

WSN Prototype for African Oil Palm Bud Rot Monitoring

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Abstract. The oil palm (*Elaeis guineensis*) is the most productive oleaginous on the planet. The world's largest producers of oil palm are located in Asia, Colombia is the fourth largest producer in the world and the first in America. In recent years, the sowing of oil palm has taken a great importance in food industry and biofuel production. Bud rot is among the factors that are most affecting this type of crop, generating to palm farmers large economic losses and the country's social problems due to unemployment. Early detection of abiotic factors that may trigger bud rot is one of the strategies that would allow palm farmers to minimize the impact on the crops. In this research, a WSN was developed to acquire, process and transmit in real time to a server acquired data as: pH, humidity, temperature and luminosity.

Keywords: WSN · Oil palm · Bud rot

1 Introduction

The oil palm (*Elaeis guineensis*) is the most productive oleaginous on the planet, it has a productive life that exceeds 25 years. The world's largest producers of oil palm are located in Asia, the first producer is Indonesia followed by Malaysia, Colombia is the fourth largest producer of oil palm in the world and the first in America [1].

In recent years, the sowing of oil palm has taken a great importance in food industry and biofuel production. The African oil palm represents an important crop in the Colombian economy. This sector has been hit hard by the bud rot disease, that reaches the crops in a biotic or abiotic way.

At present, in Colombia, African oil palm plantations represent an important part of the country's agricultural production, with a total of 450,131 hectares planted. However, bud rot is among the factors that are most affecting this type of crop, generating to palm farmers large economic losses and country's social problems due to unemployment.

There are two hypotheses about bud rot: the first one has a biotic origin, as a classical disease caused by a specific species of bacteria or fungus, sometimes with complications by several species of insects [7]. The second is of abiotic origin generally related to climatic and edaphic factors as causes of a very complex nutritional disorder but without precise specifications in causes [7].

Palm farmers have the risk that their main source of subsistence will be extinguished because of African oil palm bud rot. For this reason, it is necessary to deploy crop monitoring systems based on wireless sensor network that allows an early warning of diseases.

Different management strategies of bud rot disease have been designed: chemical control, elimination of affected tissue, planting of tolerant materials and edafoclimatics analysis, among others. Early detection of abiotic factors that may trigger bud rot is one of the strategies that would allow palm farmers to minimize the impact on the crop. This is possible if with the design and development of a system to monitoring crops using wireless sensor networks [9].

Wireless sensor networks (WSN) are composed of nodes, which are autonomous devices capable of capturing and transmitting different variables that are around the target to be monitored, such as temperature, humidity, pH and luminosity. Different researchers have used WSN to monitor the climatic variables of different crops such as: Aji Habanero [3], tomato [6], Orchids [5] and roses [4], among others. Their results indicate that they have been able to optimize the production of these crops by applying ICT (Information and Communication Technologies). When WSN have to be deployed outdoor or remote places, in many cases, they do not have access to the electrical system and data networks. In addition, it have to handle a large volume of information, therefore, the design of reliable nodes it is necessary, so Palm farmers can monitor crops in real time.

In Colombia, most crops are handled in an artisan way. Precision agriculture has begun to have importance in large business groups, this type of agriculture is going to generate a large amount of information, which is why it is necessary to use tools to process them with Big Data analysis techniques.

In this research, a nodes and the WSN have been designed and developed, thus allowing to transmit the acquired values of different sensors that are connected to the nodes. Each node of the WSN it is a unit capable of acquire, process and transmit, in real time, to a server data related to important variables to determined if there is a bud rot triggered event. Variables such as: pH, humidity, temperature and luminosity. Additionally, nodes of WSN system is equipped with power supply and geo-referencing system. The acquired data make possible to create a DataSet to be processed with Big Data analysis tools.

2 System Design

2.1 Edafoclimatic Requirements of African Palm

The African palm is a tropical region plant, therefore, it is located in those areas with average monthly temperatures that oscillate between 26 C and 28 C. Temperatures below 17 C for several days cause a reduction in the development of adult plants and in the seed nursery it could stop the growth of the seedlings. As for rainfall, the favorable conditions for this species are determined by the amount and distribution of rainfall, which ranges from 1800 mm to 2300 mm per year.

