## **SURVEILLANCE AND FORECASTING OF PEST AND DISEASE AND IT’S MANAGEMENT**

Shristy Yadav , Sima Nayak , Sonali Dutta , Subham Patra, Sukanya Sahoo, Suman Subhrajit Mohanty , Sushmita Sahoo, Tapaswini Sahoo , Abhilipsa Nanda , Bhagyashree Mishra , BiswaBijayee Chandrachuda , Sunita Malik

**C.V Raman global University , Mahura , Janla , Odisha – 752054**

**Abstract**

Crop productivity, food security, and economic stability are all negatively impacted by the prevalence of pests and diseases around the world. Surveillance and forecasting systems have developed as essential instruments for early diagnosis and proactive management to help with these difficulties. This summary summarises the fundamental ideas and recent developments in the area of pest and disease surveillance and forecasting in agricultural systems. Global food security and sustainable agriculture depend critically on efficient pest and disease management. This abstract examines the state of pest and disease control in agricultural systems, stressing the difficulties that have arisen and the potential solutions that have been developed.

**Keywords**:Agriculture,Surveillance,Forecasting,Sample,Survey,Pest,Population,Yeild,EIL, ETL, Management, Control

**Introduction:**

There is a mutually beneficial relationship between insect pests, illnesses, and weeds. Each of them can cause significant damage on its own, but ignoring even one can lead to an infestation of the others. Fungi thrive on the sugary secretions of certain insects. As well as providing a home for insect pests, weeds can act as a secondary host for rust and other fungus. Therefore, weed control is essential for effective management of insect pests and diseases. Preventative management measures include routine weeding, which reduces nutrient competition, stops pests from hibernating, and makes it easier to apply pesticides and have good air circulation. Early and accurate diagnosis of health problems and their treatment are essential to effective control of insect pests, illnesses, and weeds. Important preventative strategies include eliminating and addressing potential inoculum sources in the field. Improve the plant's resilience to pests and diseases by keeping the soil fertile, draining well, and aerated. Plant diseases can be transmitted by the soil, the air, or the seeds. In the same way, some insect pests drink the crop's cell-sap, while others devour the foliage and floral parts, dig into the stems, buds, and fruits, and some still have larvae that mine the leaves and occasionally even the stems. Prevention and control measures against each of these issues and infestations must be tailored individually. Acquiring the necessary expertise in identifying the pests is crucial for developing an efficient approach for pest management. This will help with selecting the right pesticide, as well as the right dose, application technique, and timing.

The insect population probably maintains some sort of equilibrium with its physical and biological surroundings in the wild, and its size generally varies around some central value without significantly increasing or decreasing. Temperature, precipitation, and humidity are all components of the physical environment and climate that have an impact on insect populations, both directly and indirectly by their effects on the host plant and natural enemies. Plants, parasitoids, and predators make up the biological setting. In most cases, the natural control does not respond quickly enough to prevent a field pest from multiplying out of control. As a result, the farmer needs to take additional control measures on top of the natural management in order to protect his crops.

Insects become a nuisance when their population sizes get too large. The mechanism by which this occurs needs to be grasped. Insect populations can explode in favourable climates, though the pace of expansion varies greatly between species. Furthermore, in today's agriculture, conditions are ideal for the establishment of a pest due to the rowing of new crops, introduction of enhanced and exotic varieties, adoption of intensive manuring, etc. Understanding the causes of insect pest outbreaks is, thus, crucial.

Pest surveillance, also known as "periodic assessment of pest population and their damages," or "watching the pests for the purpose of decision-making in pest management," is the process of keeping tabs on unwanted pests. Moreover, pest surveillance supplies the data required to evaluate a pest control program's viability.

Monitoring the spread of pests is sometimes known as "pest surveillance." The major purpose of pest surveillance is to anticipate, observe, and reduce the damage caused by outbreak, epidemic, and pandemic scenarios, and to expand our understanding of the causes that may lead to such occurrences.

There are three main parts to any effective pest surveillance plan. (i) Assessing the prevalence of the problematic species.

(ii) figuring out how much damage the occurrence will do, and (iii) figuring out how much financial or other advantage the mitigation will bring.

The Goals of Pest Monitoring:

i. Keeping an eye on the levels of pest population and crop damage that signal a financial tipping point at various phases of crop development.

ii) To calculate potential agricultural damage from pests.

