Input Detection, Identification and Control Techniques of Pest using Wireless Sensor Network: A Review

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Summary
This paper will extend the literature reviews related to use of Wireless sensor network (WSN) associated with precision agriculture and monitoring pests around the globe. We first review the literature related to pest monitoring and detection using WSN. Then we review existing monitoring and detecting techniques for plant diseases from contemporary literature. Later, we review the advance sensing technologies currently in use for the detection of pest from the literature. We evaluate the existing literature related to wireless sensor network and pest detection and disease monitoring. We later explore the potential and capable technologies and their characteristics which may be more feasible in future for the same job. Focusing on the cotton crop, our aim in future is to design a multi hop multi capabilities pest monitoring and detection system based on WSN. A large number of stakeholders (researcher, farmers, entomologists and engineers) are involved in this sector of pest monitoring and identification, which needs to be more aligned through effective association to make any potential solution make successful. This survey will also present a study about existing possible solutions and promote technology based architecture.

Keywords:
Cotton Pest, Identification of Pest, Wireless Sensor Network, Technology review.

1. Introduction

Insects are one of the several species on the earth, which have been giving human being a tough challenge to deal with. They have been living on this earth for about 300 million years. Since their creation they have developed various specific adaptations to survive under many complex ecological conditions. Insects were called pests when their existence became harmful for human being and affected badly on his income, ease and benefits.

To prevent the crops from pests and their related diseases is a difficult task for farmers. The pests can injure crop, reduce yields and also impact negatively on crop class. Conventional farmers use lots of techniques to battle with pests. Identification of pest and diseases is necessary before treatment. Without identifications, the use of pesticides causes many negative consequences: pest can develop immunity to pesticides leading to use an altered and stronger pesticides, along with harmful pests it also kills many beneficial pests and natural enemies of pests causing a raise in the growth of pests. Also the use of pesticides effects on the crops which are depended on insects for pollination so they fail to bear fruits.

Cotton, with its green, juicy leaves, its larger open flowers, nectarines on every leaf and flower, and its large quantity of fruit, attracts and supports various insects and mites. Over 1000 types of cotton pests have been recorded across the world. Nearly 125 species attack cotton in India [1] 125 injurious species attack cotton in United States [2] more than 93 insects and mites are found damaging the cotton crops in Pakistan [3]. Great number of damaging insects are present in crops for which the strong management is required to prevent crops and to improve end products.

There are two main agricultural seasons in Pakistan. Wheat, Rice, Cotton, and sugarcane are major crops of Pakistan. These four crops give 33 percent of the total value of agriculture production of Pakistan. Some minor crops of both seasons contribute 11.1 percent in country's overall agricultural income. Even though agriculture has been playing a pivotal role since country's creation, in recent three decades income, growth and exports of our Agri-related products have declined. The reason behind this decline is that no major investments and innovation has been adopted for improvement.

In the rest of the paper: at the outset, in section II, we review existing literature associated to pest monitoring and some disease detection work already done in Europe and India. In section III we present the comparison of characteristics of different sensing technologies with reference to their implementation. Later, we categorize them on some unique and result specific parameters for the same purpose. Finally, we summarize the paper and highlight future work in last section.

2, Material and Method (WSN in Agriculture and Pest Monitoring)

Mostly the farmers do not wants to use chemical in crops for this reason most suitable pest management strategies should be designed based on accurate information about pest and disease. Normally, detection and identification of pests is farmer's fundamental

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responsibility for which he relies mostly on his visual judgment randomly. The fields are huge and farmer cannot cover the overall fields at once, and often farmer reach pest infestation too late. Some automatic detecting system is desired for quick assessment of pest infestation in early stage.

There are two different agriculture domains in which we are currently using wireless sensor network.

2.1 Pest Detection

Pest detection directly through WSN: in which we normally use acoustic sensors. We rely heavily on acoustic devices. This is non-destructive, remotely operating and also very useful for automatic detection of hidden insect infestation.