In relation to the sunlight, the African palm is identified as heliophile plant, because its high requirements of sunlight. To achieve high productions, 1500 h of sunlight per year are required. Therefore, areas with average monthly values greater than 125 h of sunlight are considered suitable for the cultivation of this plant. The insolation also affects the emission of the inflorescences, photosynthesis, ripening of the clusters and oil content of the mesocarp. As for relative humidity, a monthly average of more than 75% is required.

It tolerates moderately acidic soils (pH 5,5–6,5), although these generally have nutrient deficiencies. In light soils, from sandy to loamy sandy, there are problems of washing and leaching of nutrients, so that their consistency is insufficient for the support of the plant. The heavy soils, of clay texture, have limitations for their handling, the difficulty to drain them and ease with which they are compacted.

Therefore, the optimal soils for African palm cultivation are deep soils with good drainage, slightly clayey texture, good organic matter content, flat to slightly undulating topography with slopes lower than 2% and with a level of fertility from medium to high.

2.2 Bud Rot

Bud rot (BR) is one of the most present diseases in oil palm plantations, this disease has been responsible for large economic losses and has generated social instability. This disease has been investigated in all Latin America by different institutes, the investigation results coincide in that it has biotic and abiotic origins.

The symptoms show the destruction of the young arrows, without presenting damage to the meristematic area in initial stages of the disease; That is, the meristematic area is the point of growth of the plant, if this is affected the plant dies. Experts indicate that when the disease is detected in time, it is sufficient to prune the affected young arrow together with a chemical control may be sufficient to control the disease. But if the attack is severe there is destruction of the arrows and the meristematic area, consequently, the emission and maturation of the new arrows is stopped, causing the death of the plant.

There is no clarity about the etiology of the disease and has been related to several abiotic factors of a physiological nature and biotic factors of a pathogenic nature. Preliminary studies have reported that no nutrients are associated with

the incidence of BR, although it is possible that nutrient imbalance in the soil, together with excess water, may become predisposing factors to the disease.

2.3 Hardware Design

Figure 1 shows the block diagram of the designed node: Data Processing, Sensors, GPS, Transmission and Energy.

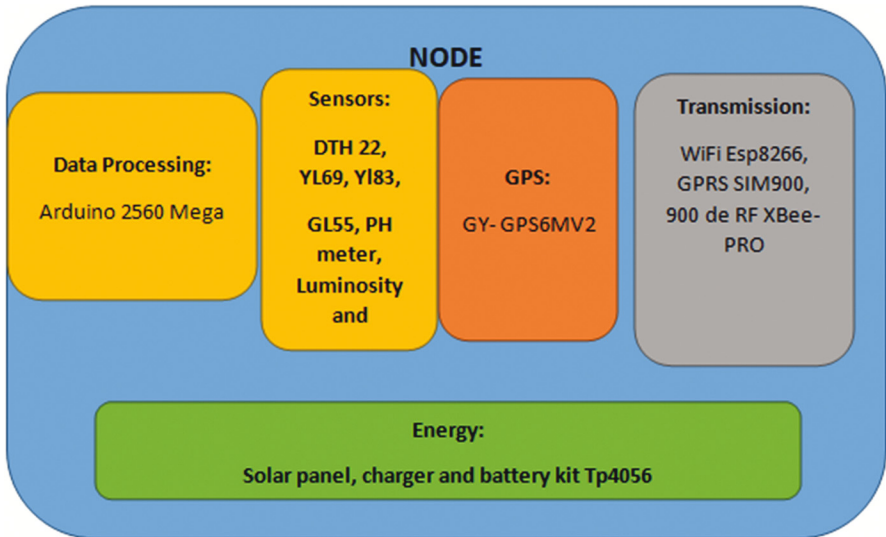


Fig. 1. Designed node

Data Processing: To perform data processing, the Mega Arduino has been chosen. This device has the following characteristics: 54 digital input/output pins, 14 can be used as analog PWM outputs, 16 analog inputs and 4 TTL-UART series receivers/transmitters. It has a 256 Kbytes flash memory, 8 SRAM memory and 4 KB EPROM.