This helps establish what should be prioritised in terms of research into the transition of a pest from "minor" to "major" status in a particular agricultural ecosystem.

iv. To track changes over time, such as the emergence of new biotypes or the emergence of resistance to pesticides.

v. to keep an eye out for exotic pests that have already made their way into a given ecosystem, and to calculate their pace of spread.

vi. To track annual changes in pest population density in order to investigate the impact of climate variables.

Evaluation of natural enemy populations and their impact across a year and a variety of cropping conditions is step seven.

There are several distinct kinds of pest surveys.

The primary goal of a qualitative survey is pest detection; results include a tally of the types of pests found in an area and an explanation of their relative abundance (common, abundant, unusual). In the case of newly introduced pests, these are used to gauge the severity of the problem. In order to prevent the introduction of invasive species, these surveys are typically conducted at international borders where agricultural goods are scrutinised.

(2) Quantitative Survey: This survey quantifies the temporal and spatial distribution of pest populations. Its data can be used to forecast population growth or decline, and it reveals a species' destructive capacity. These studies give farmers solid information on which to base their decisions on implementing pest control strategies.

There are two main types of surveying and observing: fixed plot and roving.

The third type of survey is the "fixed plot survey," in which a predetermined area of a field is used to evaluate the prevalence of pests or the extent of damage caused by insects. From planting to harvest, consistent measurements are taken from the same plot in the same field. These polls are conducted so that accurate prediction models can be constructed.

The fourth type of survey is the "rapid/roving survey," in which a broad area is surveyed quickly from a variety of randomly chosen locations in order to assess the pest population or damage. The data it gives on the pest population can be used to schedule the implementation of effective control measures. The purpose of the surveys is to track the emergence of pests in endemic regions at the start of the growing season.

(NV Maslekar, Kiran P. Kulkarni, and Akshay Kumar Chakravarthy) Harnessing Automated Unmanned Technologies for 21st-Century Pest Management, (27-45, 2020).

Unmanned aerial vehicles (UAVs) are not yet commonly used for a variety of agricultural tasks in the field in most undeveloped and developing countries throughout the world. Massive crop losses occur when insect populations explode for no apparent reason. Damage from pests can be substantial, resulting in diminished crop yields and reduced plant viability. Technology in today's farming allows for more efficient crop management. The Internet of Things (IoT), remote sensing, and data analytics are the new heroes of crop management. By collecting data from above, pests can be located, eliminated, or contained. Unmanned aerial vehicles (UAVs) have the ability to fly in challenging and rocky terrains, capturing high-resolution photos that can be used for both pest detection and management. Camera-equipped unmanned aerial vehicles (UAVS) can solve several problems in crop security that cannot be addressed by traditional pest management methods. With the help of UAVs, automated insect damage assessment in agricultural areas is now a reality.

Methods of Pest Monitoring:

Correct pest identification is the first and most crucial stage in any monitoring or survey. The decision to intervene in pest management cannot be trusted if the pest has been incorrectly identified. Misidentifications can happen when one species is mistaken for another, or when a previously unknown species is lumped in with a group of familiar species. As a result, whoever is tasked with conducting the survey needs to be an expert in pest identification throughout all life stages and common outward morphological features. If necessary, a professional, expert, or taxonomist can be consulted, and samples can be gathered and raised in a laboratory for all stages.

The second fundamental part of monitoring is the estimation of the pest population. The economic threshold for most variables is based on the density of the pest population. Understanding the workings of the life-system of a pest species is aided by research into its population, and the elements that cause numerical variations in the natural population are also identified. Improving our ability to accurately and scientifically estimate population size is crucial. There are two factors to think about here. There are two aspects to counting: first, determining the optimal time to conduct the count (egg, larva, pupa, or adult), and second, performing the count itself.

Absolute counts, even for a small region, might be difficult to get due to the substantial amount of time and labour needed. Therefore, although we would like to have information on the actual population, we must instead pick smaller collections (samples) and extrapolate from them. Taking a headcount would be the gold standard for estimating a population size.

However, counting most pest species across a sufficiently enough area to be useful in a practical study is impossible, making sampling a must.

Absolute counts, even for a small region, are generally impractical and inefficient due to the time and resources needed to collect them. Therefore, although we would like to have information on the actual population, we must instead pick smaller collections (samples) and extrapolate from them.