In [4] authors proposed a monitoring system to detect caterpillars of red palm *weevil* (RPW) through acoustic sensor devices. The authors mentioned that acoustic detection of this pest is the best and most cost-effective solution among all. According to authors it is also able to distinguish between various pests which give this technology an edge over others. The proposed system is for efficient sugarcane crop production. The system would employ an acoustic device sensor for monitoring the pest's noise level and whenever the noise level crosses the threshold, it will make the farmer to take the notice of the specific area where the infestation is occurring. By using this technology the farmer's responsibility to go to each and every part of the crop and perform survey can be reduced significantly. The acoustic sensor node will be connected to the base station to which each sensor will transmit the noise levels whenever the noise level crosses a predefined threshold level.

The base then transmits the information to the control room computer which indicates to the farm where the infestation is occurring so that the necessary action can be undertaken. After successful identification a farmer can take the necessary measures to spray insecticides over the crops. This detection will also help the farmers to curb infestation at a very early stage and consequently it reduced the high percentage of annual destruction of Sugarcane crops. The proposed monitoring method may cover relatively a big area with low energy consumption.

In [5] the authors proposed an efficient protection mechanism of palms from RPW larvae. The feeding habit of the RPW is concealed, very much like termite in wood. They can be detected acoustically by the noise emitting from them. Normally, the infestation is detected at the last stage only and when the farmer comes to know the recovery time is almost over and plant's one foot in the grave. In the detection phase, the sensor with their propagating modules (transceiver) is attached to a plant and connected to the network by accessing nearby access points. In proposed topology every access point is connected and receives information from 8 other devices located in its radio range.

In [6] the authors proposed a technique to detect hidden insect infestation of date palm tree (Phoenix *dactylifera L*) by their acoustic instruments. They use acoustic sensors to detect presence of red date palm weevil (RDPW) pest in early stage ; which is usually consider a destructive pest, commonly known as the red date palm weevil (RDPW). Its scientific name is *Rhynchophorus ferruginous* (Oliver). They record acoustic emission produced by the RDPW that infect date palm trees and then used signal processing method to analyze it. Special probe holding acoustic sensor are injected within stem of palm tree to listen and record their voice. It can record sound of its early stages of life which is known as larvae. In the larval stage of RPW insects perform so many noisy activities like feeding trunk and chewing generating the noise at maximum level. Our recording device near insect's works round the clock and records the sound produces by insects easily.

In [7] entomologists detected some major beetles of layup grain acoustically in the laboratory. They perform experiments on following beetles as well: the weevil *Sitphilus oryzae* (L) exist in rice, the grain borer *Rhyzopertha dominica* (F), the confused beetle *Tribolium confusum Jacquelin du Val* (Tenebrionidae) exists in flour and rusty beetles *C. ferrugineus usually exist in stored* grain. This is the first instance of reporting and recording acoustic emissions of the adults of the Khapra beetle *Trogoderma granarium* Everts (Dermetidae) and Cigarette beetle *Lasioderma serricorne* (anobiidae). They used a piezoelectric sensor with a handy noise recording device with emission amplifier associated with a recording machine. Most common beetle pests were detected in variety of masses. They used computerized parameterization directly and with some of its differ arrangements verified the presence of insects. The authors claims that their system is very accurate and is able to detect 1-2 pests/kg of solid grain of Wheat. It is normal standards to classify stored mass grain either 'clean' or 'infested'. The tiny body insect *C. ferrugineus*, is difficult to sense.

In [8] researchers describe their development: it is handy, smart with capable audio device with its possible use in the field for diseased palms. Their device contain sensor with a capability to mount on the palm tree. It has facility to get the sound of red palm weevil larvae. It comprises an automatic processing element, a processing unit to process the acquired sound and the earphone set to receive the audio output through recording device and the hearer. This is a battery driven portable and user friendly device.

