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DEVELOPMENT OF EMBEDDED SYSTEM FOR EARLY DETECTION OF BEETLE ATTACK IN CASHEW TREES

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Abstract:
Beetle attacks are known to be tremendously affecting the green sheet of the globe by causing 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 the results of absorbance measurement (by spectro-photometric method) performed on bark samples, at various stages of pest attack of cashew trees. The results show that there is considerable change in absorbance, which indicates presence of the defensive compounds in the sample reduced by the physiological mechanism of tree on pest attack. Also, in this paper, we have proposed the design of a portable embedded system (based on ARM micro-controller), which can perform the prompt and accurate early detection of the pest infestation by analysing the change in bark contents.
Keywords: *Stem borer, pest attack, Agro-electronics, Embedded, conductivity*

I. Introduction

Plants are the only higher organisms on the planet capable of converting energy from the Sun into chemical forms of energy that can be stored or used (Agrios, 2005). Therefore, plants are a source of food for a great many organisms, directly or indirectly.

The continued existence of plants is remarkable given the huge range of organisms that used them as a source of nourishment. The fact that plants survive in the face of continual onslaught from attackers is testimony to their defensive abilities and their ability to cope with damage inflicted during attacks. Understanding the changes that occur in plants under attack is important in attempts to produce crops better able to withstand the ravages of pathogens and pests.

Although plants have evolved a bewildering array of defences to ward off attack (Walters, 2011), many plants succumb to attack and suffer damage and disease as a result. This, in turn, can affect the growth and reproductive output of the plant, which can exert a significant effect on competitive ability and survival. In terms of crop production, damage and disease can affect the yield and quality of produce, with economic consequences to the farmer or grower. Plants have mechanisms responsible for the changes in plant growth, development and yield following attack by various organisms.

The interaction between a plant and an attacker is dynamic and for example, in an incompatible interaction, host defence is financed by primary metabolism, and often, effective resistance is associated with a cost in terms of plant growth. In compatible interactions despite the fact that attackers are able to manipulate host metabolism for their own benefits, the host plant is still able to alter metabolic processes to make life difficult for the invader.

Amongst the attackers, the borers have been found generally to infect the trees leading to their death in period of six months. The damage by the bark beetles to forests is explained from the following cases:

1) In case of forests, the insect damage causes the carbon sink of forests to turn into carbon source [1]. There has been a 4-fold increase in monoterpene emissions and up to a 40% increase in SOA (secondary organic aerosol) concentrations in some years (as observed lodgepole pine response), as result of Beetle infestations.

2) The enormous area of dead forests attacked by such pests is susceptible to forest fires, as the damaged forests trees being dry are highly inflammable [2].

The cases of the beetles' attacks all over the world are known as follows:

1) The Japanese cypress bark beetle, *Phloeosinus rudis*, *P. bicolor* and *P. thujae* killed numerous shrubs and trees of Cupressaceae in The Netherlands, in the summer of 2004 [3].
2) Extensive beetle outbreaks by mountain pine beetle (MPB), on the lodgepole pine and ponderosa pine have destroyed over lakhs of km^2 of forest throughout British Columbia and the western United States[4].
3) A tree-killing bark beetle, *Dendroctonus frontalis* is a destructive forest pest in the southeastern United States[5].
4) In Norway, *Ips typographus* is the major tree-killing bark beetle attacking spruce *Picea abies*[6].

Locally in case of the cashew (Anacardium occidentale L), the severe borer pest attacks by the Cashew Stem and Root Borer (CSRB)

Plocaederus ferrugineus pest leads to significant reduction in cashew nut yield [7]. Since cashew is an important commercial plantation crop (with an enormous potential for foreign currencies), huge financial losses are faced by the farmers.