Third, natural enemy abundance should be estimated through field studies, which compare pest population growth rates under different natural enemy levels to determine the potential for and degree of control exerted by the entire complex of parasitoids and predators.

The surveys aim, in part, to evaluate the yield loss caused by various insect pest species across a variety of geographical regions and agricultural practises. The estimated crop loss is important for proving the need for control actions to manage insect pest species. Insect pest damage assessment surveys can be conducted indirectly by recording yield or directly by recording infestation.

When it comes to pests, there are primarily two types of predictions:

(i) Short-term forecasting relies on simple sampling done by insect trapping methods or other sampling of the pest within the crop, and it only accounts for a single season or a maximum of two consecutive seasons. Predictions can also be made based on the emergence rate of the pest as observed through insectary rearing.

ii) Predicting the future of a wide area, either by extrapolating the current population density into the future or by using meteorological models to predict insect abundance. However, they are almost always inaccurate because even a minor shift in cropping technique might throw off the results.

Management of Integrated Pests, 59-78, 2014.

The development of appropriate pest management models and decision aids is greatly aided by weather data. Particularly useful for minimising the development of insect resistance owing to excessive use of chemical pesticides, optimising the timing of pesticide treatments, and minimising collateral environmental damage caused by chemical residues. Therefore, accurate weather-based pest forecasting is vital for the proper application of pesticides, the preservation of precious crops, the enhancement of crop yields, and the maximisation of the farmer's financial returns.Rabiu Olatinwo and Gerrit Hoogenboom have confirmed this.

There are three main parts to creating and implementing the forecasting plan:

Establishing appropriate monitoring and forecasting systems; determining the economic threshold for pest attack.

• Facilitating the integration of the forecasting programme into the agricultural production infrastructure

Insect economic thresholds should be used into pest forecasting. Research on population sizes (quantitative studies), the insect's life cycle, and the impact of weather on the pest and its habitat can all contribute to this goal.

(a) Quantitative analyses of populations

Research of this nature needs to span multiple years and make use of representative samples if we are to learn anything about seasonality, population variation, or regional dispersion. There needs to be a connection between the weather and topography information and the seasonal counts.

**Methods of sampling**

**a. In situ counts** - Visual observation on number of insects on plant canopy (either entire plot or

randomly selected plot)

**b. Knock down** - Collecting insects from an area by removing from crop and (Sudden trap)

counting (Jarring)

**c. Netting -** Use of sweep net for hoppers, odonates , grasshopper

**d. Norcotised collection -** Quick moving insects anaesthesised and counter

**e. Trapping -** Light trap

- Phototropic insects

- Pheromone trap

- Species specific Sticky trap

- Sucking insects Bait trap

- Sorghum shoot fly

- Fishmeal trap Emergence trap

- For soil insects

**Economic Injury Level**

- Defined as the lowest population density that will cause economic damage

(Stern et al., 1959)

Also defined as a critical density where the loss caused by the pest equals the cost

of

control measure

EIL can be calculated using following formula

where,

EIL = Economic injury level in insects/production (or) insects/ha

C = Cost of management activity per unit of production (Rs./ha)

V = Market value per unit of yield or product (Rs./tonne)

I = Crop injury per insect (Per cent defoliation/insect)

D = Damage or yield loss per unit of injury (Tonne loss/% defoliation)

K = Proportionate reduction in injury from pesticide use

**Economic threshold level (ETL) or Action threshold**

ETL is the concentration of pests at which intervention is warranted.

stop the pest population from growing to an economically damaging level.

-The Early Treatment Level (ETL) is the threshold below which preventive measures can be

Means of regulation.

Controlling Insects and Bacterial Infections

When it comes to protecting crops from pests, integrated pest management (IPM) is the most fundamental and long-term strategy.

The roots of plants can be damaged by rodents and nematodes, the leaves and berries can be eaten by snails and caterpillars, and the fruits and seeds can be devoured by birds. The list won't be complete without microorganisms like fungi, viruses, and bacteria.

IM's Positive Effects on Pests

The following are some of the primary benefits of integrated management that help to lessen the impact of non-IPM methods:

Workers' chemical exposure has been cut down on.

• utilising natural, environmentally-friendly techniques of management.

• lessening of air and water pollution; removing contamination from land to improve soil quality. avoiding the development of chemical resistance.

