these tasks. For this purpose, the behavior of a prototype has been studied, which aims at formulating, dosing and applying three solid fertilizers (Nitrogen, Phosphorus and Potassium) during planting at variable rates according to the quantities desirable for the crop and in a localized manner. In order to assess the prototype, a test bench was built with helical dosers and their respective electric motors (12 VDC) and three tanks for fertilizer storage. Complementary equipment was also used, such as: 1 power supply (12 VDC); 3 power drivers (MOSFET); 1 notebook; 1 acquisition and control board and 1 Virtual Instrumentation software. The assays will be conducted using a virtual control and instrumentation software (LabVIEW), whose function is to control the rotation of the axis of all three motors in an independent manner, founded on data from a fertilizer application map with location based on geographic information, obtaining the product's desired mass flow from point to point according to the size of the soil's sample grid. Mass flow values determined as a result of time will be compared to fertilizer mass values indicated on the application map. The lower the difference for these values, the greater system precision will be. In the assays made with the simulation software the results gotten for the high outlet were satisfactory, since the kind of preliminary control implemented was the proportional. It can also be said that in the low outlet the behaviour of the system was oscilatory around the setpoint, but it is believed that with the implementation of a PID controller, this problem will be solved.*

Keywords: *Precision farming; variable taxes fertilize; direct planting*

Symposium: *Product Engineering*

1. INTRODUCTION

In the global context, every form of economy suffers from a reduction in profit margins, bringing about the need to obtain levels of international competitiveness. Besides that, the search for natural resources conservation forces agricultural activity to take on new production processes and techniques aligned with greater control of results achieved in the field compared to previous practices. As a response towards minimizing these problems and with the advances of technology, it was possible to use satellites, computers and sensors to assist agriculture. This resulted in a new production system, which has already been in use by farmers in nations with advanced technology, called either Precision Agriculture, Precision Farming, or AP in Brazil. This system makes it possible to cognize every square meter of the field, knowledge rather lost as these farm areas evolved.

Soil richness depends on the rocks that preceded it. There are soils with great potential from a content, balance and availability perspective of essential elements for plants. In these conditions, crop quality is guaranteed for a long time. Other soils were less fortunate in their origin or underwent transformations throughout history and do not have the quality demanded for appropriate mineral nutrition of plants. In general, after successive harvests, soils present difficulties in appropriately feeding plants. Through the use of fertilizers, humans, supported by scientific and experimental bases, interfere in the process, giving the soil what it needs. This replacement of essential elements must respect the proper quantities and the right time, otherwise it would cause alterations in the plants and jeopardize harvest quality, thus justifying the use of more precise tools to deposit the fertilizer as close to the location as possible and in the ideal quantities for each plant.

Precision agriculture begins with the proposal of finding the spatial variability of the soil's previous fertility using programmed and detailed sampling. With all the information obtained from the sampling in hand, we treat soil fertility directly, applying corrections and fertilizers at variable rates to solve problems that may depreciate the quality and productivity of the field due to a lack or excess of essential nutrients. Nowadays, it is possible to do the entire soil sampling process through georeferencing, that is, mapping the area by removing soil samples and delimiting the points with their respective geographic coordinates. This process of marking sample points using the Global Positioning System (GPS) makes it possible to later design soil fertility maps, a fundamental tool for making decisions on fertilizer recommendations for the crop intended to be planted. By using the soil analyses and the geographic coordinates for the sample points, fertility maps are generated. For each analyzed element and sample area there is a map showing concentration variations in the soil. Having entered the application map in the machine, it will then administer the fertilizer in variable quantities, obeying the previous analysis of soil fertility and treating each previously sampled point in a particular way. Two motivations stand out for precision agriculture. One deals with preservation of the environment, once a reduction in fertilizers and agrochemicals being used in the soil is something increasingly wanted. The other deals with the increasingly smaller profit margins, which leads to a willing to reduce the quantity of inputs manufactured, especially fertilizers and agrochemicals needed in the production process.