Table 1. Pest Monitoring and Detection with Wireless Sensor Network

Authors	Pests	Sensing	Crop	Contribution
[4] Srivastava N. (2013)	**Borers, White Fly**	**Acoustic**	**Sugar Cane**	**Create a pest monitoring & control system using WSN.**
[5] Srinivas S. (2013)	**Palm Weevil (*Rhynchophorus Ferrugineus*)**	**Acoustic**	**Coconut Palms**	**Palm plantation can be prevented from RPW Larvae**
[6] Al.Manie (2007)	**Palm Weevil (*Rhynchophorus Ferrugineus*)**	**Acoustic**	**Date Palm Trees**	**They used acoustic sensors with some special probe with analysis of the signal processing method.**
[7] Panagiotis (2015)	**Rice Weevil (*Sitphilus Oryzae*) Grain Borer (*Rhyzopertha Dominica*)**	**Acoustic**	**Stored Wheat**	**Used piezoelectric Sensor, moveable acoustic release amplifier which is linked to machine.**
[8] Sriwardina K (2010)	**Palm weevil larvae (*Rhynchophorus Ferrugineus*)**	**Acoustic**	**Red Palm Tree**	**Develop a portable, smart and efficient acoustic device**
[9]V. Soroker (2013)	**Palm Weevil (R*hynchophorus Ferrugineus*)**	**Acoustic**	**Red Palm Trees**	**Presents pros and cons of efficient methods elaborated with efforts to be improved efficiency.**
[10]BV Laar (2002)	**Red Palm Weevil (*Rhynchophorus Ferrugineus*) German Beetle**	**Acoustic**	**Palm Trunk (Wood)**	**Develop ultrasound gate hard drive recording system that can measure sound activity from 50 Hz up to 250 KHz**
[11] Mankin R.W. (2010)	**Mediterranian Fruit Flies (*Ceratitis Capitata*)**	**Acoustic**	**Green House Experiment**	**Recorded sound produced by pest with handy device modified from a mobile pre serial bus amp and interface for audio.**
[12] Mankin R.W. (2009)	**Coconut Beetle (*Oryctes rhinoceros*)**	**Acoustic**	**Coconut and Palm Trees**	**Acoustic signal collected and perform analyses of spectral and temporal characteristics with Temporal pattern analysis.**

In [9, 11] researchers review the current research and recent development states on Red palm weevil (*Rhynchophorus ferrugineus* (Oliver)) and monitor them to get the information about its early infestation. Some intensive efforts have been put into the development of detection through visual and acoustic methods. Pros and cons of all methods have been presented here with their comparisons. It is also concluded that considerable efforts are still required to improve the efficiency and sensitivity of existing acoustic methods with other tool.

In [10] author developed a handheld detector device with some special acoustic sensors to probe. The developed device is specially designed to detect a tiny sound vibration which is a usual activity of RPW. It is tested also on German beetle species living in the wood. Laar invented "ultrasound gate hard disk recording system" and with this device he measured sound activity from 50 Hz up to 250 kHz.

In [12] researchers develop and test a prototype acoustic device for Mediterranean fruit flies (*Ceratitis Capitata*). They conducted series of tests with prototype of Mediterranean fruit fly detection system in high noise and worst traffic environment. Only male strain of *Ceratitis Capititata* were obtained for experiments. First experiment conducted in quite environment with group of 25 males in 20- by 21- by 22.5 screened cage. A Sony camcorder

(DCR-TRV27) was used to get distant observation of verification flight. Then some tests for flight detection had been conducted in noisy surroundings, which contain more male with relatively big cage. They were visually monitoring their flights in the field cage throughout recording sessions. Recommended flight monitoring system is a handy model apparatus modified from a mobile-pre USB preamplifier along with audio interface. It may provide 40-70db amplification through two variable adjustment gain control. Signal input provided to an AT 803B unidirectional lavaliere microphone. The signal was transferred to a laptop by universal serial bus and processed by customized software which runs under Mat lab. The produced noise by insect (*C. Capitata)* flights through a microphone is naturally concise and easily identifiable.

In [13] scientist detected adult and larva of *Oryctes chinoceros* acoustically in dead and alive palm trees in island territory Micronesia. They also monitor and detect *Nasutitermes luzonicus* Oshima and some sound generating tiny insects. A large and active *O. rhinoceros* usually generates low frequency, long duration sound impulse trains. There are some soaring frequencies low impulses trains generate by *N. luzonicuz.* Their unique ghostly and sequential pattern of producing noise made it possible to identify suppressing surroundings sound easily.