Sensors: The sensors have been chosen according to the variable to be measured. Table 1 describes their main characteristics:

All these sensors are compatible with Arduino, in the case of pH measurement it is done using a tester that sends to Arduino the analog input of acquired pH value.

A GY-GPS6MV2 easy to program module has been used, designed to be compatible with Arduino and integrated as a module to the system.

Table 1. Sensors to be used to measure the variables

Variable	Sensor
Air humidity	DTH 22
Soil moisture	YL69
Temperature	DTH22
GPS	GY-GPS6MV2
pH	Tester pH, temperature and luminosity
Luminosity	GL55

Transmission: Three types of communication technologies are used: GSM, WiFi and Xbee. GSM: When some nodes are out of range, because of the topography or the existing distances in the terrain, in this project GSM SIM900 model has been used. WiFi: In cases where nodes are near an access point (wireless router or another), wireless technology is the most economic form of connectivity. Here, the Wi-Fi module ESP8266 has been used. Xbee: Preferred transmission in this type of networks by its low power consumption vs. data transmission.

Energy: The node it is designed to use the charger and battery kit tp4056, a 5 v 600 ma solar panel and it is possible to connect it to the electrical grid network.

2.4 Software Design

The software has been developed using LAMP architecture, which is a solution of great performance and availability. It has great advantages since it has complete on-line documentation and is a open source way to be able to develop Big Data techniques desired to be implemented.

Operating System: Ubuntu server 12.04.4. Web Server: Apache Database: MySQL Web Programing language: PHP

Table 2 shows the decomposition of the data into four arrays in order to calculate the average value of the humidity in each of the hours.

2.5 Performed Tests

First, the Arduino 2560 has been set up with dth22, YL-69 and YL-38 sensors in conjunction with an Ethernet module. For 24 h data has been registered every 30s, the system worked without any problem showing the variations expected by the day/night change.

Secondly, the Arduino 2560 has been configured with dth 22, ph (tester), brightness, YL-69, YL-38, ESP8266 WiFi module and GPS module. Also for 24 h the system functions correctly. With an approximate consumption of 700mA. Lime dissolved in water has been applied at 4h of test start point and the expected pH change has been detected properly. It has been verified that the

Table 2. Database table of edafoclimatic variables and information fields

Array 1	Array 2
Data Humidity soil from 08:00 to 14:00	Data Humidity soil from 14:00 to 18:00
[[
Hum_S8 D1 - Hum_S14 D1	Hum_S14 D1 - Hum_S18 D1
Hum_S8 D2 - Hum_S14 D1	Hum_S14 D2 - Hum_S18 D1
Hum_S8 D3 - Hum_S14 D1	Hum_S14 D3 - Hum_S18 D1
.	.
.	.
]]
Array 3	Array 4
Data Humidity soil from 18:00 to 01:00	Data Humidity soil from de 01:00 to 08:00
[[
Hum_S18 D1 - Hum_S1 D1	Hum_S1 D1 - Hum_S1 D1
Hum_S18 D2 - Hum_S1 D1	Hum_S1 D2 - Hum_S8 D1
Hum_S18 D3 - Hum_S1 D1	Hum_S1 D3 - Hum_S8 D1
.	.
.	.
]]

GPS module gives the correct position with a margin of error of 20 meters. No data losses has been detected and the corresponding database entry has been recorded for all submissions.

Thirdly, the Arduino 2560 has been configured with dth 22, ph (tester), luminance, YL-69, YL-38, GSM/GPRS SIM900 module and GPS module. Using the TELEBUCARAMANGA operator and configuring SMS sending mechanism every hour. For 24 h the test has been done obtaining a 100% reception of the data.

Fourth, two nodes have been configured. Node1 (emitter): Arduino 2560 with dth 22, ph (tester), luminance, YL-69, YL-38, GPS module and XBee pro modules. Node 2 (receiver): Arduino 2560 with Ethernet and XBee pro modules. For 24 h the test has been performed without observing data losses. The power consumption of both nodes has been reported to be approximately the same, about 600 mA.