Currently, the machines used to fertilize the planting line do so with pre-formulated fertilizer, that is, with a mixture of proportions already defined of the macro elements (Nitrogen, Phosphorus and Potassium). This way, the element that already exists in the soil is deposited again without any need. This increases planting costs and wastes chemical fertilizers. The objective of this paper is to perform the formulation, dosage and point-to-point localized application at the moment of planting, that is, at the desired point, deposit only the necessary element at the required quantity. This makes the fertilization more precise and economical, maximizing the use of fertilizer and minimizing environmental damage.

2. LITERATURE REVIEW

In vegetables, development, production and multiplication depend on three factors: genetic inheritance, environment and degree of nutrition, which is limited by the element with less availability in the soil. This is Liebig's Law of the Minimum, as it became known in the field of vegetable nutrition. It can be represented by a keg whose maximum content corresponds to the height of the lowest slat, as seen in Fig. (1).

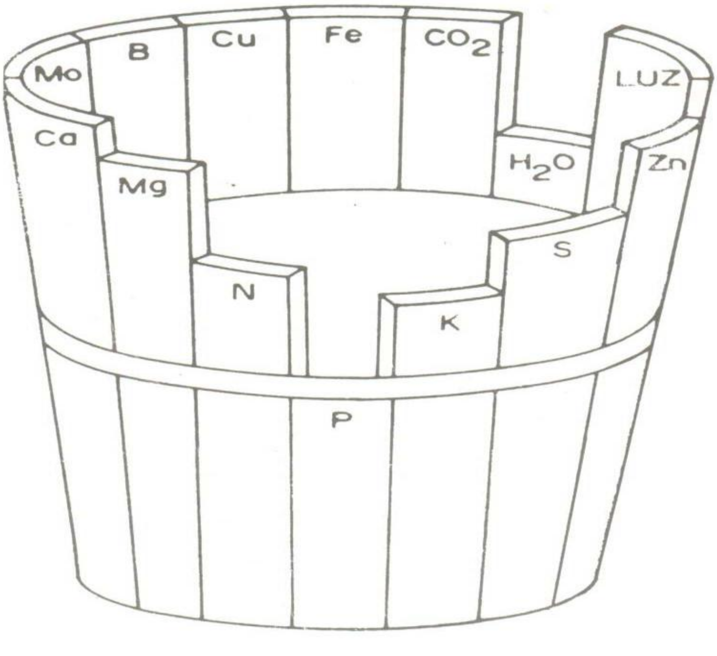

Figure 1: Representation of Liebig's "Law of the Minimum" (Alcarde et al., 1998)

It is thus useless to put a chemical element in the soil if it is already there and if this element is of a residual nature. It is important to recall that some elements used in chemical fertilizer formulations are not residual, such as Nitrogen. Therefore a balancing of elements must be made using quantities that approach the actual need in relation to macro elements (N, P and K), thus avoiding an overlaying of chemical elements in the soil.

The alternative used nowadays is to focus on large areas and view them as homogenous, leading to the concept of average needs for applying inputs – fertilizers, agricultural defensives, water, etc. This leads to the same formulation and/or quantity of fertilizer being used for the entire area, only meeting average needs and thus not considering the specific needs of each part of the field. The same occurs for the other inputs, resulting in a field with non-uniform productivity (Capelli, 1999).

The spatial variability of Brazilian fields is not news. In conversations with producers and field technicians, it is possible to apprehend that such nature is recognized, as they reaffirm that one part of the area produces more than another, or that in a specific location, nutrient contents are higher than the field's average. The valorization of spatial variability and the possibility to manage it, aimed at increasing input use efficiency, has been a challenge for technicians and producers. Precision Agriculture has gained space from this context. The new PA technology tools have been incorporated as a means to manage soil attribute variability on properties and to subsidize improvements in soil and crop management. The increase in efficiency is based on differentiated management, respecting the area's existing variability. The integration of computers and electronics are means to increase control and monitoring levels of agriculture activities in specific sites of the field. Through a detailed analysis of the fields and improved management techniques, new levels of qualitative and quantitative efficiency for crop production can be successively achieved (Santi, et al. , 2009).

