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POSSIBLE APPROACHES AND FUTURE THRUST AREA TO DETECT INFESTATION BY CASHEW STEM AND ROOT BORER- A REVIEW

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ABSTRACT

Cashew (Anacardium occidentale L., Anacardiaceae) plays a key role in the export business of India. Cashew trees were initially introduced to India at Goa, by the Portugese, who started exporting the cashews in the early 1550's from Brazil, the native of the cashew tree species. Today, India has emerged as one of the major producer and exporter of Cashews in the International scenario. The Cashew tree is a tropical evergreen growing with a short trunk. Cashew Apple produced by the cashew tree is oval or pear shaped and is literally the false fruit. Cashew apples are edible which turns yellow or red in colour when it ripens. The real fruit of the cashew tree is kidney shaped which matures at the end of the cashew apple. The true fruit has an outer hard shell and inner edible kernal called the cashew nut. Cashew nut is delicious, full of energy, antioxidants, minerals, and vitamins. It is widely used as a popular ingredient in many dishes throughout the world. Infestation of the cashew trees by various pests, which affects the tree and the fruits at different stages of growth, poses a great problem to the growers. Of these pests the major threat comes from the pest CSRB (*Plocaederus ferrugineus*). The CSRB consumes the bark of the stem, roots and reduces the yield of the tree initially. CSRB being a vigorous pest then causes the death of the tree, within 2-3 years of infestation causing a great loss to the farmers. Tackling this pest is a challenging task to all concerned in Cashew tree cultivation. Control measures in practice and the different feasible methods to detest the pest is analysed in thispaper.

Introduction

Cashew is cultivated in many states of India on a total land area of 10.27 Lakh hectares. The Cashew production amounts to 7.25 lakh MT and the unit area productiviyty is 706 Kg/ha. Cashew is produced in the states of

Andhra Pradesh , Karnataka, Goa, Odisha, Kerala, Maharastra amd Tamilnadu. Maharastra is the highest producer of Cashews among all the states with a average productivity of 1262 Kg/ha. The production of Cashew nut reduces if and when the trees are infested by pests. The pest infestation of Cashews is a major concern, which has to be dealt and is quite baffling. Fifty different species of insect pests affects the cashew trees at its various stages of growth. When the parameter, the intensity of damage to the trees is considered, four major pests are identified, namely stem and root borer, tea mosquito bug, leaf miner, Apple and nut borer.The tea mosquito bug, *Helopeltis antonii,* suck sap from the tender stem of young shoots, flowers, growingnutsand apples. The infected stem of young shoots exhibit dark brown patches, leaves crease and curl, shoots show long black lesions, immature nuts develop characteristic eruptive spots and finally shrivel and fall off. Heavily infested trees appear scorched. Management of tea mosquito bug is by removing other host plants like Neem, guava, cocoa, mahogany, cinchona, cotton, apples, grapes, drumstick, black pepper and jamun., spraying insecticides 3 times during different seasons namely, during the months of November-December, the new flushing stage, December- January, the flowering stage and during February and March the initial fruiting stage. Encouraging red ants which repel these bugs and predator spiders *Oxyopes schireta, Phildippus patch* and *Hiyllus spp*. that feed on the nymphs and adult mosquito bugs, are also done to manage TMB. The Apple and nut borer , *Thylocoptila panrosema* is another pest which causes 10% loss in rigorously affected zones. The young larvae scratches away the epidermis at the point where the nut and apple join and makes bores entering the nut and apples feeding on them. The affected fruits and nuts shrivel, dry and fall away. Control of these pests is by spraying insecticide carbaryl 50 WP 0.1% (@ 2g / lit) at the time of fruit setting, and spraying of dichlorvos @ 2ml /Iitre of water during off seasons and also completely eradicating all the dead and dried inflorescence during the preflowering season. Leaf miner, *Acrocercops syngramma* is another major pest in cashew tree. The infestation found in young plantations and nursery seedlings than the older plants. After the eggs hatch, the larvae start feeding on the epidermal layer on the upper surface of the young cashew leaves, which makes the leaves appear as the blistered patches of greyish white in colour. It later manifests as big holes when the leaves mature. Spraying Monocrotophos 36 WSC 0.05% (@ 1.5ml / lit) during the month of October-November at new flush emergence stage controls this pest. (Maruthadurai Ramasamy et al.2012)[1].