Long-term environmental benefits and agricultural sustainability are two additional positive outcomes of IPM.

Cultural approach -

Cultural technique is the use of or adaptation to various farming practises for the purpose of preventing or reducing harmful insect infestation. Common agricultural practises can be modified to kill insects or deter them from causing harm as a cultural way of pest management.

1. Plants bred to fight disease

The adoption of disease-resistant plant cultivars is a standard method of cultural regulation. The presence of natural resistance in some crop kinds makes them less susceptible to attack by a particular insect. e.g. When compared to American cotton, Deshi cotton is significantly more resistant to the white fly and the bollworm. Thus, the use of insect-resistant cultivars is useful for controlling insect pests.

2. Rotation of crops

Insects are selective in the plants they eat. Crop rotation is one method for preventing and reducing pest infestations. Planting jute after rice may help reduce the population of rice stem borer. Like jute, rice can be grown after jute to reduce the population of the jute hairy caterpillar.

3. Elimination of Agricultural Waste

Stem borer of rice and sugarcane, cucurbit beetles, etc., are only a few examples of insects that overwinter in agricultural residues and feast on the following season's harvest. Insects of this type can be managed by burning crop remains after harvest.

4. Working the soil and planting seeds

Changing the soil's features (texture, composition, temperature, humidity, etc.) has a direct impact on the life of insects that infest it. By tilling and cultivating the soil, the underground insects are exposed to light. Most subterranean bug lifecycle stages, including adults and most of the larvae, are consumed by birds and other predators.

5. Cut back and thin out

Insects and other pests often make the journey from the old to the new section. Fruit trees are especially prone to this condition. Insect infestations can be reduced with regular trimming of the unwanted parts of such plants. e.g. Pruning is used to prevent citrus leaf minor red scale, apple aphid, peach leaf curl, and stone fruit aphid. Thin the crop plants to reduce the population of harmful insects. e.g. Thinning rice plants can help prevent green leaf hopper infestations.

6. Fertilization

Plants that are well-nourished and robust are better able to fend off an infestation of a particular pest than those that are weak and malnourished. Proper fertilisation can help plants flourish. Therefore, balanced fertilisation may help prevent bug infestations. e.g. White fly of cotton infestations are mitigated when nitrogenous fertilisers are applied.

7. Honest way of life

Most insects that live or take shelter in all those unwelcome plant in the field in the season (off time) may be controlled by removing them, as this is what is meant by "clean culture," which is the practise of eliminating all unwanted plant, plant debris, and other items from the fields and only producing healthy crops. As an added bonus, the Rhinoceros beetle's larvae can be found in cow manure. The only way to get rid of pests like the epilachna beetle, the red pumpkin beetle, and others is to cultivate cleanly.

8. Controlling water use

Irrigation and field drainage have been effective in reducing bug populations. When flood irrigation is provided, most insects that live underground are killed, including Cutworm, termites, sugarcane white grubs, and others. Some people drown in the floods, and others are displaced and vulnerable to predators in the wild. Once more, an insect invasion, such as a cockroach, can cause significant damage. Water drainage from rice fields helps prevent rice caseworm infestations.

9. The use of "trap crops"

The most vulnerable plants to a given polyphagous insect are produced as a "trap crop" surrounding or within the main agricultural field in order to reduce populations of those insects. As a trap crop, lady's finger is used to eliminate jassids and spotted Bollworms from the cotton field.

10. Clean seed usage

Seeds, cuttings, and other forms of plant propagation that may harbour insect pests can spread them from one harvest to the next. For instance, pink bollworm of cotton attacks the crop the next season after overwintering as a latent pupa in cotton seeds. The next season will bring another attack from the citrus scale insects that live in the plant's branches. So, while starting a new crop, it's important to utilise only pest- and disease-free certified seeds.

11. Changes in planting and harvesting schedules

To lessen pest infestation, try shifting your planting schedule around. e.g. Planting jowar seeds early helps them avoid being eaten by shoot flies, and planting rice seeds early helps them avoid being damaged by gall midges.

12. Grounding oneself

Timely earthing up of the field helps prevent damage from insects like the sugarcane early shoot borer and the potato tuber moth. Insects won't be able to deposit eggs there.

Mechanical and Physical Regulation

1. Mechanical and Physical Regulation

2. For their survival and other activities, insects need specific ranges of physical conditions, and any departure from such ranges is fatal. This is why physical control, the modification of physical factors in the environment, is so effective at reducing or preventing pest problems.