As it can be observed in Fig. (2) – Complete PA cycle shows concern with soil preparation, planting, crop accompaniment and harvesting. It mentions the following techniques: soil analysis, application of fertilizers and corrective factors at variable rates, planting with variable rates, plotting the field to map pests and diseases, localized application of agrotoxins, harvesting with machines using sensors and the generation of productivity maps, also observing concern with soil preparation involving fertilizer analysis and application (Arvus, 2007).

Figure 2: Complete PA cycle, (Arvus, 2007)

Soil analysis to find causes of variations in productivity
Application of fertilizers and correctors at variable rates
Variable rate planting according to the production potential of each area
Follow-up of field to map pests and disease
Localized application of agrotoxins
Harvest with machines using productivity sensors
Generation of productivity maps
Soil Preparation Planting Field Follow-up Harvest

The variability of production factors is tied to multiple causes, from climatic variability to variability represented by the environment surrounding a single seed (soil, oxygen, availability of water, nutrients, etc.) deposited in the soil. However, the forms of variability studied and managed in PA can be classified in "Spatial Variability" (which occurs with an attribute in the area, for example: variation in phosphorus concentration in the soil in a 20 hectare section), "Temporal Variability" (which occurs over time, for example: availability of water in the soil as a function of rainfall seasonability) and a third (which represents human action in the first two), called "Management Induced Variability" (which is generated by management decisions taken in crop areas, for instance: crop allocation and machine adjustments). The latter occurs, for example, when machines are worn and poorly adjusted, there are different farming systems, parts of the field are left to rest for several years and there are weed control deficiencies (Farnham, 2000).

In order to minimize variability, it is necessary to know its magnitude and to identify and quantify it by using soil, plant and climate parameters, plotting out “problem areas” (with levels below those considered adequate) and then employing management practices capable of minimizing them.

The Direct Planting System (DPS) causes changes in soil behavior by eliminating mechanical actions that homogenize the soil. With distribution occurring predominately on the surface, and plant action accumulating nutrients in the air biomass, there is an accumulation of nutrients, especially P and K, on the superficial grumous layer, in the first 10 cm. Over time, there is a tendency to increase the efficiency of fertilizers used and the availability of nutrients by means of microorganism action (N), reduction in nutrient fixation by clay in the soil (P) and cation movement in the soil profile (Ca, Mg). Soil fertility must also consider the physical and biological aspects, such as porosity (distribution of pore size, total volume and continuity), susceptibility to compaction, friability in different humidities, content and quality of organic matter and biological activity (Freitas, 1994).

After the consolidation of DPS, the recommendation for fertilization (based on soil analysis) begins to consider the system and not the crops in an individual manner. Finally, fertility management begins to unite the use of chemical fertilizers with the power of biological recycling of cover and rotation crops (Souza & Lobato, 2002).

There are several possibilities for variable rate applications that include the main plant nutrients (N, P and K), lime, seeds, genotypes, agrotoxins, water and soil management practices. A strategy must be developed for each input to guide the variable application with precision (Doerge, 2000).

With the fertilizer application map generated by specific software and with the help of high-precision GPS, all connected to an on-board computer and entered in the machine, the latter applies the fertilizer in variable or fixed quantities, obeying the prior analysis of soil fertility processed beforehand so the required quantities and necessary elements (N, P and K) from the maps are deposited in the exact location and at the moment of planting.

In this context, PA is a modern tool to help the producer define the best management strategies to be adopted, aimed at increasing farming activity efficiency. Specifically in soil management, PA’s main concept is to apply the quantities of inputs (quantity) necessary for agricultural production in the correct place (space) and at the appropriate moment (time) for increasingly smaller and more homogenous areas, as permitted by technology and the costs involved (Dodermann & Ping, 2004).

