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Research Article

Wireless Sensor Network to Predict Black Sigatoka in Banana Cultivations

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Abstract

Black Sigatoka is a disease caused by the fungus *Mycosphaerella fijiensis Morelet* and is considered worldwide as one of the most destructive diseases in the musaceae, as it produces foliar necrosis in the leaves of banana and banana plants, and consequently the fruits do not possess the necessary characteristics for their consumption or for an effective commercial activity. This disease has spread to all areas where plantains or bananas are grown. The goal of this paper is the use of prediction models of Black Sigatoka outbreak in banana cultivation in order to design a wireless sensors network for remote monitoring of climatic variables related to the disease, allowing, this way, scheduling of fungicide treatments for early removal.

Keywords: Prediction Model; Precision Agriculture; Black Sigatoka; Wireless Sensor Network; Remote Monitoring

Abbreviations

GS: Gross Sum; ES: Evolution State; PE: Piché Evaporation; ED: Evolution of Disease; WSN: Wireless Sensor Networks; TAP: Total Accumulated Path; BS: Base Station; PP: Path of Propagation.

Introduction

Consuming of bananas has great significance in feeding of people. It is an essential part of the daily diet of citizens of one hundred tropical and subtropical countries. The banana is ranked as the fourth most important crop in the world after rice, wheat and corn.

Black Sigatoka is a disease caused by Mycosphaerella fijiensis morelet and it is regarded worldwide as one of the most destructive diseases in Musaceae[1] because it produces leaf necrosis on leaves of banana plants fruits (Figure 1) and therefore do not have the necessary characteristics for consumption or for effective commercial activity. This disease has managed to expand to all cultivation areas, that is, why it has been fought with systematic treatment with fungicides and cultural practices. Cost fungicide applications represent a large percentage of production cost of banana and such measures entail harmful effects to the environment. On the other hand, cultural practices alone are not enough to control the disease.

Figure 1: Banana leaf affected with Black Sigatoka.

Alternatively, model-based programs have developed for early prognosis of possible outbreaks of this disease in order to make more efficient application of fungicides. These models are based

[1]Musa (Musaceae scientific name) are a family of monocot plants known for their fruit (bananas and plantains)

on the correlation between the disease and weather variables that such as temperature, humidity, solar radiation, precipitation and wind speed. The favorable conditions for the proper development of banana plants are those that follow:

- Warm weather
- Constant humidity in the atmosphere at a level of 90 to 95%
- Growth stops at temperatures below 18°C.
- Damage occurs at temperatures below 13°C and over 45°C [1].

Bioclimatic forecasts

The main problem of Black Sigatoka management is that this is a very persistent disease, which over time has become resistant to the main agrochemicals (fungicides) that are used worldwide to combat it.

The disease sampling systems seek to make the application of fungicides more efficient based on the early prognosis of possible outbreaks of this disease. In this regard, various forecasting or early warning techniques have been developed, on the one hand manual sampling methods and on the other bioclimatic forecasts. Commercially, two manual sampling systems have been applied to decide the applications of fungicides in plantations of bananas, the Stover method modified by Gauhl and the method of biological warning or prediction.

The method of Stover modified by Gauhl

The method of Stover modified by Gauhl [2] is based on the quantification of the state of development of the disease, according to the symptoms it causes in the affected plants (type and number of lesions, number of affected leaves, percentage of affected leaf area, younger leaf infected, weighted average of infection and number of functional leaves). The method consists of making a visual estimate of the diseased leaf area in all the leaves of nearby plants to flourish and that are representative in the population of the garden.

The biological warning system

The biological warning system is based on the analysis of biological and climatic descriptors for the timely application of fungicides, in periods in which the severity of the disease begins to increase and the climatic conditions lead to a favorable development of the pathogen.

The notice is based on weekly observations of symptoms in the young leaves of actively growing plants. Arbitrary coefficients are assigned to the three youngest leaves, according to the incidence and severity of the disease and with them two variables are calculated: the Gross Sum (GS) and the Evolution State (ES) [3]. The GS refers to the present state of the infection and is an arbitrary value that increases with the advance of the symptoms and the youth of the leaves. The EE is calculated using the GS and the leaf emission rate of the plants.

With these variables and methods it is possible to perform the applications of agrochemicals by biological signaling, that is, that it will be fumigated only when the disease warrants it and if these variables behave with critical values; so the application of the fungicide must be carried out with haste to cut the advance of the disease because the conditions are favorable for the development of the same. It also allows knowing if the fungicide achieved progression or regression of the pathogen, if it is possible to change it in time and conclude which is the ideal pesticide for the phytosanitary combat.