The Cashew Stem and Root Borer (CSRB) known as *Plocaederus ferrugineus* is the major grave pest which causes a huge loss in the yield of nuts and also the loss of trees itself. The female beetle lays eggs on 4-5years old trees, with rough bark having more cracks caused by previous season boring by pests or by heavy pruning. The eggs are creamy white in colour, oval in shape and resemble rice grains. The eggs are laid into live tissues, which hatch within 4-7 days, as tiny grubs. The grubs are oval in cross section with the distal end tapering slightly, with cream coloured body having segmental protrubances. The head capsule is strongly sclerotised, deeply retracted into the prothorax.

The grubs have prognathus mouthparts with strong, short, stout mandibles and feed on the bark voraciously. (Vasanthi. P, T. N. Raviprasad 2013)[2]. The tiny grub of CSRB bores into the fresh tissue and feeds on the phloem and xylem tissues of the trunk and root. It makes irregular tunnels, resulting in exudation of gum (gummosis) and extrusion of fibrous frass from the bored holes.. (Sathiamma, 1977)[3]. The leaves oftheaffectedtreesturnyellowincolour, wiltslowlysincethegrubseatawaythetissuesofthetree arresting the flow of sap and ultimately the tree dies within two years, causing irreparable loss to the farmers. (Misra and Basu Choudhary, 1985). [4] The grubs on hatching, bores the heartwood under the bark forming irregular tunnels inside the stem and this poses a great difficulty in detection of the grubs. Similar damage symptoms on Cashew in Ghana by the pest *Mecocorynus sp.* was also observed and researched.(Dwomoh.E.A et al.) [5] The diverse measures taken to control the pest, methods to detect the pest and possible methods of detection of CSRB is reviewed in thispaper.

MANAGEMENT METHODS OF CSRB

Mechanical control together with insecticides:

Many methods were formulated by research scientists to control the CSRB pest. Mechanical measures and the application of insecticides were considered. Field studies against the cashew stem and root borer *Plocaederus ferrugineus*.L on the effect of cultural and mechanical control measures revealed that at the beginning stages of stem borer infestation, when both mechanical removal of grubs and application of BHC on the trees were done, the damage caused went down to 2.9%. When the plantations were not cared for, the extent of damage was 17.2%. This method was effective only at the earlier stages and could not save trees which were severely affected. Damage was also found to be less in orchards where cleanliness was maintained by removal of dead trees. A lab study on the ovicidal activities of insecticides on eggs of stem borer showed that for fenthion 0.1% insecticide, egg hatching was 20% less, followed by neem oil 25%, NSKE 25% and monocrotophos 0.07%. Egg hatching reduction was moderate for Chlorpyriphos, dichlorvos, endosulfan, carbaryl, Methomyl and BHC. Egg hatching was high inPhosalone.[6]

Measures using microbial pesticide and plant products:

Insecticidal control measures were found to be not so fruitful in controlling the CSRB. Entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana* were found to be positive in combat against insects.[7][8] Use of the fungal pathogens for the management of cashews stem and root borer at Baster region of Chhattisgarh was explored. Biocontrol measures using two plant products like neem oil and cake, microbial pesticides *Metarhizium anisopliae* and *Beauveria bassiana* were used with different blend ratios and at different intervals. Fortnightly observations of the trees revealed that the combination of *Metarhizium anisopliae* young 250 g/tree along with 500g

neem cake applied during the months of October to November was effective at controlling the pests. It was noted that the treated trees were free of attack for a maximum of 120 days, which may be due to the presence of fungalcolonyaroundthetreeswhichcausesahighrateofdeathofthegrubs.Thecombinationof *Beauveria bassiana* young 250g/tree along with 500g neem cake was also effective but the trees where free of attack for only upto 105 days. The percentage of the death of grubs was up to 60% when the mixture of microbial pesticide and plant product was openly sprayed.[9]

In the year 2010, the performance of fungal pathogens like *Beauveria bassiana* and *Metarhizium anisopliae* on cashew stem and root borer *Plocaederus ferrugineus* was again tried in the fields, analysed and the results compared with the straight prophylactic treatment with insecticides. Different methods for the application of the fungal entomopathogens were employed namely 1.swabbing over tree trunk, 2.pouring aqueous suspension through the entry bore holes and 3.fungal spawn incorporated in the soil. The performance of the fungal pathogen was evaluated based on the extent of the recovery of the infested tree. It was found that both pathogens were equally effective. According to delivery methods, effectiveness was decreasing in the following order: 1. Pouring into bores, 2.Swabbing, 3.Soil incorporation. Compared to conventional chemical insecticides, fungal entomopathogens were found to be less effective but it could be more effective in the longterm.[10]

The above mentioned measures though used by the farmers, only 50% of the infected trees could be saved. It still remains a challenge to overcome the problem of CSRB pest in cashews.