Finally, the installation of the software (LAMP) has been performed on a Raspberry PI 3 (in the other tests it was installed on a laptop). In this case the node had: Arduino 2560 with dth 22, ph (tester), luminance, YL-69, YL-38, GSM/GPRS SIM900 module and GPS module. For 24 h data has been taken, data loss has been observed and it has been found that access to it is slow because performance limitations of Raspberrry. Also the approximate energy consumptions has been calculated obtaining 600mA for the Arduino and 2.5 A for the Raspberry.

3 Results

3.1 A Single Transmitting Node

The data acquisition was performed 4 times a day, at following times 8 am, 2 pm, 6 pm and 1 am; Since in these hours is when data have a significant variation. A soil sample from an African oil palm crop was analyzed where bud rot was not present.

In the database a table was created to store edafoclimatic variables and three information fields: Control ID, the number of node that is transmitting and timestamp.

3.2 Two Nodes Transmitting

Figure 2 shows the connection scheme used in two nodes that performed the acquisition of edafoclimatic variables, without presence of bud rot (Node 1) and presence of bud rot (Node 2).

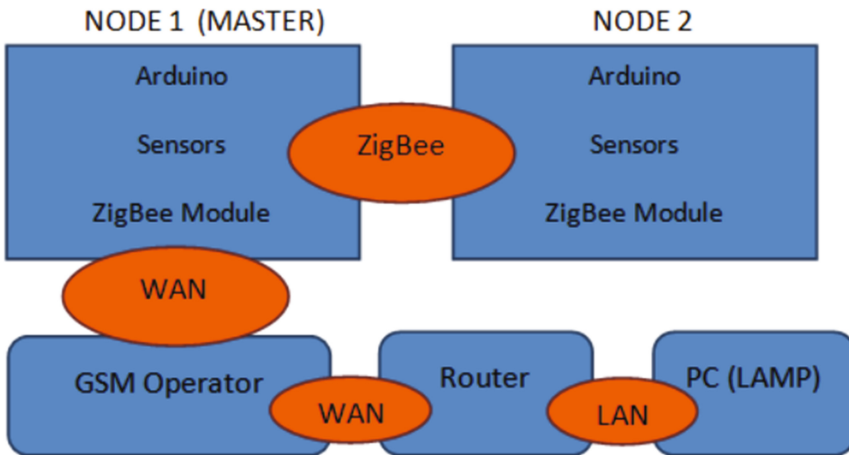


Fig. 2. Connection scheme

3.3 Tests Made with Soil of a Crop Without Presence of Bud Rot

The acquisition was performed 4 times a day, at 8 am, 2 pm, 6 pm and 1 am, Since in these hours is when data have a significant variation. The transmission of acquired data will be done 3 times a day. The acquisition at 1 am will be transmitted, to minimize the energy consumption, along with the data acquired at 8 am.

The nodes were interconnected with ZigBee protocol. One of them acted as master and sent data to the server through GSM network of CLARO operator.

Tests Performed on Crops Without Bud Rot Transmitted by Node 1.

Figure 3 shown that the soil where palms that does not suffer from bud rot (BR) have pH that is neither alkaline nor acidic soils, in addition it can be observed that there is no significant variation of pH.



Fig. 3. Soil pH variation of crop without bud rot [pH/s]

The results corresponding to luminosity are shown in Fig. 4 You can see day and night cycle.

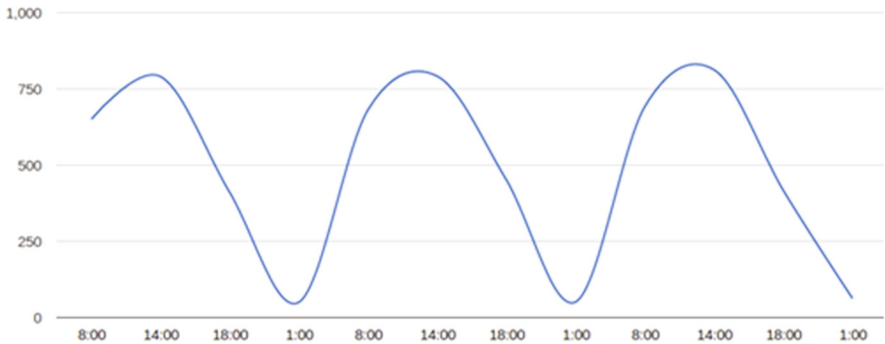


Fig. 4. Luminosity variation of crop without bud rot [lux/s]

Figure 5 shows temperature changes that occur during the 72 h of the evaluation in a soil sample without but rot presence.