Bioclimatic forecasts

The principle of operation of for these models is the lookup of correlation functions between the climatic variables and the disease severity, which is achieved by applying iterative methods. In order to accomplish it statistical and data mining analysis is carried out where independent variables are the climatic variables and dependent ones are the biological, both registered chronologically.

The climatic variables with the highest correlation with the predictive models biological data as the Black Sigatoka epidemiology as a target are the air temperature, evapotranspiration, solar radiation, wind speed and relative humidity.

Three forecast models [3-5], applied in different regions of the Americas were analyzed. From them [5] was chosen to be oriented to a wider range of banana varieties.

Model description

The climatic variables chosen to be measured were temperature, intensity and duration of rainfall, intensity and duration of wetting of the leaf and Piché evaporation (PE). With the data of maximum temperature (Tmax) and minimum (Tmin) daily were calculated the sum of daily rates of evolution of the disease (ED) using (1) with which weekly accumulations were obtained.

$$ED=7.18T_{max}+79.16T_{min} \quad ....(1)$$

Recording equipment for measurements were used, located in a standard weather house, it comprised thermometers for maximum and minimum temperatures, a Mechel MT 1500 thermohydrograph, a Mechel UM 8100 rain gauge, a Piché evaporimeter and a Woelfe-type humectograp.

The data of rainfall amount in mm and rainfall duration in minutes were accumulated for periods of 7, 10 and 14 days and submitted to correlation analysis with the SE records obtained in the same week and between 1 and 8 weeks after; with the results of these analyzes a matrix of correlations was constructed. The same procedure was followed with the records of intensity and duration of the wetting of the leaves. The statistical analyzes were carried out with the statistical program STATISTICA [6]. Figure 2 shows the curves of the State of evolution (EE4H), observed and calculated as a function of rainfall accumulated during 14 days, 5 weeks before. Weighted Piché Evaporation (PE) was considered 4 weeks before. For the calculation of the latter it was determined that the model equation must follow the law that appears in (2).

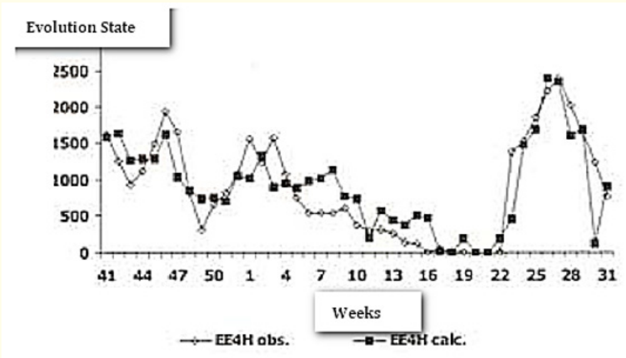

Figure 2: Evolution State (ES) curves calculated according to accumulated rainfall for 14 days.

$$ES_{4H_{cal}} = 6.002(S_{14d} * LL_{mm}) - 183.95EvPp + 1732.57 \quad ....(2)$$

Remote perception of bioclimatic variables

Wireless sensor networks can contribute to the analysis of crop health status by means of regular monitoring at specific sites of physiological conditions of plants, as well as collecting information on various climatic variables, such as temperature, precipitation, humidity, hours light, radiation levels, wind and evaporation.

Wireless sensor networks were selected among the remote monitoring technologies, its best features are scalability, low cost, auto configuration capacity and low consumption.

For application of WSN in resolving an precision agriculture issue, the methodology displayed in figure 3 [7] fit all design requirements but several recommendations in [1-8] were included.

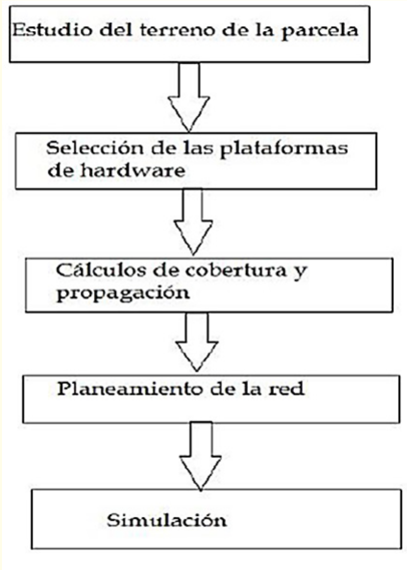

Figure 3: Methodology for WSN application to precision agriculture issue.

