MEPIQUAT CHLORIDE APPLICATION ON COTTON AT VARIABLE RATE.

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ABSTRACT

Mepiquat chloride (1.1 - dimethylpiperidinium chloride) are used to control excessive vegetative growth in cotton (Gossypium hirsutum L.) broadcast sprayed by ground or air. As proven by previous researches the variability of the cotton plants height in the field is large enough to justify the application of Mepiquat at variable rate. The major advantages of it are: (i) yield increase; (ii) economy of the applied input; (iii) reducing the potential of environmental pollution. The main objective of this project was to develop a prototype device capable to accomplish the application of Mepiquat at variable rate in real time. This project used an equipment previously developed for automatic mapping of the cotton plants height based on ultrasound transducers. An electronic control device for ground sprayers was designed and constructed based on microcontroller PIC, using open source tools as Java, Linux operational system and IDE Netbeans. The device controls the pressure and flow in the spray line and uses Varitarget® nozzles due to its characteristics of linearity of flow and pressure. The calculation of the Mepiquat dosage to be applied is based on the obtained information of the plants heights and the map of previous application. The laboratory results demonstrate the accuracy of the equipment, with low response time considering the commercial sprayers velocity (3 $m.s^{-1}$ to 5 $m.s^{-1}$).

Keywords: microcontroller, Varitarget, sprayer, open source tools.

INTRODUCTION

The application of growth inhibitors such as mepiquat chloride allows increasing the productivity addressing photo-assimilated of the vegetative growth of the plant to the reproductive organs, besides maintaining the plants at a tolerable height to aid harvesting. The application time and rate is a decision of the agricultural technicians empirically base on the average plants height and growth rate. One of the methods for determining the mepiquat chloride application rate is measuring the average internodes length of the top five nodes of the plant, by using the mepiquat chloride rate and timing stick. If the average internodes length is greater than 36 mm, then the plant will receive an application of mepiquat chloride (Stabile, 2005). Handling in an average way usually causes unnecessary application of product in areas of the field where the plants have stop growing (Shiratsuchi et al. 2005).

The choice of uniform doses applications is justified by the lack of commercial technologies that allow measuring the plants heights in a fast way that will allow the calculation of the necessary doses of mepiquat application in real time. Some variable rate application strategies have been based on plant height, where taller plants receive more mepiquat chloride and shorter plants less. Queiros et al. (2005) developed a prototype based on group of ultra-sonic sensor mounted in a bar, coupled in the front commercial sprayer. The equipment was able to map crop height for further calculation of mepiquat dose to be applied at variable rate according to the plant height. Stabile (2005) mentioned that an alternative to a variable rate application according to height is using the height mapping system to calculate plant rate of growth. Through the use of historical height, the system can determine the recent rate of growth and, using the previous mepiquat chloride applications at each point throughout the field, the system will determine the appropriate application rate to achieve the desired concentration of mepiquat chloride. The author suggest as an optimum technique would be collecting height information for the whole field and calculate trough a software the rate of growth of the plants in real time, based on previous height maps. During field testes the author used a light been light curtain system to measure the plant height and commercial sprayer equipped with an variable rate application module on-off flow control for mepiquat application. The conclusions were although the height estimation algorithm works properly the flow control needs improvement to optimize the system.

Based on those results the objective of this study was to design a control system capable to read the plant height and based on previous crop growth map calculate the necessary rate of mepiquat to be apply and using a pressure control valve regulate the flow rate of a spray nozzle to be applied according to the need of each position and the speed of a sprayer.

MATHERIAL AND METHODS

The overall system consists of five principal components: a crop height measuring system (CHMS), based on ultrasonic sensors; a DGPS receiver with a sub meter accuracy to measure plant location; a software to register data, calculate the rate of growth based on previous map, and determine an appropriate mepiquat chloride application rate; sensors and actuators to regulate the mepiquat flow at the desirable rate; and a spray boom using Varitarget® nozzle that is capable of controlling flow rate and maintaining proper spray pattern and optimum droplet size over the range of flow rate control (Bui 2005). This nozzle can be used with a pressure regulator so the nozzle flow rate can be controlled on-the-go to obtain a desired application rate and sprayer speed.