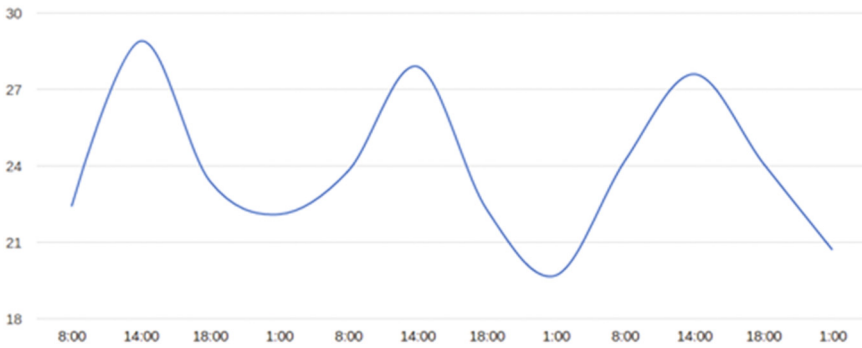


Fig. 5. Temperature variation of crop without bud rot [°C/s]

Figure 6 shows ambient humidity taken by the node installed on the ground that does not have bud rot presence.

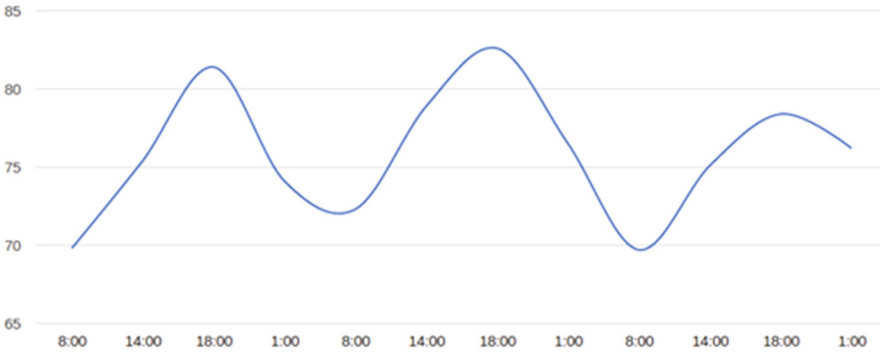


Fig. 6. Humidity variation of crop without bud rot [%/s]

Tests Performed on Crops with Bud Rot. The next node is installed in a container containing soil taken from a crop having bud rot.

In order to verify that there was a variation of pH in soil with bud rot presence, twenty-four (24) h after the transmission began, an application of lime dissolved in water was performed.

In Fig. 7 it is possible to observe ambient temperature which was measured during a period of 72 h.

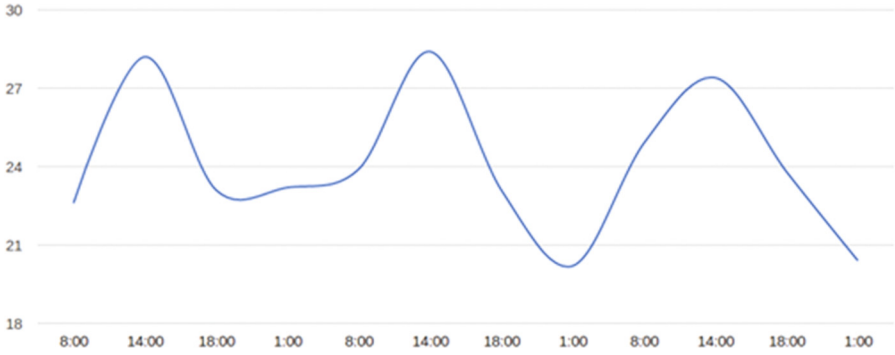


Fig. 7. Temperature variation of crop with bud rot [°C/s]

Figure 8 shows the behavior of the pH. As can be observed the soil pH is acid, it is transformed to neutral pH soil using lime.