POSSIBLE METHODS OF DETECTION OF CSRB

Non – Destructive Methods Of Detection:

Detection of pests in crops and agricultural produce is vital for prevention of damage or for protection of crops, and products.Task of detecting pests in crops though daunting can be accomplished by visual appraisals by humans . Eye detection categorized under remote sensing, though feasible is nevertheless liable to variations, inaccuracy, under or over estimation of infestations imputable to diverse conditions like illumination,background colour, vision impairments like colour blindness and other eye ailments. Great strides in the evolution of technology has furthered the detection of pests using modern day equipments.

Non- destructive technique is expedient in the facet of identifying the diseases and the stress in plants.Thermal imaging is one such non-destructive and non invasive technique under remote sensing category. Basically developed for military requirements from night vision technology, thermal imaging presently finds application in diverse fields due to its unique capability of sensing the slight variations in temperature with or without light.Thermal imaging technique is a non-contact method where images of plants, leaves, plantations can be captured using thermal sensors. The images, called as thermograms, reveal the temperatures or heat generated by the objects. The thermograms can be analysed correlating it to different parameters.Photography, aerial photography, Photogrammetry, Satellite-borne and aerial Radiometry, groundbased and hand held Remote sensing, videography, IR Thermography are different methods and instruments used as passive sensors in thermal imaging. Passive sensors measure the reflected or emitted radiation of the object under study in natural conditions. Active remote sensing methods use active sensors which create their own source of electromagnetic energy transmits it, and measures the reflected radiation. Light Detection and Ranging (LIDAR), which uses laser light, analogous to Radio Detection and Ranging (RADAR) are active remote sensing systems.[11] The detection of diseases, pests using Infra red thermal imaging is discussed.

IR –Thermography:

Estimation of plant temperatures from the radiations measured from different plant canopy using IR thermometry instruments, is an important index which provides information on the transpiration differences in the plants, indicating the moisture stress levels of the plants. Ariel IR photography survey for estimation of damage to crops by diseases was undertaken through measurement of leaf temperature, canopy –air temperature,and soil moisture stress .[11] Tests conducted on potato plots related the plant temperature to transpiration, stomatal closure, moisture stress,and thus in estimation of plant water regimes.[12]Research on cotton leaf indicated that moisture stress levels are related to leaf temperature, measured using IR radiometers.[13]Ariel photography had been useful in detecting the location of crop damaging pests in wheat, field beans, and also to track grasshoppers and ants. [14]

Thermal and visible images of canopy were combined yet in another method and the data classified to pinpoint the different areas namely, the leaf, sunlit and shaded areas of the canopy. This was possible by using remote sensing software, and the temperature components were calculated. This method was applied to the data received from a greenhouse where the plant *Vicia faba* L was analysed for water- stress and the field data of plant, *Vitis vinifera* L., in two different conditions of both dry and wet. Dry condition was maintained using Vaseline cover and wet condition by spraying water. For each *Vicia faba* plant the thermal indices were calculated and compared with the stomatal conductance which was already measured. Considering the field plant *Vitis vinifera* L., the temperature distribution of the leaves in sunlight

and the shade during the rainy season and when irrigated were analysed.This new method gave a more precise valuation of the thermal indices, which are more closely related to stomatal conductance and moreover allows for easy computation of the relation between temperature variation and stomatal conductance [15]. This enables detecting the infected trees and areas, when compared to data of non infected trees.

Heat is generated due to plant metabolism changes, when the physiological state of the tissue of the plants is infected by pathogens. This concept was analysed on three species of tomato plants namely Zheza205, Zheza207, and common type, cultivated in an controlled chamber at Zhejiang University. The plants were routinely injected with TMV-U1. Thermal Images were taken on all plant species. Once infected the defense system of the plant was activated which produced or synthesized phytoalexins which gets deposited to increase the cell wall strength and also the pathogenesis- related proteins(PR‘s) of which Salicylic acid(SA) acts as a signal in the defense mechanism of the plant against the pathogen infection. This generation SA reduces the stomatal aperture which alters the surface temperature of the leaf. The thermal images of these leaves were captured, analysed using the MikroSpec2.7 software. The temperature distribution was analysed and it was found that the temperature of the infected plant tissue was 0.5-1.3 C lower than the healthy plant tissue which paved way for the non-destructive detection of diseases in the earliest stages ofinfection.[16]

