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Farmer-friendly portable system for diagnosis of pest attack in cashew trees

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Abstract Owing to the continual attacks by pests particularly the bark-beetles (viz borers), there has been tremendous destruction of the forest resources. Beetle attacks are also responsible for severe production loss in commercial crops, thus leading to distress to farmers. In this paper, we have presented a novel approach to detect the pest attack in yielding cashew trees at early stage, i.e. to develop a portable unit. The preliminary analysis of bark samples (taken at height of 1.5 meter) shows a clear distinction between the good and infested trees. Also, the chlorophyll analysis performed on leaf samples shows the result for good and different stages of infestation as decrease in absorbance values of the leaf extract. The proposed design will indicate the status of a cashew tree by analysing the chlorophyll content of leaves and conductivity of bark, both of which will be utilised to make an ultimate confirmation.

Keywords Diagnosis · Pest-attack · Chlorophyll-absorbance · Conductivity-electrodes · Portable embedded meter

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1 Introduction

The greatest threat to agriculture worldwide has been from pests. The pests can be ranging from microbial type (i.e. fungus and bacterial infections) to insect type, which cause significant tree mortality.

Borers [1] are one kind of insect pests which are known to particularly target upon matured trees [2] . An alarming number of incidences of borer attacks on forest resources have been reported [3]. The damage by bark beetles to green coverage of the globe [4] is so tremendous, that it transforms the carbon sink to carbon source, owing to the tendency of dead dry trees to forest fires [5]. Apart from forests, in case of commercial plantations the borers attack vital bark portions of yielding trees causing untimely death of the tree.

In regions of cashew plantations, the Cashew Stem and Root Borers (CSRB) *Plocaederus ferrugineus* pest is nocturnal, i.e. rarely visible during daytime [6]. They flourish under the bark of tree, while making irregular tunnels through the tissues of the bark. Moreover, if there is 50% or more damage to the bark circumference or with the leaf canopies yellowed, there is least possibility to restore it back to its healthy status, as no measures of cures can save the infected tree.

Over a period of few months, a CSRB attack on certain plantation causes huge financial losses in produces of cash crops, thus distress to the farmers.

Also in future, there will be increase in extent of areas affected by bark beetles owing to climate changes and global warming. Thus, the detection of presence of borer attack is financially as well as environmentally vital.

1.1 Related works

Earlier works have focused towards developing various electronic methods or systems to determine the presence of pest incidence as well as assess the extent pest attack in a given location up to maximum accuracy.

Remote sensing is one such method to detect bark beetle-caused tree mortality using single-date and multi-date Landsat imagery [7]. Here the accuracies between the best single- and multi-date methods across a range of tree mortality within a pixel were compared; the single-date method was found to be more accurate at high mortality levels, whereas the multi-date method was more accurate at intermediate levels of tree mortality. The results indicate that Landsat-based mapping (using either single-date or multi-date methods) of forest attack scenarios can result in high classification accuracy.

A further idea of combining of field data with remote sensing [8] helped in minimizing the reaction time and reducing costs of monitoring programs expansing the vast forested areas. RapidEye and TerraSAR-X data were analysed both separately, and in combination to detect bark beetle green attack. To distinguish healthy areas and areas affected by bark beetle green attack, three statistical approaches (generalized linear models (GLM), maximum entropy (ME) and random forest (RF) were compared. The accuracy of ME models was considerably higher than the accuracy of GLM and RF models.

Another study implemented the accurate classification of flying insects using inexpensive, non-invasive sensors [9]. The pseudo-acoustic optical sensors produced vastly superior data for extracting the additional features, both intrinsic and extrinsic to the insects flight behaviour. A Bayesian classification approach was utilised to efficiently learn classification models that are very robust to over-fitting.

In another study, the image processing and SVM classifier was used to develop software prototype system for early pest detection on the infected crops in greenhouse [10]. Images of the infected leaf were captured by a camera and processed using image processing techniques. The SVM classifier was used for classification of pest based on their features. Results show more precision in identifying the presence of pest at early stage.