The system was simulated in a laboratory conditions adopting two sprayer speeds 5 $m.s^{-1}$ (18 $km.h^{-1}$) and 2.5 $m.s^{-1}$ (9 $km.h^{-1}$) using water instead of mepiquat.

Figure 1 shows a flow chart of the whole system. The system calculated a rate base on plant height average for each cell, which is function of the sprayer, boom, and ultrasonic sensor location. Considering a 21 m width boom and a 6m long sprayer and an ultrasonic sensor located 1.5 m ahead of it, the application cell will represent 157.5 m^2. A new mepiquat rate will be calculated for each cell and the rate of calculation will be function of the sprayer traveling speed, Figure 2.

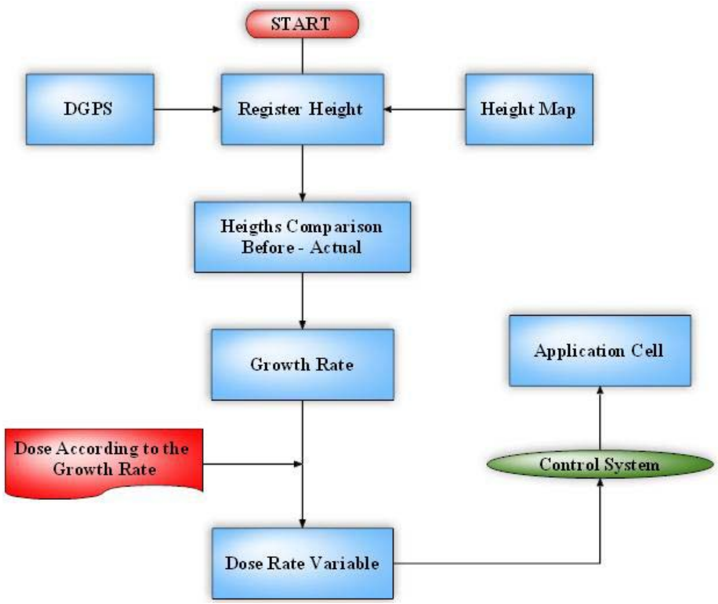

Fig. 1. Flow chart of the mepiquat control application system.

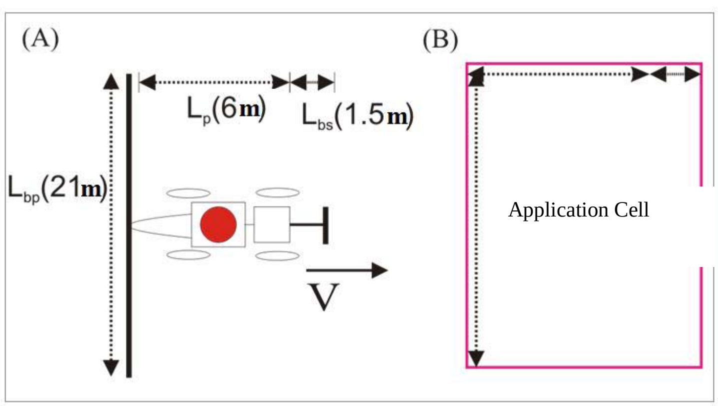

Fig. 2. Control cell for mepiquat application.

The onboard computer receives the information from the ultrasonic sensors and DGPS and trough software compares the average cell plant height with previous information stored in memory. A new control signal is calculated by the control algorithm at every new data acquisition cycle and sent out to the proportional flow control valve. The control valve converts the electrical signal into a corresponding pressure level, which is then applied to the electric actuator which controls the flow valve aperture.

Hydraulic circuit

The hydraulic circuit consists of: a piston pump (Yamaho LS-22C) with maximum rotation speed of 800 rpm and capacity of 15 L min^{-1} at 27.6 bar, driven by a 2 cv electric motor, which is controlled by a frequency inverter (Weg Model CFW080160T2024PSZ); a proportional electric valve (Geoline model 8386011) maximum flow 60 L.min^{-1} at 40 bar, with a 7s cycle; a flow meter (Gray Flow 1-100 L.min^{-1} model FL GFL 001) with maximum pressure of 10 bar; On/off valve (Geoline model 8388005) maximum flow 15 L.min^{-1} at 20 bar, with 0.2 s cycle; a pressure sensor (Teej C209 - 844E 0 to 10 bar), and 4 Varitarget® nozzles, Figure 3.