With the popularization of GPS devices (Global Positioning System), which use satellites as shown in Fig. (3), precision agriculture development processes have been consolidated, because it is possible to attribute any property to a specific coordinate, whether chemical or physical of the soil, such as productivity, pests, disease, among countless others.

Figure 3: Satellite in orbit (Serrana, 2007)

For soil sample collection by georeferencing, a quadricycle can be used in order to conduct the entire soil sampling process by coordinates. That is, it can plot the area removing soil samples and delimiting the points with their respective geographic coordinates, as shown in Fig. (4).

Figure 4: Quadricycle for soil sampling (Serrana, 2007)

This process of marking sample points using GPS enables posterior elaboration of soil fertility maps, primordial tools for making decisions on fertilizer recommendations for the crop to be planted in the system. After plotting a specific planting field, it is necessary to subdivide it in smaller areas in order to work on small pieces of land, generating more information about local fertility. A grid over the area's perimeter, called a sampling grid, is used for this, as seen in Fig. (5). The grid size depends on some factors, such as: production uniformity, relief and history of the area (Serrana, 2007).

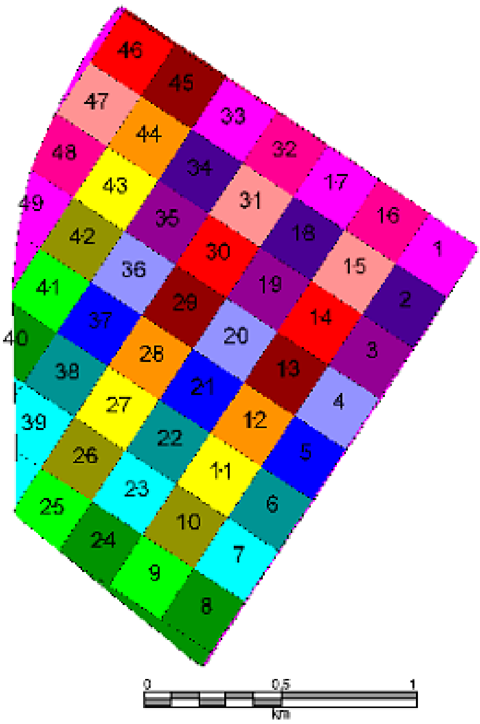

Figure 5: Soil sampling grid with specific sampling points (Zulli, 2008)

Using the soil analyses and the geographic coordinates for the sample points, fertility maps are generated, where you have a map showing concentration variations for each element in the soil, for each analyzed element and for each sampled area, as shown in Fig. (6).

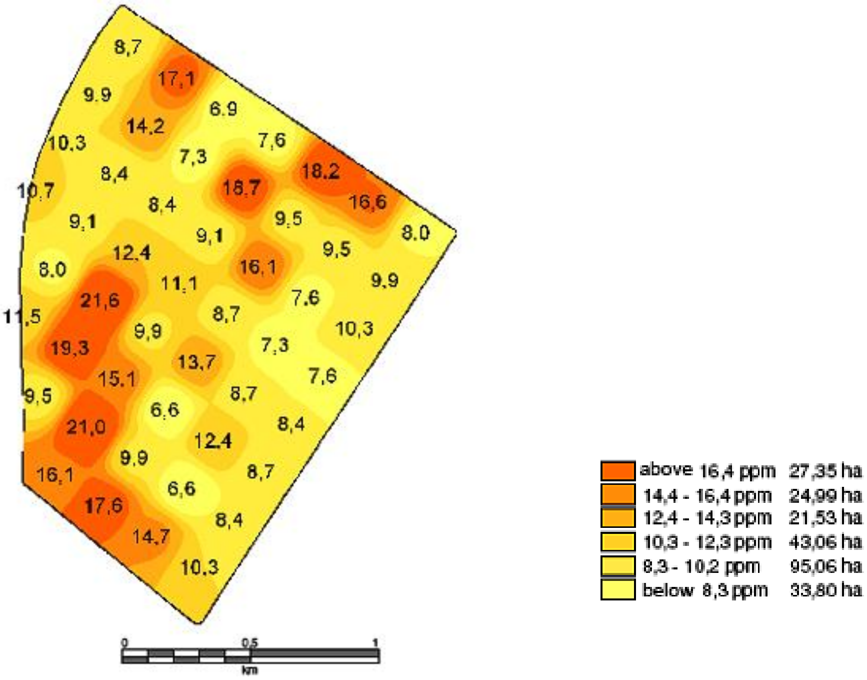

Figure 6: Soil fertility map (Zulli, 2008)