Citrus Longhorned Beetle (CLB) a quarantine pest (in EU) in young trees does not display any external signs of influx. Destructive analysis causes irreparable loss of plants. Therefore non- destructive method was applied for detection of pest inside the trees. CLB status was a quarantine one, hence the native goat moth, *Cossus cossus* L., was used as surrogate for the IR thermography studies. Thermal imaging cameras of three different types were used to capture images of the larvae of *Cossus cossus* L and borings during two long-term measurements to study the movements based on temperature difference. The results revealed that there was no great difference in surface temperature with the larvae inside the bores and it was concluded that pests inside trees could not be effectively detected using Infra red Thermal imagingtechniques.[17]

Thermal imaging finds much application in disciplines like civil engineering, industrial maintenance and in agriculture. Thermal imaging differs from other remote sensing since the emitted radiations from the target objects are measured whereas in optical imaging the reflected radiations are measured. Thermal imaging was first used in civil sectors to monitor thermal bridging in buildings and overheating processes like engines and devices in electronics. Later thermal imaging has found many applications in fields like medicine, Aerospace, Industrial Maintenance, Pharmacy, Electrical. Mechanical Engineering and in Veterinary. The application of the thermal imaging technique is diverse in agriculture. The research work in IRTI for the different pre and post harvest operations were analysed and discovered to be very useful for site specific management and precision farming. Sorting of

vegetables and fruits after harvest, maturity evaluation, bruise detection and alien bodies detection in food products is made possible by this IR Thermal imaging. Formulating a common approach with the thermal imaging of plants is difficult since plants behave differently in various climatic conditions.[18] Thermograms help to calculate schedules for irrigation, detect pests and diseases, monitor green houses and nursery, detect maturity of fruits and bruise detection of fruits and vegetables. Though this thermal imaging finds potential usage in diverse aspects of agriculture which could be further advanced through research, it is a costly procedure and cannot be an accurate assessment, in the sense, plants behaviour vary at different environmental conditions.[19]. Further thermal imaging is a tool used in agriculture and in food Industry to detect pests in trees and grains, bruises in fruits invisible to the human eye. Use of IR Thermal Imaging for Pest detection is a less explored field and poses a challenge for IR Thermal Imaging research.[20]

Sensors for detection of pests:

In these days of advanced developments in the field of Technology farmers can gain information about their farms and lands without personal visitation. Sensors, the precision farming tools, provides, real time data orinformationto the farmers, on moisture content of the soil, humidity, vegetation, temperature, texture, structure, physical character, nutrient level, vapour, air, pest detection, pest monitoring, etc. Remote sensing data helps farmers in managing their farms in a better and profitable manner.[21]

Modern technology renders assistance to farmers in vigilant monitoring of lands to be devoid of pests, to prevent 40-50% yield reduction. Wireless image sensors were used to detect the pest Red Palm Weevil (RPW, Rhynchophorus ferrugineus (Olivier)) in palm trees. Wireless image sensors periodically captured images of insects inside the RPW traps, set at different locations and formed a Wireless Image Sensor Network (WISN). Image recognition algorithms used to process and analyse all these images stored in the control room,identified the RPW insects with a higher rate of 95% . The information regarding this monitoring can be retrieved anytime using the internet service providers like (WiFi, WiMAX, 3G/4G, ADSL, Cable, Satellite, etc.), from the centralstation for comparative study.[22]

Another pyramid shaped low cost automated trap incorporated with a wireless image sensor recorded accurately the plum curculio pest, *Conotruachels nenuphar,* and can also be used for studying other species due to its simplicity and flexibility.[23]

The pest Red Palm Weevil (RPW), though not visible is audible. Audio signals recorded over a long period of time by the bioaccoustic sensors installed at the site were stored and processed. The system was programmed to send warning signals when the alarm predefined thresholds of sound were reached enabling to check the status of the orchards.[24]