Control system design

The flow chart of pressure valve controller program shown in Figure 4 includes three parts: main program to initialize system, routine to operate PID control algorithm for generating flow valve signals, and control of the on/off valve. The proposed strategy consists of controlling the pressure in the line through a proportional flow regulator valve using a PID system and a PIC microcontroller. The signals between plant and control systems are transmitted using a ZigBee protocol.

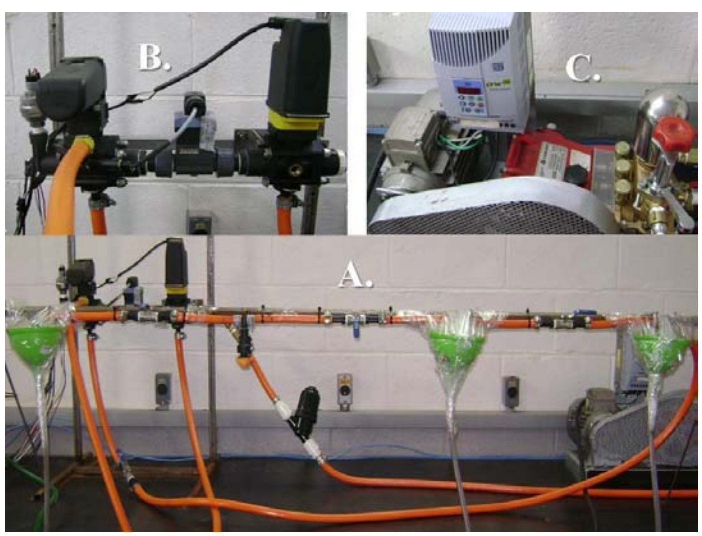

Fig. 3. Hydraulic circuit and components. A. general view; B. from left to right: pressure sensor, on/off valve, flow sensor and proportional flow valve; C. electric motor, frequency inverter and hydraulic piston pump.

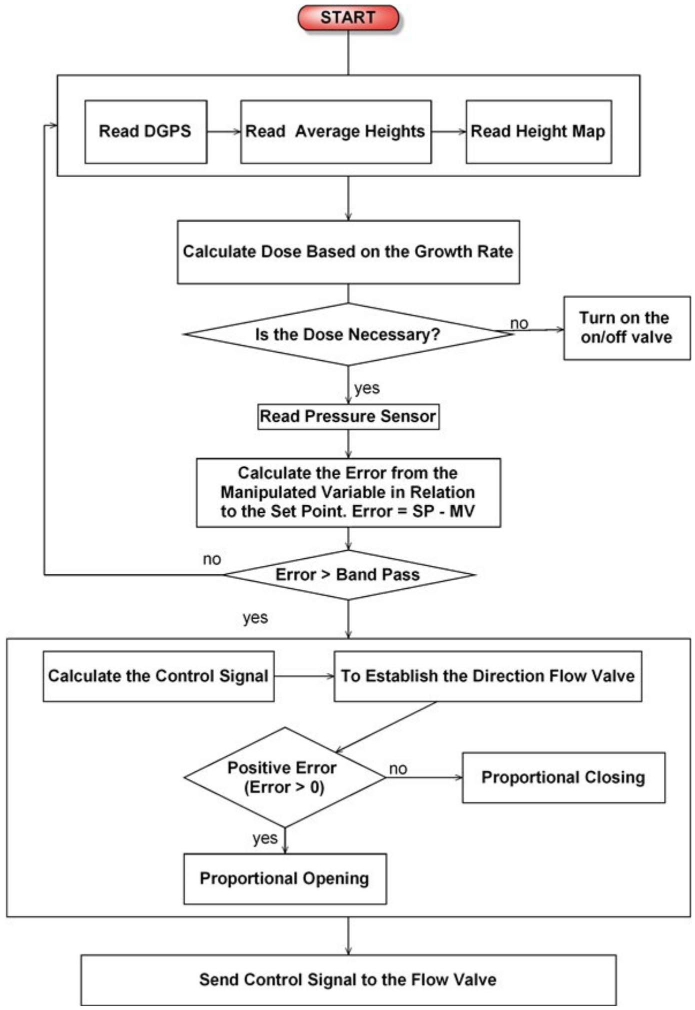

Fig. 4. Flow Chart of Pressure valve Controller Software

Data acquisition system

An electronic circuit using a microcontroller PIC 18F451 for data acquisition was designed. The circuit was able to receive data from the pressure sensor and flow sensor and actuate in the proportional flow valve and the on/off valve. This circuit used a terminal a Wiring (PCLD-8710-AE) and processor AMD Athlon 1.1GHz. The control software was written in Java language (JDK 1.6 update 19) using IDE Netbeans.