By using an application map obtained after the entire soil fertility study and entering it in a computer with the help of GPS for the exact information of geographic coordinates, it will control the three independent electric motors whose function is to regulate rotation by means of virtual control and instrumentation software, where flow is a dependent variable for rotation so that each motor has a different rotation, depending on the quantity of fertilizer needed at each soil sample point at the moment of planting. More efficient and economic fertilizing is expected with this procedure, since only the exact amount of chemical element needed for plant development will be deposited. Mass flow values determined as a result of time will be compared to fertilizer mass values indicated on the application map. The lower the difference for these values, the greater the system precision will be.

3. MATERIAL AND METHODS

With the application map in Fig. (7), elaborated from soil fertility studies and obtained from georeferenced sampling for each element (N, P and K), the prototype simulation process firstly attempts to analyze the doser behavior and verify each element's mass flow.

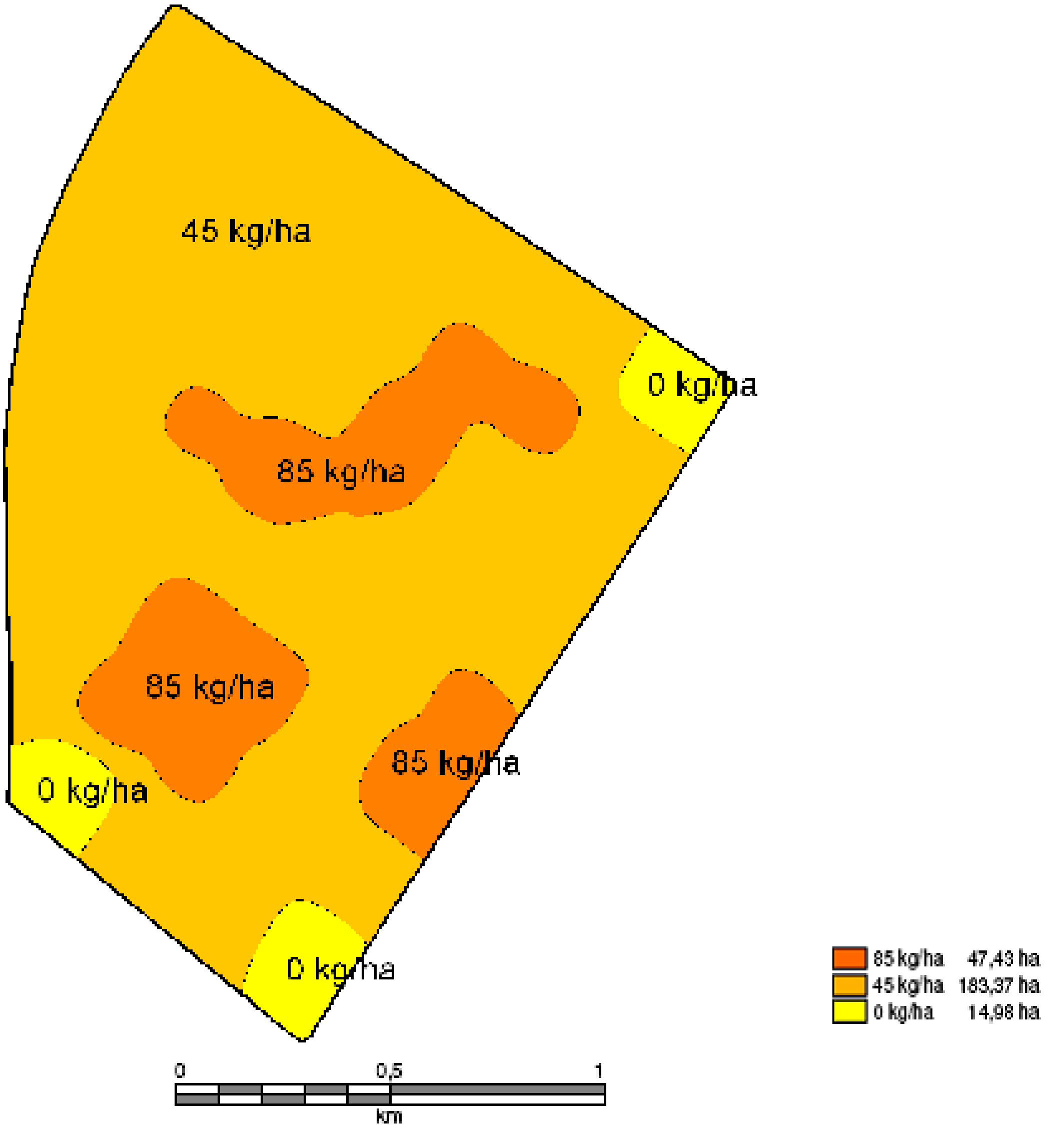

Figure 7: Fertilizer application map (Zulli, 2008)

The test bench was made of carbon steel (20 x 30mm metalon) with 3 glass tanks for storing chemical elements, 3 John Deere helical dosers, 3 2-inch x 50 cm long rubber hoses, 3 polyethylene containers to collect chemical elements with 4 rollers for transport, as shown in Fig. (8).

