Sustainable Pest Management: As an Alternative to Chemical Pesticides

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Abstract

It is critically necessary to make a major transition to a whole system approach for crop protection in order to address the growing environmental and economic effects of managing agricultural pests. The use of chemical pesticides, which can kill non-target species, pollute water supplies, and destroy ecosystems, is lessened through the use of sustainable pest management (SPM). SPM reduces ecological disturbance by utilising biological controls, natural predators, and other eco-friendly techniques. SPM encourages crop diversification, the application of natural enemies, and ecological farming methods that increase biodiversity. As a result, insect outbreaks are decreased and ecosystem resilience is increased.

Keywords: *Entomopathogenic organisms, Insect-pests, Sustainable agriculture, Push-pull technique*

INTRODUCTION

Sustainable pest management (SPM) is a holistic, whole-system approach to managing pests in agricultural and other managed ecosystems and urban and rural communities that builds on the concept of integrated pest management (IPM) with broader consideration of human health and social equity, environmental protections, and economic vitality. It contains scientific and significant cumulative methodologies. When we split the term, we will get "sustainable" and "pest management." The term sustainable stands for the implementation of integration of different techniques to achieve any outcome without any damage or harm to nature for a long period of time. On the other hand, pest management denotes the reduction or prevention of the pests that cause harm to the crop, human health, industry, and environment. So the prevention of various pests from causing harm in a unique way is called "sustainable pest management," which was not explored before. Many potential chemical compositions lose their effectiveness in controlling pests as they get the resistance as well as the resurgence power. To break the resistance of pests, various integrated methods have come into the market to take over the responsibility. But it has been observed that these new approaches are effective for a certain amount of time. In these circumstances, the concept of sustainability arises. Sustainability is important in the pursuit of faster economic growth. Sustainable pest management approaches are advantageous to preserve the biodiversity. It is also cost-effective for the implementers. It's a long-run process, so the farmer should have to keep patience for a better outcome. Although it would take time, the control is effective and efficient. The demand for organic materials is getting higher by using sustainable agriculture.

HISTORY OF PEST MANAGEMENT

- Pest management has been essential to human health and lifespan since the dawn of humanity. Natural pest management has been documented since 2500 BC, thousands of years after agriculture first appeared in Mesopotamia's Fertile Crescent. Brimstone, or sulfur, was the first known chemical to be employed as a pesticide. Pagan priests are the ones who are known to have utilized it for medicinal purposes, fumigants, bleaching agents, and incense in religious ceremonies. The Romans utilized sulfur, which comes from combustion fumes, as a pesticide, to rid the air of evil and sanitize sick rooms. Homer wrote about the similar applications of sulfur in the Odyssey around 1000 BC.

- With time and experimentation, along with a little bit of luck, more compounds with pesticidal properties were found. For instance, the first insecticides were made from plants and contained pyrethrins to control a wide range of insect pests, hellebore to combat body lice, and nicotine to control aphids.
- In the decade of 1940–50, the use of broad-spectrum insecticides was getting accelerated after the invention of the insecticidal properties of DDT.
- In the era of the green revolution, the indiscriminate use of synthetic pesticides can be seen.
- A biological insecticide, *Bacillus thuringiensis* (Bt), hit the market in 1960 for insect control in lettuce and cole crops. Bt is a bacterium that is pathogenic to the larvae of some pests, especially lepidopterous pests. The bacterium contains endotoxins that can paralyze and lyse the insect gut, causing mortality through starvation. Several generations of Bt products have evolved since its introduction.
- In 1970s and 1980s introduction of world greatest selling herbicide glyphosate come into the market and at the same time introduction of 3rd generation synthetic pyrethroid like cypermethrin, deltamethrin, benzoyl urea, triazole, morpholine, imidazole, pyrimidin and dicarboxamide group of fungicide takes place.
- In 1990 of new group of pesticides like spinosyn, fipronil, pyrazole, diamide were introduced into the market.