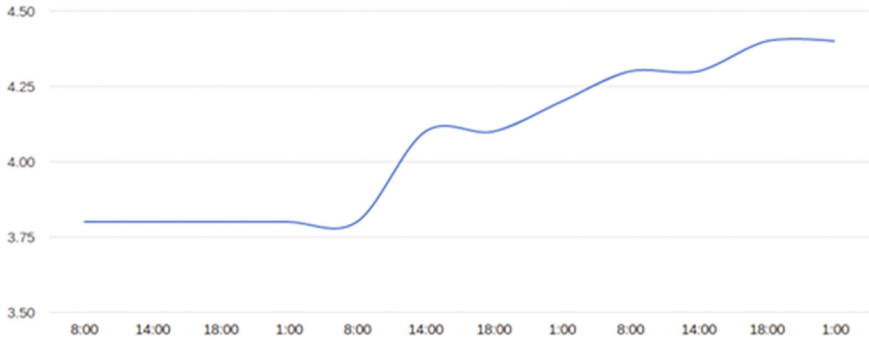


Fig. 8. pH variation of crop with bud rot [pH/s]

Figure 9 shows luminosity variable for soil with bud rot presence.

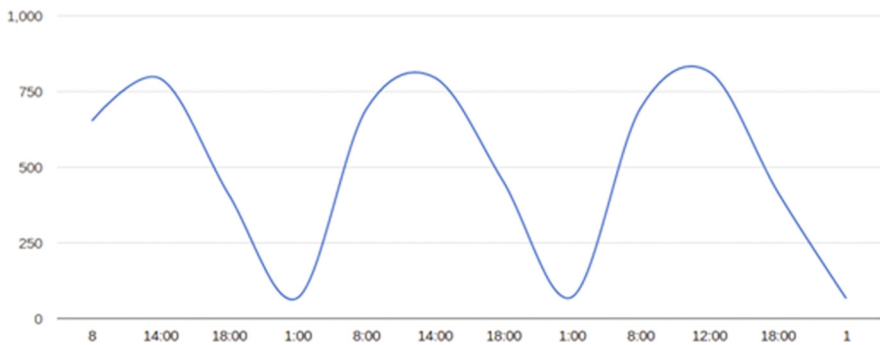


Fig. 9. Luminosity variation of crop with bud rot [lux/s]

Figure 10 shows humidity present in the container containing soil of a crop with presence of bud rot. Here it is necessary to take into account that after 12 h of test start a lime dissolved in water is applied, for this reason humidity increases abruptly in about 10%.

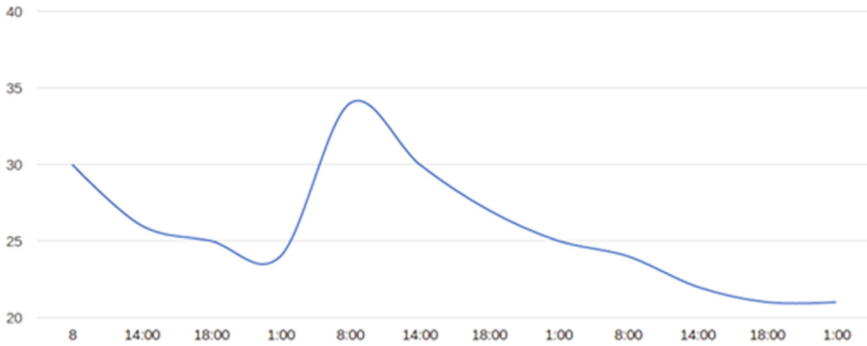


Fig. 10. Humidity variation of crop with bud rot [%/s]

4 Conclusions

In this paper a WSN system and node design has been presented. The WSN nodes that make possible acquire, process and transmit sensor measurements has been developed. The prototype can send measurements in real time mode to a central server process. In this project the prototype in set up to capture variables such as: pH, humidity, temperature and luminosity from African Palm trees. Additionally, the WSN device is equipped with different source of power supply and georeferencing system. The results indicate that the proposed system makes possible an early detection of abiotic factors that may trigger bud rot in African Palm trees. Thus, enforce early detection of triggered environment for bud rot, farmers could apply strategies to minimize bud rot impact on crops.

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