In this portion of paper, we reviewed some early pest infestation techniques as mentioned in Table 1. We also compare it with respect to their target crops, with those sensing technologies heavily used in agriculture field by means of WSN. Early detection of infestation play a vital role to recovery of attack.

2.2 Disease Detection

In this portion, we illustrate crop / plant disease detection with the help of WSN and image processing with its analysis those involve color histogram, edge detection and some other processing tools.

In [14] authors use internet of things (IOT) technology to design a platform for detecting diseases. Their main focus was on general diseases. They use an IOT to turn it into the key system to acquire data with communication because it is the most important technology among others. In their system; detecting sensor is used to obtain data then compare and synchronize it. After analyzing the obtained data they finally carry out an immediate activity without any human involvement. They applied this process to the whole data related to pest plant disease and insect pests. They used global information system (GIS) software to manage and present data for linking it to the exact location. WSN and ZigBee with GSM are largely used networks in precision agriculture field. They designed a platform which includes administrators, experts and ordinary visitors by computers and mobiles etc. It also includes information system for agriculture disease and insect pests' disaster information monitoring system.

System is capable to capture image and send them to a remote control station with specific event stipulated through application. Basically, these image sensors monitor and count inhabitants with relatively advanced resolution. However, there seems to be no intelligent image processing activities. During this monitoring process no human intervention is required. According to authors, there is a significant reduction in monitoring cost as well.

Main focus of this work is red palm weevil (RPW, *Rhynchophorus Ferrugineus* (Oliver)) but it is not limited to that pest. It could be used to monitor many other similar pests. A trap monitoring process which works on unattended mode has some extra benefits like it reduces the monitoring cost: it is programmable and high resolution monitoring data. In addition, real time data can be retrieved in any time by web portal.

There have been a number of valuable studies to monitor pest insect using latest technologies. However, none of these studies is able to provide a self-sufficient information system totally relied on inexpensive image sensors covering areas with very low energy utilization. High scalability with low power consumption made it possible to deploy this system both in greenhouses and larger plantations.

It is also used for several kinds of insects instead of some specific insects. Using an image recognition algorithm; that is capable to identify RPW insects with higher success rate up to 95%. System is smart and its corresponding Meta data, time stamp, GPS coordinates and results etc. are duly saved in main monitoring station. Anyone can access to the data in real time through internet which is obtainable from the location of the main control.

In [15] authors conduct a survey to detect crop disease using image processing with wireless multimedia sensor network. Pest related diseases are now become a recent predicament. It is the main cause of significant decline of product quality and quantity as well. Efficient and accurate disease detection has become one of the hottest topics these days. These scientist used machine vision approach, with some morphological features like size, shape, texture with pest's color. Also they applied some location based attribute to monitor and detect infected plants and leaves.

In [16] authors proposed a solution to detect specific disease (downy mildew) in Grapes in India at a very early stage. The current system that detects disease (downy mildew) is based just upon collected update climate information. In the proposed system, architecture, there is a remote node which is inexpensive and the user have to keep secure only an isolated remote node as a replacement for main node which is located in control station. A central server can be accessed through web applications to get all details of current weather conditions and disease forecast, which depends strongly on climate of the farm.

In [13, 18, 19 and 20] researchers define research on acoustic detection of insects with their management and control techniques. Also it has been explained how we use olfaction, vision, noise, and hearing capabilities of insects as their destroyers. It is a remote, non-deleterious, automated observing tool for farmers and researchers to find concealed 'insect invasion'. A few milligram of pheromone in the right context can attract a male moth to its mate or to its deaths. Similarly a flash of pen light can attract a firefly male from 30 meters.