The motors that activate the bench's helical dosers are attached to a worm-and-gear set and are powered by a 12 VDC power supply, each one connected to a driver and controlled by acquisition and control software installed in a desktop. With the help of an application map and GPS, the computer sends a signal (voltage) to the motors, varying their rotation and thus varying product mass flow.

Figure 8: Prototype

The big advantage of the electric variable rate fertilizing system compared to other systems is its low cost. Another advantage is the possibility of precise and compact control, because they use reduced size, easy-to-build, electronic components, as seen in Fig. (9).

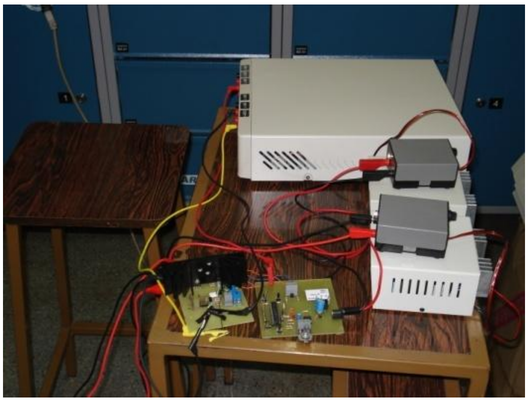

Figure 9: Electronic components

For the proposed job, it would be ideal to use a motor with linear rotation voltage graph behavior and also obtain dosages that approach zero. The motor used in the assay is low rotation and low torque, with reduced size and low cost. It is manufactured by Mabuchi, Cod. ED454908, 12 VDC, Fig. (10).

Figure 10: Electric motor

The dosers are manufactured in polyethylene of high resistance and stainless steel, with a 1-inch pitch carbon steel screw conveyor, as shown in Fig. (11).

Figure 11: Helical doser (John Deere)

4. RESULTS AND DISCUSSION

Assays were conducted with a single element (Potassium) using the fertilizer application map, on a grid defined in the sample point map with 223.60 x 223.60 meter cells, thus each cell measuring 50000 m^2 or 5 hectares. Observe in the map that there is a 0 to 85 kg/ha variation in potassium along a route that passes through 8 sample cells that must be followed in a straight line at a constant speed of 1.6 m/s for the exact application of the product, obtaining mass flow values as shown in Table (1). It is important to highlight that the assays were conducted using only one motor and a 1-inch pitch screw conveyor doser.