Thus, our main objective is to develop an embedded system for early detection of 'Stem and Root Borer' pest in cashew trees so that remedial measures can be adopted to restore the Tree. Here we are trying to detect the early attack by analyzing the change in conductivity of the bark of tree by obtaining its Absorbance spectra**.**

II. Literature review

Insects are estimated to consume approximately 10% of all plant bioass produced annually (Barbosa &Schulz 1987) (Coupe & Cahil 2003). Precisely how much plant bioass is consumed will depend on number of factors, such as type of vegetation & the geographical locationIn our country, the cashew plantations are facing great threat from the two major insect pests; which are Cashew Stem and Root Borer –CSRB (scientifically known as *Plocaederus ferrugineus*), and Tea Mosquito Bug (scientifically known as *Helopeltis antonni*).

The infested trees do not recover from the damage if the damage of the bark circumference is 50% or more, or with the leaf canopies yellowed [7]. And, the trees are becoming more vulnerable for pest insects such as *phloeosinus* species, as the summer drought and heat waves are predicted to be increased upon the climate change.

Thus, it is concluded that, the timely detection of the presence of CSRB infestation is of prime importance to the benefit of the farmers in the State**.**

The literature review focuses on the fact that upon attack by the pest, there would be changes in the physiology of the plant.

The two major changes are:

3.1 Reduction in chlorophyll content.

Leaf colors of a plant can be used to identify stress level due to its adaptation to environmental change (here in this case is infestation by pest) [8].

The proportion of chlorophyll a/b is considered as sensitive bio-marker of pollution & environmental stress. The absorbance properties facilitate the qualitative & quantitative analysis of them [9].

3.2 Measurable change in conductivity of the stem.

The two causes that would induce change in the conductivity of a healthy tree upon infestation, are as follows:

3.2.1 Destruction of xylem and phloem channels

Cashew Stem and Root Borer in its larval stage (grub) feeds on the bark portions of the stem and roots, by making irregular tunnels which enlarge as the grubs grow in size[7]. Thus, the water and food channels (i.e. xylem and phloem) get destroyed or clogged. This will result into a measurable change in conductivity over the desired concentration range.

3.2.2 Production of chemical (defensive) compounds in tree

In order to function and survive, plants produce a wide array of chemical compounds not found in other organisms. Because they cannot move, plants must also defend themselves chemically from herbivores, pathogens and competition from other plants. They do this by producing toxins and foul-tasting or smelling chemicals. Because the biology of plants differs from animals, their symptoms and responses are quite different [10]. Thus the study of defensive mechanism of plants plays the key factor in the designing the system for detection of pest damage by analyzing chlorophyll content.

III. Proposed Design

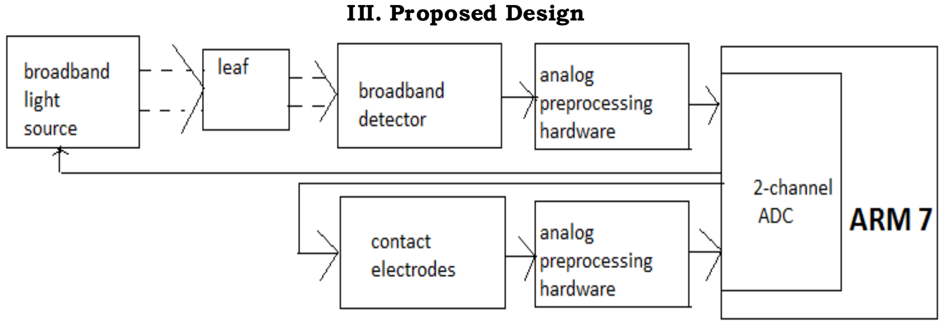

Figure 1: Block diagram of the system

The Proposed embedded system unit will have three major sub-blocks:

1) **ARM7 unit**: This is the heart of the entire system which controls the operation of the two channels, Conductivity measurement channel and Chlorophyll measurement channel.

The program memory of ARM will be loaded with the algorithm of the Prediction model. The

Prediction model will decide the status of a productive plant, w.r.t. presence of infestation. Its working will be designed based on the inferences (i.e. range of data values) obtained at the end of the certain analysis procedures**.** The data memory of ARM will be stored with data of pre-determined values, which are belonging to the conductivity measurement and chlorophyll measurement.