Table 2. Disease Detection with Wireless Sensor Network

Author	Disease	Technology /Tool	Crop	Contribution
[14] Shi Y. (2015)	***General Plant disease***	**WSN / GIS / IOT**	**General**	**They designed / proposed agriculture disease and insect pest disaster monitoring information system.**
[15] Wang J. (2014)	***General Plant Disease***	**Multimedia WSN with Image processing tool with IOT**	**General**	**Perform a Survey for applications of Image processing in Disease detection**
[16] Dater S. (2014)	**Downy Mildew**	**WSN with web based GPRS system.**	**Grapes**	**Developed a Web application which provide a forecast on the basis of weather parameters like humidity, temperature and wind speed.**
[17] Triparty A. K. (2013)	**General Groundnut Diseases**	**WSN with Data mining technique**	**Groundnut Crop**	**They tried to understand the hidden relationship among interrelated disease / Pests and weather parameters.**

In [17] the authors' review the weather relation with pest and crops along with data mining and WSN. They focused on peanut crops pest and disease interaction in India. They conduct an experiment to examine the crop with climate and insect relation using WSN. They also review independent pest and disease dynamics of peanut crops. To turn the data into useful information they used smart technique of data mining to draw relation among crop / pest / disease and climate field. They tried to comprehend the concealed association between interrelated insect and disease with climate parameters. In the end, they develop a collective prediction model, which could help farmer to improve measures with this prediction model in future.

As mentioned in Table 2. We review some existing disease detection techniques which are used with the help of a type of WSN. Early detection of diseases is as important as pest detection to prevent heavy crop loss.

It's very old technology and we have been using it since the start of the century mentioned in Table 3. In recent year's various kind of sound catching equipment are widely used in market to monitor crops. The efficacies of acoustic devices are limited. They are only used for sound generating cryptic insects and estimate population density while silent killers are beyond its domain. Success rate is depended on different type of parameters, sensors, range of frequencies, substratum structure, the correlation among the substrate, time and duration, crop field with size and behavior of insects, and also the distance between sensor and insect.

We got significant success in field of passive acoustic devices to monitor grain, palm / wood insets i. e. Red palm weevil. The Microphone is useful for airborne signals while vibration sensors are very useful for those signals which are produced in solid substrate; however, ultrasonic sensors are practically very effective to detect wood-boring pests [13, 20 and 21]. Complexities in distinguishing sounds of target insects are major restrictions in using acoustic devices. Currently, some other tools like signal processing and smart sensors have greatly increased the acoustic use and its reliability.

We review some early infestation techniques which are heavily used with the help of WSN in agriculture field. Early detection of infestation is important to recovery of attack. So it not just WSN, but also so many other techniques which are used for it like image processing, canny edge with color histogram [22 and 23] and laser induces breakdown spectroscopy [24].

Table. 3. Insects detection and monitoring acoustically, Publication since 1900. [13]

Decade	No. Publications
1901-1910	1
1911-1920	1
1921-1930	2
1931-1940	4
1941-1950	0
1951-1960	5
1961-1970	4
1971-1980	4
1981-1990	22
1991-2000	44
2001-2010	50
Total	137

3. Advanced Sensing for Agriculture Sensor Networks

Every remote technique which could be used in wireless sensor network depends on the electromagnetic propagation or acoustic energy between the sensor and a target pest. We must use some motion / vibration sensors, which are highly sensitive as they can capture even tiny pulsation of pests in the field. We can also use such acoustic sensors which are able to record some special frequencies produced by pests. Although, we are unable to identify directly by these sensors but at least we are able to point out the presence of some insects in specific area of our field. Image analysis and processing with other advanced computer technologies are existed to identify pests directly. Some digital automated identification systems (DAISY) also here to identify special pests. [25, 26, 27, 28, 29 and 30) A detailed review of every aspect of the sensing of the insects, geographical terrain, favorable / unfavorable climate for target insects is out of the scope of this paper.

We have so many sensor products in the market for agricultural monitoring i. e MOTE, Field Server, SUN SPOT [31, 32 and 33].We further have so many other kind of products with latest wireless IR, Zigbee (IEEE 802.15.4), ultrasonic [34] technologies.

Our main concern is on the development of locally made, affordable device which would be a good and adoptable addition in industry. Many technologies mentioned in this paper are operationaly verified in past and will be used in future. Some other technologies also exist but yet to be applied in entomology hence not proven. Following are some possible potential candidates in sensing technologies to detect and monitor cotton pest specially boll worms in Pakistan.