RESULTS AND DISCUSSION

The Varitarget® nozzles were calibrated at ESALQ laboratory and the results are presented in Figure 5. As can be observed there is a good linear correlation when using this nozzle between pressure and flow (r = 0.975), which allows to continue to use the proposed control strategy.

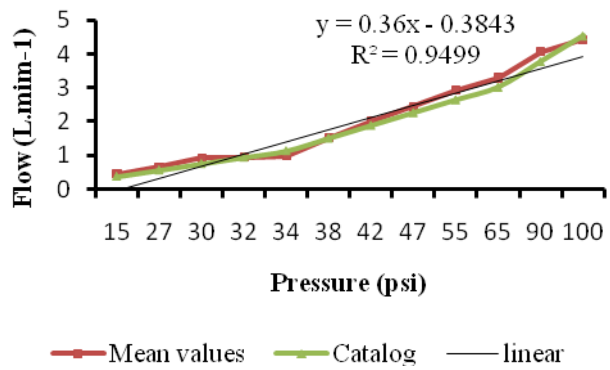

Fig. 5. Varitarget calibration curve

The PID parameters for the flow control valve were obtained from laboratory tests and Matlab simulink. The results can be observed in Figure 6, where it is possible to observe that the PID control was well adjusted.

Flow control simulation

To evaluate the performance of the design flow control system a simulation based on real values was conducted in the laboratory. The data from a 7.3 ha cotton field obtained in September 2005 in Correntina-Bahia, was used assuming that was the first reading from the CHMS, Figure 7. A 2 psi band pass was adopted in the control system to avoid instability. Rules for mepiquat application were set according to Table 1.

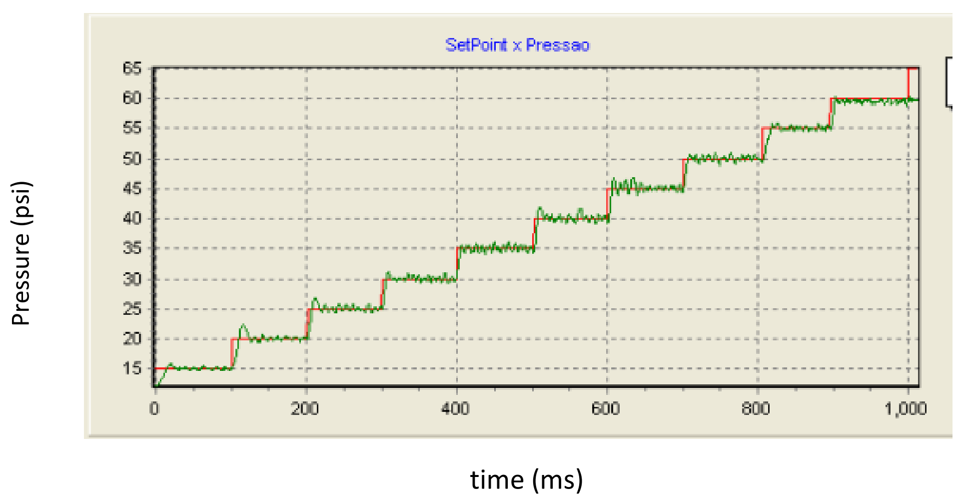

Fig. 6. Pressure readings after flow valve PID control, red set point, green valve response.