2) Conductivity measurement channel: It will comprise of electrodes, which will be inserted within the bark portion (at height of around 1 mt. from ground) of tree under consideration. The input to the electrodes will be frequency signal from the ARM 7. The Electrodes output is then conditioned and given to ADC of ARM 7 Board. The design of Conductivity measurement channel will be for the purpose of detecting the continuity of food & water channels (i.e. phloem & xylem) in the tree. Thus its role would be to verify or to determine the passage of nutrients to the plant [11] [12] [13] [14].

3) Chlorophyll measurement channel [15] [16] [17] [18]: It will comprise of LED unit (to emit the light wavelength for the detecting the concentration of chlorophyll, i.e. the violet-blue (400-450 nm) and reddish orange-red wavelengths (650-700 nm), leaf, silicon detector (to detect the absorbance phenomenon) and signal conditioning unit (to convert the output of the detector to suitable level for ARM 7). The input to the LED unit will be voltage signal from the ARM 7 unit. The output of the signal conditioning unit will be converted to digital form by ARM 7.

IV. Experimental setup

Spectroscopy was performed on the samples of bark extracts of infested trees, in the visible range and NIR range, wherein spectra were obtained using SpectraAnalysis of the Jasco SpectraManager software.

The light sources used were in-built within the Jasco J-770 Spectrophotometer.

Material and Methods

Collection of plant samples: In this study, we have focused on levels of infestations of CSRB infestations.

The cashew trees in a plantation were surveyed to identify the level of infestation in the CSRB affected trees, and three categories of infestation were decided as initial, middle and severe stage of infestation.

Analytical procedure: To prepare the extraction samples, we work on mass basis, by weighing the material.

Accurately weighted 1.0g of fresh plant bark sample and 3.0 gms of hot water as solvent was taken, and crushed in a crucible.

V. Results

The absorbance characteristics of bark content of infested cashew tree was obtained (Fig. 3) over the visible light range and absorbance value was noted for the wavelength (in nm) 400.

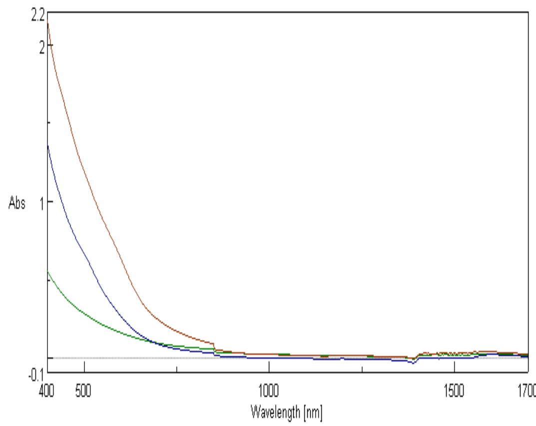

Figure 3: Spectra of bark in the three stages of attack-initial , middle and severe stage of attack (in green blue and red respectively)

As shown in the Fig 3, there is an increase in the absorbance (in OD) of light (in case of severely infested cashew tree) compared other stages i.e. middle and initial stage of attack at the wavelength of 400nm.

At wavelength of 400nm, the absorbance values are 0.55,1.35 and 2.17 in the initial, middle and severe stage of infestation respectively. The results (refer Table) indicate that the bark absorbance increases substantially in infested cashew tree.

Stages of infestation	**Absorbance at wavelength of 400 nm**
Initial stage	0.55
Middle stage	1.35
Severe stage	2.17

Table 1: Spectro-photometric determination of Absorbance (in OD) of bark extract of CSRB infested cashew tree

VI. Conclusion

Infestation by borer causes stress to the yielding cashew tree and lead to huge yield loss.

The results of Spectrophotometric measurement method of Absorbance of bark of cashew trees shows that there is considerable change in the sap content i.e. conductivity of bark (due to production of defensive compounds by the attacked tree), which means tree is under attack by pest.

A conductivity probe will be designed which will be capable of monitoring the conductivity changes I he bark of tree under suoervision.

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

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