Also, a progress related to detection of cell wall degradation caused by bacterial wetwood, the Ultrasonic decay detectors (UDDs) are proven to be used for detecting the same in red oaks (in the southern United States and in a Chilean hardwood species) apart from successfully detecting decay in live hardwood and conifer trees [11]. A UDD records time-domain and frequency-domain waveforms that can be positively linked to individual types of defects, and that uses smaller, pointed transducers to minimize tree wounds.

1.2 Our contribution

Following the discussions in Sect. 1.1 it can be deduced that the set of previous works on pest attack detection emphasized towards considering the wide areas of plantations or forests as whole information, apart from one work advocating the focus on certain individual trees (affected with bacterial wetwood problem).

After exploring the area of pest-detection of Agro-electronics, we learnt that the study of probable changes induced in plants under attack including the study of defensive mechanism of the trees, plays as a key factor in the designing the system capable of detection of pest damage.

Thus, the aim of this research is to develop an Embedded System, with functionality of indicating the status of a given tree, w.r.t. presence of infestation by CSRB. The implementation of this system will be based on design comprising of the results obtained after series of certain analysis procedures i.e. spectrophotometry in suitable light regions.

The rest of the paper is organized as follows: Sect. 2 presents in detail the proposed approach to detect the existence and severity of infestation. The planned design is based on conductivity measurement (of trunk region of tree) and chlorophyll measurement (of leaves region of tree). Section 3 presents the detail description of our newly obtained results of NIR spectroscopy performed on samples of bark and visible spectroscopy performed on samples of leaves, where-in the samples were collected from a plantation with suspected CSRB infestation problem. Section 4 presents in detail the employed experimental protocol, and Sect. 5 gives details of the results of spectroscopy performed on samples of bark and leaves collected from a plantation with on-going infestation problem. Finally, Sect. 6 presents the concluding remarks.

2 Proposed method: development of embedded platform for CSRB detection

The Proposed embedded system will primarily consist of an ARM7 unit, which will be the heart of the entire system (Fig 1). ARM will run a prediction model to establish the decision about the status of a productive plant, w.r.t. presence of infestation. The inferences (i.e. range of data values, which are belonging to the conductivity measurement and chlorophyll measurement) obtained at the end of the spectroscopy analysis procedures will be stored in the data memory of ARM.

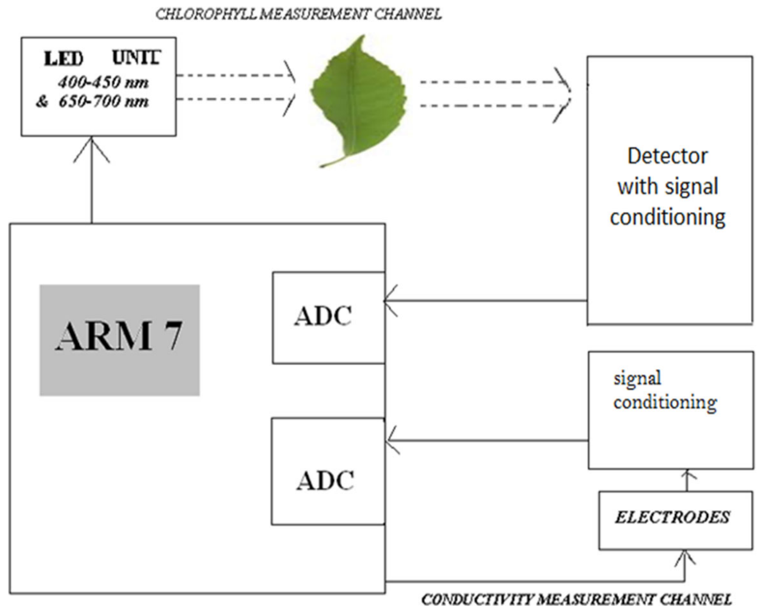

Fig. 1 Block diagram of the proposed system

The remaining part of the system comprises of conductivity measurement channel and chlorophyll measurement channel. The final implementation of both these channels will extensively utilise the preliminary results obtained using spectroscopy for bark analysis and leaf chlorophyll content of good & infested trees.