3. Controlling pests via physical means

4. Manipulating the temperature is an effective way to alter insect behaviour and metabolism. Normal insect activity requires a specific temperature window.

5. Extreme heat: hot water treatment of excellent seeds in the sun for 15 minutes (between 52 and 54 degrees Celsius) is fatal. Flaming (Flame thrower) locusts, white tip nematode, and moringa hairy caterpillar.

The potato tuber moth can be killed by storing potatoes at temperatures below freezing.

7. Cereals are dried in the sun.

Seeds are soaked in hot water for step 8.

9. Extinguisher of flames

10. In the freezer

Well-dried grains (moisture content10%) make it impossible for store gran pests like the price we puise beetle to survive. Fields can be protected from brown planthoppers by being flooded and then allowed to dry alternately.

12. Light Manipulation Light has an orienting effect on human behaviour. As a result of the illumination, 1. Red Hairy Caterpillar 2: Reducing Mating Frequency. Fertility declines in Indian meal moths 3. All insects experiencing diapause experience disruption.

13. The use of light traps has multiple applications, including the tracking of insect populations over time and across different contexts (such as seasons and weather).

Mechanised Regulating:

The killing or removal of pests through the application of mechanical means or human work.

Pests can be eliminated at every step of their life cycle by using either mechanical means or human effort.

2. Destructive Technology

3. Hand picking: red hair caterpillars, American boll worms, Spodoptera, and RHC egg masses Brushing woollen materials for cloth moths Combing to remove head lice Crushing bed bugs and lice

4. Pests can't invade hosts because of physical obstacles. Covering material—red earth coating on red gramme grains to control pulse beetle Banding—banding with grease or polythene sheets to control mango mealy bugs Wrapping—covering the fruit with perforated polybags to control pomegranate fruit borer and cloth bag to control fruit pests of grapevine.

5. Water barrier—ant pans for ant control Tim barrier—metallic sheet fixed around tree trunks in coconut for rat control Netting—mosquito control in residence, vector control in greenhouse.

6. We use a variety of traps, including the box trap, the back break trap, and the wonder trap, to catch rats. Preserved vermin.

7. Banding

8. Wrapping

9. Netting

10. Trenching

11. A Waterproof Wall

Pests can be controlled with chemicals:

Chemical control refers to the practise of using man-made chemicals to reduce insect populations, whereas pesticides are the specific chemicals employed for this purpose.

Crawling bugs that take refuge in cracks and other inconspicuous places can be effectively exterminated with pesticides.

Although this strategy has proven to be highly effective in reducing pest populations, recent research has linked pesticide use to a precipitous drop in the populations of pollinating insects that are essential to the success of many agricultural crops. The decreases might increase expenses and diminish yields for farming operations. To reduce the risk of pesticide exposure for farm workers, the EPA has suggested new regulations. However, detractors argue that federal agencies should also prioritise health concerns related to prolonged exposure to extremely low amounts of pesticides.

Different chemical approaches exist;

• Rodenticides

• Fungicide

• Insecticide

Sulphur, the Element

• Phosphide, lead, arsenate, and zinc are all inorganic compounds

Organic substances.

• Nematicides

Plant-based chemicals include fugenol, neem oil, pyrethrum, and nicotine.

Fish oil, diesel oil, and other animal and mineral oils.

Malathion and Diazinon are examples of synthetic organic chemicals.

Ethyl bromide, ethylene dichloride (ED), and carbon tetrachloride are all examples of poisonous gases.

The benefits of the chemical approach:

1. This is a really efficient way.

2. With this strategy, we can achieve our goals rapidly.

3. The results of chemically-induced death are plain to see.

4. This technique is adaptable to a wide range of weather situations.

5. You can choose from a large variety of substances.

6. This strategy also saves money.

The use of living organisms to combat pests:

Biological control is the practise of employing natural enemies to reduce the numbers of potentially harmful pests. Different methods and chemicals are employed for different pests, but biological management is effective against insects, vertebrates, plant infections, and weeds. Insect and pest management will be the main topics covered in this publication. Natural predators and parasites are crucial in keeping pest populations under check. This has been seen time and time again when insecticides have wiped off natural predators of pests. The release of insects from the control of their natural enemies often causes them to become destructive pests, even if they were previously of little economic value. In contrast, secondary pest populations and harm are often reduced when a non-toxic alternative is discovered to control a key pest. This is because less pesticides are used and more natural foes survive. Predators, parasitoids, and diseases are the three types of natural enemies of insects.