Table 1: Mass flow values for the helicoid doser

Cell Number	Required Need from the Application Map in kg/ha for the Respective Cell	Product Applied by the Helicoid Doser in kg/ha in the Respective Cell	Axle Rotation (rpm)
1	0	0	0
2	45	45	17.5
3	45	45	17.5
4	45	45	17.5
5	85	71	25.3
6	85	71	25.3
7	45	45	17.5
8	0	0	0

With the values obtained in the assays, a rotation graph was constructed by the Duty Cycle (PWM), as shown in Fig. (11). No rotation was observed in the 0 to 10% duty cycle band. The rotation presents an accentuated increase in the 10 to 15% duty cycle band. The rotation maintains its proportionality in the 15 to 60% duty cycle band and after the 60% duty cycle band, the rotation stabilizes. This behavior by the curve is due to worm-and-gear set reduction, needed to increase electric motor torque. It is known that the rotation in direct current electric motors is proportional to power voltage.

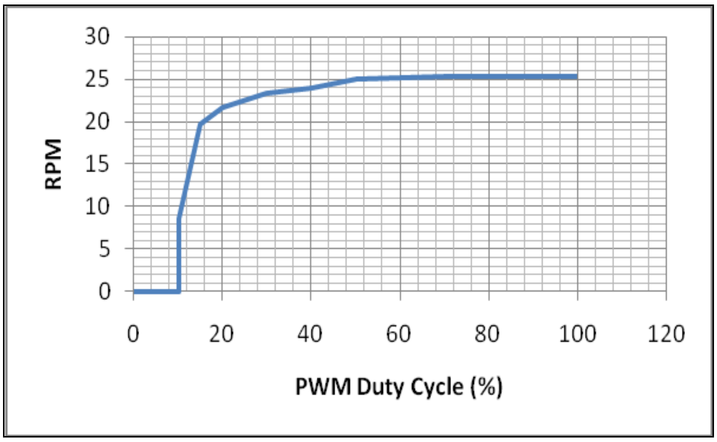

Figure 11: Rotation Curve by Duty Cycle

5. CONCLUSION

The tested helical doser proved to be efficient in dosages between 30 and 71 kg/ha, but it did not achieve maximum required values in the application map due to the 1-inch pitch screw conveyor. In order to solve this problem, simply change the screw conveyor and use one with a 2 inch pitch. However, the minimum values were provided. It is important to point out that for different dosages than those used, it is necessary to change screw conveyors, using one of the three different pitches: ¾, 1 or 2 inches. It was observed that by varying the rotation, the mass flow also varies. This was our goal at the outset of the study and it could be proven in the assays conducted in laboratory. Since the motors and dosers are the same, this also applies for the others. Thus, it is only necessary to establish communication between them using acquisition and control software for the system to work. Linear behavior was expected in the rotation and voltage graph for the motors. However, this did not occur due to the worm-and-gear set reduction to diminish rotation and increase torque. Therefore, constant amperage was obtained even with maximum load and rotation ranging between 10 and 25 rpm. The rotation and voltage graph also revealed that the difference between static and dynamic torque did not permit motor rotation of 0 to 10% of applied voltage. This can be solved by implementing a closed grid control with PID controllers. In other words, the system will be refed as needed so the motor can work at the intended rotation.

In a comparison with a hydraulic system, Umezu (2003), in a study along the same line of research, with similar purposes, but using different methods and materials, observed the existence of similar problems. Perhaps the most evident one is the control of the motors in the open grid system. On the other hand, in the electric system, similar behavior is observed between the motors. What calls attention in the hydraulic systems is the high cost of the equipment.

According to Umezu (2003), initial tests revealed a good correlation and linearity between command voltage and hydraulic motor rotation. However, the existence of problems was verified due to the occurrence of hysteresis and changes in rotation behavior with the heating of hydraulic oil. These phenomena jeopardized rotation control behavior of open grid motors. Other important results involved the similar behavior among the three motors and their non-interdependence.

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