The function of the conductivity measurement channel [12–15] will be to detect the continuity of food and water channels (i.e. phloem and xylem) in the tree. It will comprise of electrodes, which will be inserted within the bark portion (at height of around 1.5 mt. from ground) of tree under consideration.

Spectra of samples of bark of healthy cashew tree, initial stage of infestation and end stage of infestation of cashew trees will be analysed to note down the Absorbance values (in OD) at the peaks in spectra and wavelength values corresponding to those peaks. The wavelength values would be utilised to constitute a range of frequency values. This range will be the input to the electrodes given from the ARM 7. The Electrodes output is then conditioned and given to ADC of ARM 7 Board.

Further, the function of the chlorophyll measurement channel [16, 17] will be to monitor the change in absorbance values at pre-defined wavelength. An LED unit will emit the light wavelengths for the detecting the concentration of chlorophyll [18, 19] in a given leaf. The silicon detector would collect the wavelengths transmitted through the leaf to detect the absorbance phenomenon, and the signal conditioning unit convert the output of the detector to suitable level for ARM 7). The ARM 7 unit provides the input to the LED unit, and also converts the output of the signal conditioning unit to digital form.

3 Experiments for the preliminary analysis

This section of the paper describes the two sets of experiments performed in this work: **Experiment 1** aims at obtaining the absorbance spectra in UV-Vis light region, for extracts of samples of bark of cashew tree (Fig 2). The range of wavelength of the spectrophotometer was fixed to 200nm to 2000nm.

Whereas, the **Experiment 2** aims at obtaining the absorbance spectra in visible light region, for extracts of samples of leaves of cashew tree (Fig 3). The range of wavelength of the spectrophotometer was fixed to 200nm to 1000nm

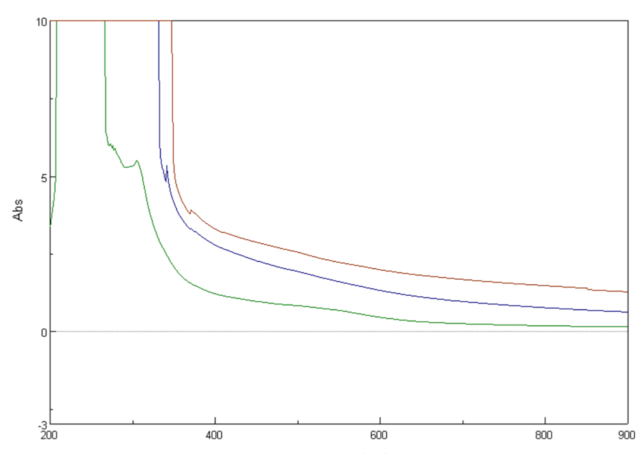

Fig. 2 Spectra of samples of bark of healthy cashew tree (in green color), initial stage of infestation (in blue color) and end stage of infestation (in red color) cashew trees. (Color figure online)

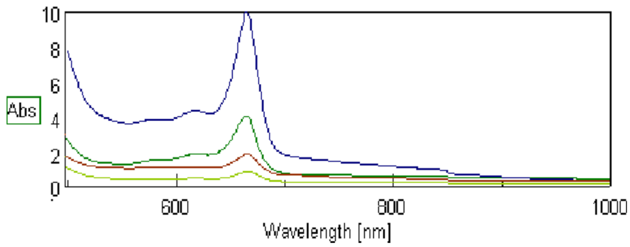

Fig. 3 Spectra of samples of leaves of healthy cashew tree (in blue color), initial stage of infestation (in green color), middle stage of infestation (in red color) and end stage of infestation (in faint-green color) cashew trees. (Color figure online)

Table 1 Absorbance values (in OD) at the peaks in spectra and wavelength values corresponding to those peaks, of healthy cashew tree, initial stage of infestation and end stage of infestation of cashew trees