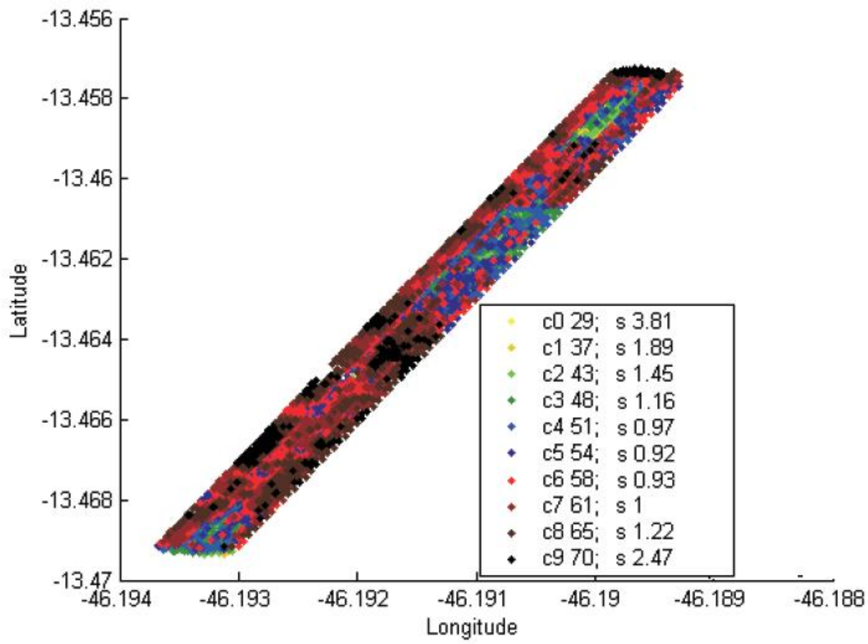

Fig. 7. 7.3 ha cotton field height map, Correntina-Bahia. c - classe of height in centimeters, s – standard deviation in centimeters.

Table 1. Mepiquat application rules.

High (mm)	Pressure (psi)	Dosage
< 200	0	1
> 200 and < 300	20	2
> 300 and < 400	30	3
> 400 and < 500	40	4
> 500 and < 700	50	5
> 700	55	6

The forward speed of the sprayer was set to two different values, 5 and 2.5 $m.s^{-1}$. At 5 $m.s^{-1}$ the cycle of application was 1.5 s, and the results obtained are shown in Figure 8. The mean error calculated over this area was 2.7 psi and the standard deviation was 5.7 psi. As a control strategy every time that the CHMS system detected that the plant height was below 0.2 m instead of closing the flow valve, it opens the on/off valve and deviate all flow beck to tank. This avoids plant instability and reduces product consumption.

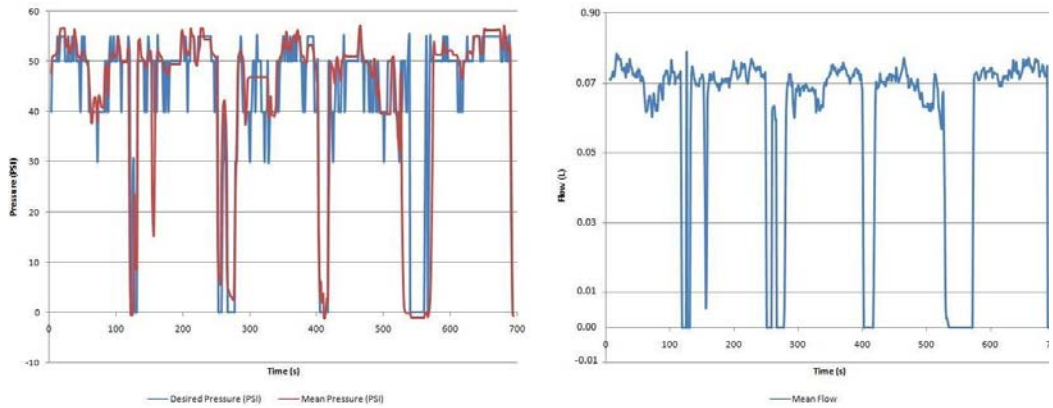

Fig. 8. Desired pressure and measure pressure during a simulation period (a) and the mean flow over the same period (b) at sprayer forward speed of 5 m.s^{-1}.

When the forward seed was reduced to 2.5 m.s^{-1} the performance of the system improved, Figure 9. The mean error was reduced to 2.1 psi and the standard deviation to 4.7 psi.