Insects are a staple food source for a wide variety of predators. Birds, amphibians, reptiles, fish, and mammals, among others, rely heavily on insect food sources. Unless there are excessive numbers of them, these insectivorous vertebrates will eat a wide variety of different kinds of insects. As they eat on a more limited number of prey species and as their population densities may fluctuate in reaction to changes in the density of their prey, arthropod predators are more commonly used in biological control. Lady beetles, ground beetles, rove beetles, flower bugs and other predatory true bugs, lacewings, and hover flies are all significant insect predators. Predators of insects, pest mites, and other arthropods include spiders and certain families of mites.

Parasitoids are a type of parasitic insect whose juvenile stage only lives on or within a single insect host and causes the host's death. Adults usually have a nomadic lifestyle and may prey on other animals. They could also eat things like honeydew, plant nectar, and pollen. Many parasitoids are extremely specialised and have a narrow host range because they have adapted so thoroughly to the host's life cycle, physiology, and defences. In order to effectively use parasitoids for biological control, it is essential to correctly identify the host and parasitoid species.

Insects, like other animals and plants, are susceptible to infection from pathogens such bacteria, fungus, protozoa, and viruses. Insect pests may have their eating and growth rates slowed by these diseases, have their reproductive processes slowed or stopped altogether, or even perish from them. Some types of nematodes also attack insects, and together with their bacterial symbionts, they can be fatal. It is possible for diseases to proliferate and spread spontaneously across an insect population, especially in areas with a high insect density and under certain environmental conditions.

Implementing Biological Field Control

Conservation of existing natural enemies, introduction of new natural enemies and establishment of a permanent population ("classical biological control"), and mass rearing and periodic release (seasonal or inundative) are the three main ways to use biological control in the field.

**Conclusion:**

The Department of Plant Protection and Quarantine Services (DPPQS) is the primary government agency in India responsible for pest surveillance programmes. Plant Protection, Quarantine, and Storage Directorate, Government of India, Ministry of Agriculture. in 22 different states and Union Territories by way of its 26 IPM centres. To aid state governments in pest surveillance on main crops, the DPPQS pest surveillance programme is also carried out by a number of crop-based institutes and Directorates of the Indian Council of Agricultural Research (ICAR). In the 1960s and 1970s, DPPQS organised rapid roving surveys on various crops with the help of state agencies to determine the prevalence of green leaf hoppers and natural enemies of insect pests in order to provide advice on how to best manage these pests. The surveys were expanded to include additional states because the initial project was so fruitful. The many ICAR institutes in the country have periodically undertaken similar schemes for key pests and diseases of various economically important crops. The Central Silk Board's main Research institutes are located in Mysore (Karnataka) and Berhampore (West Bengal), and the Board's extension sections there have begun a surveillance campaign. Some significant pests have seen progress in the areas of situational modelling, simulation modelling, and model design in recent years. In addition, plant protection experts and farmers do regular sampling to inform IPM decisions:

Early warning systems are a crucial part of any pest control programme, but their development requires authentic data and an expert system. While some scattered efforts on the pest-weather relationship have been done in different crop systems.

A pest control system needs to be economically viable, environmentally sound, and simple to adopt, and this cannot be done without accurate forewarning of the pest appearance, population dynamics/abundance, and peak activity period.

In order to develop reliable early warning and forecasting systems, it is important to learn as much as possible about the biology and ecology of a pest, conduct quantitative seasonal studies over multiple years, consider the pest's seasonal range, population pattern variation, geographical distribution, key mortality factors, and weather records.

**References :**

**Finch, S., Collier, R. H. and Phelps, K.** 1996. A review of work done to forecast pest insect attacks in UK horticultural crops. Crop Prot. 15(4), 353-357. <https://coi.org/10.1016/0261-2194(95)00135-2>.

**Franklin, J.** 2010. Mapping Species Distributions. Spatial Inference and Prediction. Cambridge: Cambridge University Press.

**Fussmann, K.E., Schwarzmüller, F., Brose, U., Jousset, A. & Rall, B.C.** 2014. Ecological stability in response to warming. Nature Climate Change, 4: 206-210.