NEED FOR SUSTAINABILITY IN PEST MANAGEMENT

At the forefront of agricultural operations is sustainable pest management, which necessitates creative solutions that strike a balance between social concerns, economic feasibility, and ecological health. Agriculture's constant struggle with pests is characterized by both possibilities and problems, reflecting a changing environment that necessitates constant adaptation. There are many difficulties since pests are becoming more resistant to traditional methods of control, which exacerbates crop losses and jeopardizes food security. Climate change adds complication, influencing pest distribution and behaviour. Traditional techniques, which depend on artificial pesticides, frequently cause environmental damage and harm to beneficial organisms. Solutions derived from nature offer a convincing way to tackle pest-related issues and take advantage of chances for sustainable farming. Lack of resources is another issue, especially in emerging nations. It is difficult for many smallholder farmers to implement sustainable practices because they do not have access to efficient pest management techniques and technologies. Especially in underdeveloped nations, inadequate infrastructure makes it difficult to apply integrated pest management techniques. Containment attempts are made more difficult by the ongoing acceleration of invasive pest distribution caused by globalisation. Furthermore, an excessive dependence on chemical therapies creates a vicious circle of dependency and restricts the investigation of natural, alternative solutions. The effectiveness of nature-based solutions may be limited by a lack of research and development, particularly in the identification and enhancement of beneficial organisms. Furthermore, the majority of countries lack explicit legislation regarding these solutions, which limits public understanding and implementation. Nature-based remedies present encouraging chances for long-term pest control in spite of these obstacles. An agricultural landscape's natural checks and balances can be established by utilizing biodiversity, which is essential to healthy ecosystems. Pest populations can be managed without the use of chemicals by introducing or enhancing the presence of beneficial insects including ladybugs, parasitic wasps, and predatory beetles.

OBJECTIVE TO IMPLEMENT SUSTAINABLE INSECT MANAGEMENT

- **Decreased reliance on chemical pesticides:**

IPM lessens the use of chemical pesticides, which have the potential to be hazardous to both human health and the environment. Rather than using a single pesticide, IPM employs a range of techniques, such as cultural practices, biological oversight, and the sparing use of less hazardous pesticides.

- **Enhanced pest management:**
 Integrated pest management (IPM) can enhance pest management by employing a blend of techniques tailored to the individual pest and its entire lifespan. IPM can lessen the chance of pests becoming resistant to pesticides by using less insecticides.
- **Protection of benefiting organisms:**
Integrated Pest Management (IPM) examines how control strategies affect beneficial organisms, including pollinators, natural enemies, and soil microorganisms. IPM contributes to the preservation of a healthy ecosystem by protecting these organisms.
- **Decreased environmental effect:**
IPM can lessen the negative effects of agriculture on the environment by using fewer pesticides, contaminating less water, and maintaining the health of the soil. This may contribute to the upkeep of a sustainable agricultural system.
- **Cost-effectiveness:** Since IPM reduces the need for recurring pesticide applications and lowers the possibility of creating pests resistant to pesticides, it may prove to be cost-effective over time.
- **Regulation dedication:** IPM can assist growers in adhering to environmental laws pertaining to the application of pesticides and lower their chance of facing fines and other legal ramifications.

BIOTECHNOLOGICAL APPROACHES FOR SUSTAINABLE INSECT-PESTS MANAGEMENT

Agricultural biotechnology is becoming a vital instrument to address the needs of the expanding global population in terms of food, fibre, and other necessities. Agricultural insect pests pose a serious danger to crop output globally, resulting in an annual loss of millions of dollars. Globally, the use of genetically modified (GM) crops to control agricultural pests in a secure manner has increased dramatically. Plant breeders have recently developed crops that express proteins from the Bacillus thuringiensis (Bt) bacterium, making them highly resistant to many of our most challenging insect pests. Transgenes derived from B. thuringiensis are being used more frequently to prevent pest damage to vegetables and staple crops. This chapter will go over various techniques, sterile insects, and the function and applications of biotechnology in insect pest management.

- **Sterile Insect Techniques**
Transgenic insects offer a promising means of controlling insects. Enhancement of the Sterile Insect Technique (SIT) by transgenic methodology may offer novel perspectives on managing insect pests. The SIT is a safe, efficient, and environmentally friendly way to manage pests. This method involves releasing a large number of sterilised organisms or pests into the wild after they have been raised in artificial environments. This causes sterile mating, which lowers the population of pests (Klassen and Curtis 2005).
- **RNA interference (RNAi) technology**
The soil nematode *Caenorhabditis elegans M.* was the first organism to be found to employ the RNA interference technique (RNAi). A promising technique that could provide targeted interventions against insect pests without affecting non-target organisms is RNA interference. It is an effective method that uses double-stranded RNA to downregulate expression of genes in a variety of organisms. This method involves using RNA provided by plants to prevent the pest from expressing a certain gene. When dsRNA is delivered to insect pests, its genes are downregulated, which disrupts the pest's ability to develop and metabolise, ultimately leading to its death.
- **Manipulation of insect resistant molecular markers**
A mutant variety of floral bract in cotton is called a frego bract. It is a crucial feature of insect resistance. Its twisted, narrow structure prevents insect eggs from sticking to the surface. In contrast to typical broad bracts, the eggs that insects lay on these bracts are more vulnerable to the whims of the environment. This bract is small and narrow, and the eggs tend to slip out. Despite the trait's apparent promise as an insect resistance feature, very little research has been done on it, and no commercial variation has been developed around it.