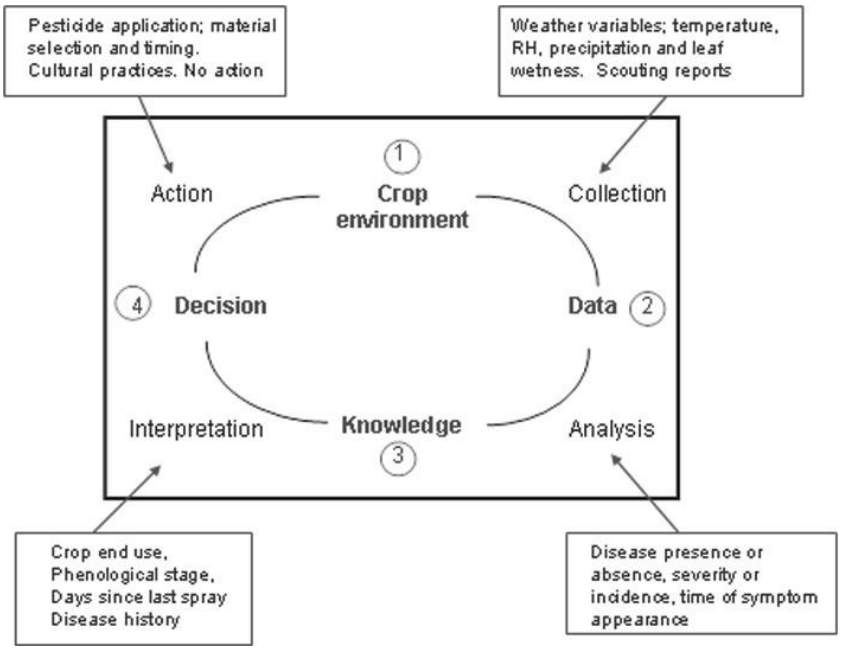
Computerized tomography (CT) and image processing for detection of *Anophophora glabripennis* beetles known as the "Asian Longhorned beetle", in trees in United states forests was experimentally carried out using a set of eight slices of *Eucalyptus grandis.* Wood damage and density measurements

were carried out by simulation of this prepared set of Eucalyptus grandis, having holes inside harbouring a typical insect. Algorithm for beetle detection by means of linear attenuation coefficient measurements on CT images was used. It was concluded that the beetle presence and damage represented by holes inside the wood samples can be observed, by means of a density variation graphic.[25]

Information Technology In IPM -Integrated Pest Management

The Web and databases, are the two technologies that are playing an increasingly important role these modern days in the field of Information Technology. The applications of Information Technology in agriculture is varied and has a very large scope. Any computer can access information ordatafromtheWebwhichisacollectionof computer etiquettes and standards. Databases are collection of data managed by a data management system which gives access to users to store, retrieve and modify data. The major advantage of data storage is data sharing. Sharing of data is beneficial especially in the research arena since it enables scholars to explore new topics. Decision Support Systems which are interactive software based system helps decision makers to arrive at a decision easily with the available data.[26]

INFORMATION TECHNOLOGY IN IPM



Overview of a DSS (adapted from Magarey et al., 2002).An idealized Decision Support System for plant disease management showing components , methodology, and tools .

Table:1- Areas to Detect Infestation in affected area

S.no.	References	Methods	Infest detection	Afected area	Findings of the study
1.	[12]	IR –Thermography	pest	potato plots	Potato plots related the plant temperature to transpiration, stomatal closure, moisture stress,and thus in estimation of plant water regimes.
2.	[13]	IR –Thermography	pest	cotton leaf	Moisture stress levels are related to leaf temperature, measured using IR radiometers.
3.	[14]	Ariel photography	grasshoppers and ants.	Wheat , beans	Detecting the location of crop damaging pests
4.	[15]	Thermal and visible images	pest	leaf, sunlit and shaded areas of the canopy.	Detecting the infected trees and areas, when compared to data of non infected trees.
5.	[16]	IR –Thermography	pathogens	tomato plants	Non-destructive detection of diseases in the earliest stages of infection.
6.	[17]	IR thermography	Citrus Longhorned Beetle	young trees	Destructive analysis causes irreparable loss of plants.
7.	[18]	IR Thermal imaging	bruise	vegetables and fruits	Formulating a common approach with the thermal imaging of plants is difficult since plants behave differently in various climatic conditions.
8.	[19]	Thermograms	bruise	fruits and vegetables	Plants behaviour vary at different environmental conditions.
9.	[20]	IR Thermal Imaging	Pests,bruises	Trees, grains	Used in agriculture and in food Industry to detect pests
10. \	[22]	Wireless image sensors	(RPW, Rhynchophorus ferrugineus	palm trees.	Modern technology renders assistance to farmers in vigilant monitoring of lands to be devoid of pests, to prevent 40-50% yield reduction.
11.	[23]	Wireless image	plum	plum	Pyramid shaped low cost

Conclusion

Many are the managing methods to control the pest infestation of the cashew trees.Insecticidal control measures taken were found to be unfruitful in controlling the damage caused by the pest CSRB.The mechanical control along with insecticides and measures using microbial pesticide and plant products were found to control pest in the earlier affected stages but had very little effect or none at all on trees severely affected.Controlling the pest CSRB is still elusive to agriculturists. The various Non-destructive methods of detection of pests like thermal imaging, sensors, CT and image processing as mentioned can also be applied to detect the CSRB in cashews. The Information and communication technology (ICT) would enable the farmers to receive information concerning the infested trees personally in future to take neccessary control measures at the earliest stage saving trees .

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