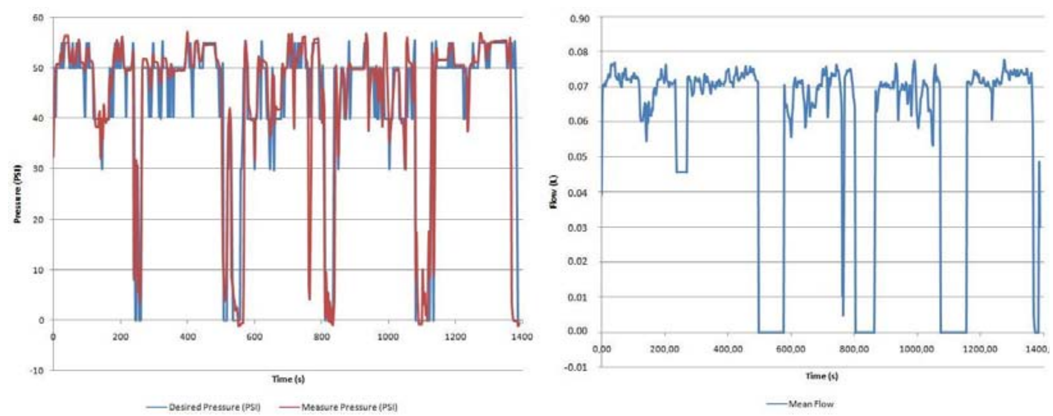

Fig. 9. Desired pressure and measure pressure during a simulation period (a) and the mean flow over the same period (b) at sprayer forward speed of 2.5 m.s^{-1}.

Simulation of a nozzle obstruction

Another concern of the system was to check if the system was capable to maintain the desired mepiquat dose in each nozzle if one nozzle of the section was obstructed, partially of full, during application, since the approach was to control the system pressure an regulate the flow valve aperture. To test the system performance in this situation a obstruction of one nozzle was simulate using a ball check valve which was closed manually. The result can be observed in Figure 10, where the flow of three nozzles is reduced to one third after 2 nozzles have been closed, and there was no significant alteration in the pressure.

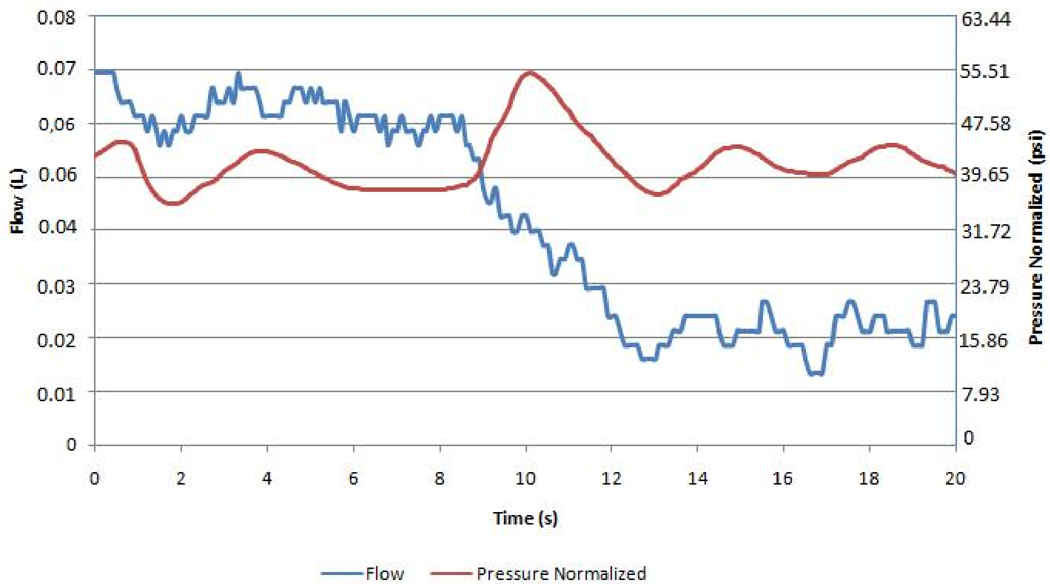

Fig. 10. Flow and pressure in a 3 nozzles system when the flow in 2 nozzles was obstructed.

CONCLUSION

The proposed strategy for Mepiquat application at variable rate work properly, and will attend the needs of farmers which adopt precision agriculture technique. The system response was fast enough to have a rate cycle of different Mepiquat application at 0.6 Hz with a mean error and standard deviation among reasonable values.

ACKNOWLEDGMENTS

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