An analysis of the fibre characteristics of frego lines compared to commercial varieties revealed that the frego-bract character would be a useful trait for the establishment of insect resistant cotton cultivars. It was also reported to be effective in suppressing the population of boll weevils (*Anthonomus grandis B.*) (Jenkins and Parrott 1971).

GENETICALLY MODIFIED ENTOMOPATHOGENIC ORGANISMS

Biotechnology and genetic engineering have provided safe and effective biocontrol agents to prevent pollution and contamination in the natural ecosystem. Biocontrol agents such as fungus, nematodes, bacteria, and viruses effectively combat insect pests that harm crops. These biocontrol chemicals, sometimes known as bioinsecticides, are widely used.These pesticides do not leave hazardous residues and are safe for non-target insects.

- **Entomopathogenic Fungi**

  Many different insecticidal proteins are produced by entomopathogenic fungi, but agricultural biotechnological methods have not yet made use of these. Due to their wide host range, certain fungus, such *Beauveria bassiana* and *Metarhizium anisopliae*, can be employed to effectively biocontrol insect pests. Certain enzymes that break down the cuticle help the entomopathogenic fungi penetrate the host.

- **Entomopathogenic Virus**

  When consumed or used topically, many of the peptides and toxins now on the market are useless against insect infestations. Some insect viruses, including baculoviruses, facilitate the passage of these toxins to the insect's hemocoel, where they act. The best biocontrol agents and potential bioinsecticides are viruses that express neurotoxins. The only viruses that have been genetically modified to function as bioinsecticides are baculoviruses (Black *et al*. 1997).

- **Entomopathogenic Bacteria**

  Entomopathogenic bacteria have been the subject of comparatively more research due to their ease of culture and genetic manipulation through plasmids. The focus has primarily been on B. *thuringiensis* (Bt). Bt toxins are renowned for being safe and specific. Numerous insecticidal crystal proteins (ICPs) are produced by Bt. These ICPs are extremely poisonous to lepidopteran, dipteran, and coleopteran larvae and build up in the cytoplasm as crystalline form.

ASCOMYCOTA AND INTEGRATED PEST MANAGEMENT

The use of fungal infections to control agriculturally significant insect pests has become more popular because of its host specificity, availability, and environmentally favourable nature. Prospects for success in the future include mass production, genetic manipulation, appropriate strain selection, efficient and improved research methodologies, and other cutting-edge approaches. The creation of formulations that will improve pathogen virulence and range of action, as well as persistence, extended shelf life, and simplicity of application, are other factors.

It's a unique approach to control insects through ascomycota. With ideal conditions of moderate temperature and relative humidity, their spores germinate and breach the host cuticle with the combined aid of enzymes and mechanical pressure. Later on the germ peg invades the tissues, multiply yielding a mycelium that produces more spores, killing the host by a variety of means such as starvation through multiplication or production of toxins.

INTERCROPPING FOR SUSTAINABLE INSECT PEST MANAGEMENT

Intercropping, one of the main cultural practices in management of pests, is based on the theory that boosting biodiversity in a particular area will reduce the frequency of insect pests. Intercropping occurs when two or more crop species are cultivated together and cohabit for a period of time(Bruce *et. al., 2005)*. Therefore, by using appropriate crop integrating for intercropping and planting crops that can kill or repel infestations, capture natural enemies, or acquire antibacterial properties in between the rows of economic crops, it is possible to reduce the harm caused by diseases and pests and lower the need for pesticides.

ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

To improve the sustainable pest management system, ecological engineering is the new paradigm. To accomplish the objective of sustainable pest management, it is a crucial tactic for advancing biointensive IPM. It is predicated on customs that utilize habitat modification in an agroecosystem of agricultural fields to augment the bioagent population. To improve the survival of insect pest bioagents, the main goal of ecological engineering is to modify the agroecosystem's external environment. Repellant and trap crops can be used in a push-pull strategy to accomplish this. Employing stimuli that obscure host apparency, the pests are repulsed or discouraged from the resource. Using plants that are suitable for the farmers and that also take advantage of bioagents, the strategy combines the use of intercrops and trap crops. (Gurr *et al.,* 2004; Cook *et al.,* 2007).

Through the integration of stimulation that act to make a secured resource unappealing or unsuitable to the insects (push), push-pull methods involve the behavioural manipulation of the insects and their natural enemies while luring them towards an attractive source (pull) by which the insects are subsequently removed. In general, the push as well as pull parts are safe. As a result, the measures are typically combined with population control techniques, ideally biological control. By combining the additive and beneficial effects of behaviour-manipulating stimuli, push-pull techniques optimise their effectiveness.

CHALLENGES OF SUSTAINABLE PEST MANAGEMENT

- It can be challenging to forecast pest behaviour and efficiently manage them due to the complexity of ecological relationships.
- Farmers may find it difficult to implement sustainable methods since they may need larger initial investments or may not yield immediate financial benefits.
- Pest control specialists and farmers alike frequently lack knowledge and training regarding sustainable techniques.
- Current laws might favour conventional pest management techniques over creative, environmentally friendly ones.
- The adoption of sustainable practices may be hampered by misconceptions regarding their efficacy and safety.

ACHIEVEMENTS OF SUSTAINABLE PEST MANAGEMENT

- Multiple farms have effectively reduced their dependency on artificial pesticides, resulting in improved ecosystems and a drop in chemical residues found in food.
- Practices like crop rotation and intercropping have enhanced biodiversity, helping to maintain beneficial insects and natural predators.
- Sustainable techniques frequently improve soil quality, which increases crop resilience and lessens insect load.
- By employing sustainable practices to increase yields and reducing their use of pesticides, many farmers have achieved financial benefits.
- Considerable progress in the development of pest-resistant crop types and biological control techniques has resulted in improved management approaches.

CONCLUSION

The development of new and improved products to replace traditional hazardous pesticides has been the main focus of recent efforts to provide long-lasting, safe, and effective pest management systems. We contend that rather than the goods we employ, our core operating philosophy is the primary vulnerability in our pest management tactics. Biological, chemical, or physical treatment instruments cannot be sustainably used as the main method of controlling pests; instead, they should be used sometimes to supplement natural regulators and bring pest populations within acceptable bounds. This goes against fundamental unifying principles. Creating agricultural methods that are in balance with ecosystems and creating cropping plans that inadvertently prevent an organism from becoming an issue are the directions we should go more often. It's an environmentally sustainable method of controlling pests that's also practical, affordable, efficient, and safe for the environment and public health. There are many different pest management strategies that have been used, ranging from conventional to contemporary. Biotechnology, Genetically modified entomopathogenic organisms, Ecological engineering, IPM have been found to be major current advances in innovative approaches for sustainable pest management.

REFERENCES

Black, B. C., Brennan, L. A., Dierks, P. M., & Gard, I. E. (1997). Commercialization of baculoviral insecticides. In The baculoviruses (pp. 341-387). Boston, MA: Springer US.

Bruce, T. J., Birkett, M. A., Blande, J., Hooper, A. M., Martin, J. L., Khambay, B., ... & Wadhams, L. J. (2005). Response of economically important aphids to components of Hemizygia petiolata essential oil. *Pest Management Science: Formerly Pesticide Science*, 61(11), 1115-1121.

Cook, S. M., Khan, Z. R., & Pickett, J. A. (2007). The use of push-pull strategies in integrated pest management. *Annu. Rev. Entomol*., 52(1), 375-400.

Gurr, G. M., Wratten, S. D., & Altieri, M. A. (2004). Ecological engineering: a new direction for agricultural pest management. Australian Farm Business Management Journal, 1(1), 28-35.

Harrison, R. L., & Bonning, B. C. (1999). Genetic engineering of biocontrol agents for insects. In Biological and biotechnological control of insect pests (pp. 243-280). CRC Press.

Jenkins, J. N., & Parrott, W. L. (1971). Effectiveness of frego bract as a boll weevil resistance character in cotton 1. *Crop Science*, 11(5), 739-743.

Klassen, W., Curtis, C. F., & Hendrichs, J. (2021). History of the sterile insect technique. In Sterile insect technique (pp. 1-44). CRC Press.