3.1 Acoustic detection

In theories, there is a rule of thumb that distant monitoring must contains the transmission and reception of electromagnetic waves from sensor to target and viseversa. Researches [4, 5, 6, 7, 8, 9 , 10, 11 and 12) have done enough work see table 1 to develop passive acoustic devices to detect insects out of our sight. They are hidden in stored commodities as well as around plants, timber, and fruits. Insects are detected usually through low strength (0.5- 150 kHz) incidental sounds which they generate during flying, feeding or calling their gender opponent. There are so many factors involved in the use of acoustic devices such as interference and noise ratio, back ground noise, distortion and attenuation during travel in the medium and uniqueness of voice example from non target and seperate organism [35] . Sensing elements includes transducers (condenser / piezoelectric microphones), vibration transducers, mobil or fixed in any hard media such as timber , stone and underground.

Some atmospheric sound detection And ranging (SODAR) devices are also provides meteriological data to monitor pests migrations [36]. Similary research has been done in [37] where simple non doppler sodar machine is used for verification and the actual observing height of the night climate data. It also determine the best altitude for netting above ground level accordingly.

3.2 Ultrasonic

Another technology ultrosonic sensing is also very strong candidate. It has been used in the past and can be used in future as well to monitor crops and pest closely. We have been using ultrasonic technology in crop production since 1988 [38]; where researcher used commercial ultrasonic range transducer to measure some specific parameters. Thid system was mounted and tested with an air blast sprayer and its results will be used to optimize the sprayer in future. Later on the same scientists [39]; investigated spray volume saving using an ultrasonic measurement and results varied greatly depending on target crop morphology.

Table 4. Sesning Technologies and their characteristic's comparison.
[4,5,6,7,8,9,18,19,22, 29,35,36,37, 40,41,42,43,49,50,51,52,53,54,55,56,57,58,59,60 and 61]

Characteristics / Technology	Range	Accuracy	Cost	Outdoor Performance	Sensitivity	Complexity of Support Electronics
Acoustic	Medium	Medium	Low	Medium	Medium	Medium
Optical	Medium	Medium	Medium	Medium	Medium	Low
Laser	High	High	High	High	High	Low
Ultrasonic	High	High	Medium	High	High	Medium

Group of researchers [40, 41, 42 and 43] conducted some studies in different aspects of ultrasonic sensing, its applications and drew a comparison between laser and ultrasonic transducers for crop constraints and canopy volume measurements of citrus trees. The laser sensors performed relatively better than ultraslonic, since

It had a higher resolution. In [44] author invented a model sprayer which would calculate the size of target and approaching density using ultrasonic sensing.

Segment array is used and also suggested in [45] with the combination of ultrasonic systems which might be very helpful to track small insects in short range (e.g. Aphids and whiteflies) those are in flying range of a crop shades. In their studies a web of more a dosen ultrasonic transmitters emits pulses more than 40 kilo hertz which are delayed by phase to enable the system to sweep across the entire volume which need to be sensed (2.5 long x 1.5 width x 2 hight in meters). Echos those returns after hitting to the bugs are picked by multiple installed observer which also boost their energy and send them to digital signal processing capable machine. Actual position of insects with movement direction within the tracking space could be predictable and also displayed in real time. Until now complete system has not been operated below real condition of field but a small indvidual device was tried to determine how it copes with more than one objective (Target) with high backgroung noise.

These type of studies are very important and vital to develop a smart, portable ultrasonic devices to monitor insects / pest in field. But there is a gap and still a huge vaccume is empty in this field to pridict crop disease and presence of insects.

3.3 Laser

We have been using LASER since 1970, in many areas, however it was late 80's when laser was used for forest biomass detection and crop production [46]. In which scientist implemented an airborne pulsed laser system to access forest biomass and temper volume. The same scanning techniques could be applied to detect of pest and tiny bugs. Later on in early 90's [47], a laser altimeter to quantify vegetation properties and their results showed a variation in the canopy heights between two to six meters. Collected data is connected and compared to similar data which is gained from other methods. This study also exposed to us that a similar application can be applied to detect disease in any type of crop. Some other laser [48], was also implemented with the combination of

Lidar and satellite imagery which was also very useful to monitor changes. In recent era a newly developed laser sensing system was applied [49] to citrus crop to measure height and width of trees and covering capacity. System has been tested to calculate its resolution and high accuracy and later on reported less than 5% noticed error. Further the same authors in [50], implemented scanning system based on laser to calculate vegetation thickness. Results also revealed good occurrence and of less than 3% avg. coefficient of variation (CV). Recently [51] also utilized a laser system with implementation of range finder technology to estimate location precise foliage factors, such as height of plant, its coverage besides biomass solidity which could be a major factor in optimizing crop harvesting method.