Condition of cashew tree	Wavelength value at peak absorbance (in nm)	Absorbance value
Good stage	305	5.49142
Initial stage	341	5.28
Severe stage	371	4.14519

4 Experimental protocols

In this section, we discuss about the experimental protocols adopted for Experiment 1 and Experiment 2. For conducting the experiments, the extracts were prepared by resorting to mass-basis, i.e. by weighing the samples collected from plantations. In order to carry out the **Experiment 1**, we accurately weighed 0.1g of fresh bark sample as solute, and 4 ml of boiling water as solvent, and crushed in a crucible. In order to carry out the **Experiment 2**, we accurately weighed 250mg of fresh leaf sample as solute, and 5ml of DMSO (Dimethyl Sulphoxide) as solvent, and macerated/crushed in a crucible.

Both the experiments were conducted using instrument: Jasco J-770 Spectrophotometer and spectra were plotted using SpectraAnalysis of the Jasco SpectraManager software.

For collecting the samples for the experiments, the cashew trees in a plantation with reported cases of recent deaths were visually surveyed to identify the existence of borers, and also the levels of their infestation. The categories of infestations were established as INITIAL, MIDDLE and SEVERE stage of infestation. Further, the results of all the three categories were compared with results of good cashew tree (Tables 1, 2).

Table 2 Absorbance values (in OD) of leaves samples at the three peaks of wavelengths: 664 nm, 620 nm and 585 nm, of healthy cashew tree, initial stage of infestation, middle stage of infestation and end stage of infestation of cashew trees

Condition of cashew tree	Absorbance value at peak of		
	664 nm	620 nm	585 nm
Healthy stage	4.05385	1.8505	1.52
Initial stage	1.87772	1.68	1.66
Middle stage	1.79969	1.05	0.85
Severe stage	0.877145	–	–

5 Results

The conductivity analysis performed in Experiment 1 on bark samples of good cashew tree, and bark samples of initial and severe stage of infestation shows a prominent shift in wavelength values (in nm) at their respective peak absorbance values (Fig 2).

The obtained absorbance spectra indicate a distinct peak at wavelength of 305 nm, 341 nm and 371 nm, for good stage, initial stage of infestation and severe stage of infestation respectively.

The chlorophyll analysis performed in Experiment 2 on leaf sample of good cashew tree, and leaf sample of initial, middle and severe stage of infestation shows the observable decrease in absorbance values of the leaf extract (Fig 2).

The obtained absorbance spectra indicate three peaks at wavelengths (in nm) at 664 nm, 620 nm and 585 nm. The absorbance values at these peaks were obtained as 4.05385, 1.8505 and 1.52 for a good non-infested tree; 1.87772, 1.68 and 1.66 for tree at initial infestation stage; 1.79969, 1.05 and 0.85 for tree at middle infestation stage. However, the absorbance spectra for tree at severe infestation stage showed only one peak of 0.877145 at wavelength of 664 nm.

The changes in absorbance values are attributed to the production of various chemical (defensive) compounds in tree, as per the functioning of defensive mechanism of plant upon infestation.

6 Conclusion

The stress to yielding cashew tree by the current widespreading extent of borer infestation is causing their mortality, and the resultant huge yield loss is a financial burden to farmers of the state. In this study, the results of experiments for the preliminary analysis obtained through spectroscopic method assert that physiological changes occur within the plants as the infestation progresses.

In case of leaves, there is observable change i.e. decrease in the three peaks of absorbance values in the chlorophyll spectra of healthy and different stages of infested trees.

Whereas in case of bark, there is prominent shift in wavelength values (in nm) at the peak absorbance values, in spectra of healthy and different stages of infested trees.

Since both the above changes illustrate a confirmed distinction between the good and infested trees, it is concluded that they will be accepted as the basis for the development of the technique for diagnosis of pest attack in cashew trees.

Hence we have decided to propose the Portable embedded infestation detection meter which farmer will be able to use without any expertise help.

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