**Giles, K. L., McCormack, B. P., Royer, T. A. and Elliott, N. C.** 2017. Incorporating biological control into IPM decision making. Curr. Opin. Insect. Sci. 20, 84-89. <https://coi.org>. /10.1016/j.cois.2017.03.009.

**Giraldo, J. P., Wu, H., Newkirk, G. M. and Kruss,** 5. 2019. Nanobiotechnology approaches for engineering smart plant sensors. Nat. Nanotechnol. 14(6), 541-553. <https://coi>.

**Gogoi, N. K., Deka, B. and Bora, L. C**. 2018. Remote sensing and its use in detection and monitoring plant diseases: A review. Agric Rev. 39, 307-313.

**Guarnieri, A., Maini, S., Molari, G. and Rondelli, V**.2011. Automatic trap for moth detection in integrated pest management. Bull. Insectol. 64, 247-251...

**Garrett, K.A., Dendy, S.P., Frank, E.E., Rouse, M.N. & Travers, S.E.** 2006. Climate change effects on plant disease: Genomes to ecosystems. Annual Review of Phytopathology, 44:489-509.

**Garrett, K.A., Nita, M., De Wolf, E.D., Esker, P.D., Gomez-Montano, L. & Sparks, A.H.** 2021. Plant pathogens as indicators of climate change. In T.M. Letcher, ed. Climate change: Observed impacts on planet Earth, 3rd edn, pp. 499-513. Amsterdam, The Netherlands, Elsevier.

**Ghini, R., Bettiol, W. & Hamada, E.** 2011. Diseases in tropical plantation crops as affected by climate changes: Current knowledge and perspectives. Plant Pathology, 60: 122-132.

**Ghini, R., Hamada, E. & Bettiol**, W. 2008. Climate change and plant diseases. Scientia Agrícola, 65: 98-107.

**Garibaldi, L., Kitzberger, T. & Chaneton, E.J**. 2011.Environmental and genetic control of insect abundance and herbivory along a forest elevational gradient. Oecologia, 167:117-129.

**Harvey, C. D.** 2015, Integrated pest management in temperate horticulture: Seeing the wood for the trees. CAB Rev. 10(28), 1-13.

**Higley, L. G. and Pedigo, L. P.** 1996. Economic Thresholds for Integrated Pest Management. Lincoln, NE University of Nebraska Press.

**Higley, L. G. and Peterson, R. K. D.** 2009. Economic decision rules for IPM. In: Integrated Pest Management Concepts, Tactics, Strategies and Case Studies. Cambridge: Cambridge University Press, 25-32.

**Hamby, K. A., E. Bellamy, D., Chiu, J. C., Lee, J. C., Walton, V. M., Wiman, N. G., York, R. M.and Biondi,** A. 2016. Biotic and abiotic factors impacting development, behavior, phenology, and reproductive biology of Drosophila suzuki. J. Pest Sci. 89(3), 605-619. <https://doi.org/10.1007/s10340-016-0756-5>.

**Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano G., Wild, J. et al.** 2017. Forest disturbances under climate change. Nature Climate Change, 7:395-402.

**Taylor, R.A.J., Herms, D.A., Cardina, J. & Moore, R.H.** 2018.Climate change and pest management: Unanticipated consequences of trophic dislocation. Agronomy, 8(1): 7 [online]. [cited 29 December 2020]. <https://doi.org/10.3390/agronomy8010007>.

**Wright, D., Hammond, N., Thomas, G., MacLeod, B. & Abbott, L.K.** 2018. The provision of pest and disease information using Information Communication Tools (ICT); an Australian example. Crop Protection, 103:20-29.

**Books to be refered:**

**common-Sense pest control -** willium olkouski , Sheila daar , Helga olkowski

**Natural pest and disease control –** H.A .E Well

**Ecological engineering for pest management –** Geoff M Gurr , Steve D Wratten

**General concept in integrated pest and disease management –** A. Ciancio , K.G.Mukarji

**Physical control methods in plant protection –** Charles Vincent , Barnhard Panneton

• **DeBach,** P. 1991. Biological control by natural enemies. 2nd edition. Cambridge University Press.

**• US Congress**, Office of Technology Assessment.1995. Biologically based technologies for pest control. OTA-ENV-636. US Government Printing Office.