These type of technology advancements and studies are very useful in future developments. We can also use some new technologies and build a prototype which may help us to protect crops from insect and disease.

3.4 Optical Sensor with Trapping

Optical sensors are also used to get the exact time of entry of pests into trap as well as exit recording. Such as in [36, 52 and 53] it was some extra facilities provided by them to assign captured insects to different classes according to their morphology. It is due to different momentary of insects over an irradiated exposure of light scattered. Sometimes this might show good enough to substitute that trap altogether [37].

a. Night Vision Devices

These devices are used to observe and monitor insect's movement at night when human vision cannot work adequately. The capabilities of these devices can be amplified by some extra devices such as telescope. The night vision device's light is consists of photocathode later they releases electrons. Total number of following lights is significantly increased by some form of light voltage and in results some electrons are used to reproduce the duplicate on phosphors canopy [38]. These devices are divided into three generation which extend the operational life of these device. Occasional entomological uses of graphic intensification tool mentioned in [54, 55 and 56] i. e. specific *Helicoverpa* moth low elevated flights tracked through an observer. His weapons were night vision goggles and inferior red light illuminators. They were ridding on special 4 wheeler vehicle. Their experiment proved that when observer follows the moth, he is just able to see them up to 100 meter heights; and while vision opposite the sky. [55]

b. Light Emitting Devices

Another method we are using traditionally is light emitting devices for nocturnal pests. It usually works with the combination of some other technologies i. e. we are using traps with light.

c. Optical-Electronics Devices

Some more focused and specialized devices for insect monitoring and specialized opto electronics devices are crossed- beam infrared detectors [57 and 58]. When pests move over designed capture capacity, it may be sense. Frequencies of their wing beat are also recorded. These systems are specifically designed for *Spodoptera exempta* and *Helicoverpa armigera* moths monitoring while they fly underneath detector shadow. Farmery's apparatus is unsuccessful in dusk and daylight.

4. Conclusion and Discussion

This paper showed the wide variety of researches to monitor and detect pests. However we have mentioned techniques with their pros and cons and we have also given very good overview of crop insects, their, favorable weather parameter and disease indications. Standalone technique can solve the matter but researchers also use the combination of sensing technologies. Such as, we have been using pheromone light traps.

We draw a comparison of existing technologies as a result of their review (See table 4.) those already used in sensing of pests or diseases in wireless sensor networks. This review of technologies are help full to go further and develop more accurate sensors to target pest or diseases. We are working on these ideas and something new will be design in the agricultural-entomology and sensors field.

I. Future Work

It is now clear from this review that we can develop any device that can use to monitor and detect pests in early in early infestation stage with the help of discussed sensing technologies. It is also clear that studies of insects' behavior will benefit greatly for development of sensing devices along with communication technologies. We want to add in this field some additional work on behalf of our review on existing researches.

Moreover, some development in electronic circuits made it clear for us that more customization is possible: although expensive now, we hope it will become cheaper eventually and will be available on reasonable prices. There is big gap in the field of pest monitoring and pest detection with the help of sensors. So, to design a system for insect capturing with high accuracy is our objective in near future.

Firstly, we are working on a special locally made sensor with ZigBee communication module to monitor and detect bollworm in cotton crops here in Pakistan. Digital signal processing is one of the option we may use with above mentioned prototype module if it is necessary to identify pests accurately.

Secondly, we are of the view that there should be a high level collaboration between sensing technology, artificial intelligence and entomologists to make flying and walking sensors and robots to monitor more parameter which we could not imagine to monitor in past. Making these innovative devices is but not only beneficial for farmers, engineers and entomologists but also for our under develop agriculture industry and country.

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