Coverage and propagation calculations

For the implementation of the wireless sensor networks in the plots, the deterioration of the signal must be considered due to the existence in the propagation path of a dense vegetation of the crops. The total loss accumulated in the trajectory (TAP Loss, Total Accumulated Path Loss) can be expressed as the sum of the losses in the path of propagation of the wave (PP Loss) and the losses introduced by the dense vegetation (Veg Loss) of the cultivations, see (3).

$$TAPloss(db) = PPloss(db) + Vegloss(db) \quad ....(3)$$

The power available in the receiver, depending on the power delivered by the transmitter and the different losses and gains that appear in the path from the transmitter to the receiver, can be calculated by (4)

$$Prx = Ptx - LTT + Gtx - TAPloss + Grx - LTR \quad ....(4)$$

Where Ptx is the transmission power (dBm), Prx is the reception power (dBm); LTT and LTR are losses (dB) in the terminals; Gtx and Grx are gains (dB) of the transmit and receive antennas respectively, in relation to the isotropic antenna and TAPLoss are losses (dB) accumulated in the propagation path. In addition, a margin of protection (M) should be considered in the calculations against fading over the receiver threshold.

The maximum distance at which two adjacent sensor nodes can communicate within a crop that has a dense vegetation is bounded by the attenuation imposed by the crop itself (Veg Loss) and the characteristics of the hardware platform. By means of (5) the physical height of the antenna (h) can be calculated.

$$h \geq hc + 5.194\sqrt{\frac{D}{f}} \quad ....(5)$$

Figure 4 shows the dimensions of the banana crop plot, taken as a case study. It also represents the location of the sensor nodes. BS denotes the Base Station

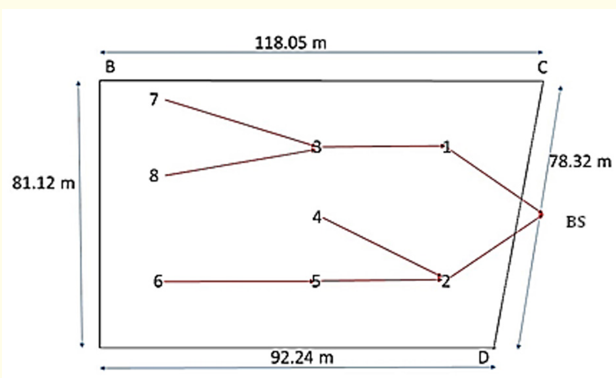

Figure 4

Two topologies were compared, in tree and mesh, resulting in mesh topology which presented the best performance. To do this, OPNET Modeler was used: an event-based simulator aimed at simulating telecommunications networks.

Considerations for Wire Sensor network application (4)

Sensors were needed for measuring the following primary variables: relative humidity, temperature, rainfall intensity and wind velocity. Once the variables are received in the sink processing terminal, all prediction model equations are applied in order to forecast the evolution state of Black Sigatoka disease.

For the calculations of coverage and of propagation, signal attenuation models in presence of vegetation was considered, so as the, the possible obstructions of Fresnel's zone and the network topology that better fit terrain geometry.

Conclusions

One hectare of banana-cultivated terrain in a farmer cooperative was selected as a test bed. Libelium was preferred as the company equipment provisioning because it allowed more freedoms for the WSN's design as well as the capability to select the frequency band and transmission technology. They network comprised 8 nodes with a maximum distance between nodes in 54,70 m and radiolink antenna's height were about 3,67 m. The nodes were distributed in a mesh topology which proved better performance and throughput.

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Bibliography

1. EAA Espinoza. "Diseño de una red inalámbrica de sensores para monitorear un cultivo de plátano en el distrito de Mala". ontificia Universidad Católica del Perú, (2011).
2. J de JC Gutiérrez. "Sistema de adquisición y análisis de información para el diagnóstico de sigatoka negra".
3. JA. Freitez. "Desarrollo de un Modelo Predictivo del Brote de Sigatoka Negra para las Plantaciones de Plátano al Sur del Lago de Maracaibo". 9 (2007): 191-198.
4. L Hernández., *et al*. "Estudio preliminar de vigilancia y pronóstico para sigatoka negra (Mycosphaerella fijiensis Morelet) en el cultivo de plátano (Musa AAB cv Hartón) en Macagua-Jurimiquire, estado Yaracuy". *Revista de la Facultad de Agronomia* 22 (2005).
5. L Pérez Vicente., *et al*. "Epidemiología de la Sigatoka negra (Mycosphaerella fijiensis Morelet) en Cuba. I. Pronóstico bioclimático de los tratamientos de fungicidas en Bananos (Musa acuminata AAA)". *Revista mexicana de fitopatología* 18 (2000).
6. http://www.statsoft.com/Products/STATISTICA-Features
7. IP Vizcaíno Espinosa. "diseño de una red de sensores inalambricos aplicados a la detección de pesticidas en aguas de zonas bananeras". Universidad Rey Juan Carlos, Machala, Ecuador, (2011).
8. Daniel Villón Valdiviezo. "Diseño de una red de sensores inalambrica para agricultura de precision". Pontificia Universidad católica del Perú, Lima, Perú.

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