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Integrated Pest Management Strategies for Sustainable Agriculture: A Review of Current Practices and Future Directions

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ABSTRACT

The population of India is expected to approach 1.6 billion by the year 2030, with a yearly growth rate of 1.8%. This population growth would result in a yearly demand for an additional 2 million tonnes of edible cereal. Concerns regarding food security will continue to exist in India despite the country's recent success in achieving food grain self-sufficiency. The potential to bring additional land under cultivation is limited, agricultural production technology has begun showing signs of fatigue, and the natural production resource base has degraded. Despite these realities, increases in agricultural productivity must be achieved without compromising the natural foundations of the industry. There is a pressing need for innovative instruments that can simultaneously produce sufficient sustenance while safeguarding the environment and human health. M.S. Swaminathan, a famous scientist in agriculture suggests that 21st-century farming practices make use of Bioengineering, Information Technology, and environmental technology. IPM is an abbreviation for Integrated Pest Management (IPM) which describes this method. This study examines a review of IPM strategies for sustainable agriculture, its current practices, and future directions.

Keywords: Pest control; management of pest; integrated pest management; sustainable; agriculture.

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1. INTRODUCTION

To keep up with population growth over the next 30 years, India will need to boost its annual grain production by at least 2 million tonnes [1]. "The expansion of farmland, the planting of high-yield crops, the application of chemical fertilizers and herbicides, and the expansion of irrigation systems all contributed to greater historical agricultural output. Neither expanding farmland nor employing more advanced machinery appears to boost crop yields. There is less farmable territory as the region's borders draw in. The Green Revolution's enabling tools are now ubiquitous, but their consumers report declining returns. Several biotic and abiotic factors can increase or decrease agricultural output. Crop output is negatively impacted by insects, diseases, and plants. 25% of rice, 5- 10% of wheat, 30% of beans, 35% of oilseeds, 20% of sugarcane, and 50% of cotton are lost to pests [2]. It is possible to lessen the impact of a loss, but not to prevent it completely. Chemical herbicides were widely used to reduce agricultural production until relatively recently. From 15 g/ha in the 1955–1956 crop year to 90 g/ha in the 1965–1966 harvest year, pesticide use in India rose. As a direct consequence of the green movement that started in the mid-1960s, herbicide use rose from 266 g/ha in 1975-1976 to 404 g/ha in 1990-1991 [3]. Although there is a lack of trustworthy time-series data, anecdotal evidence suggests that output losses due to pests are on the rise [4]. No amount of pesticides could prevent this. Pests, the ineffectiveness of pharmaceutical pesticides, and adjustments to the production process all play a role in this anomaly. With little impact on crop yields, herbicide use has been gradually declining since 1990–1991, hitting a low of 265g/ha in 1998–1999 [5]. Financial planning and new insect-control technologies helped to reduce farm herbicide use in the 1990s. The price of using herbicides rose in the 1990s, and farmers no longer received assistance to help with the expense." Agricultural workers and outreach agents across the country received instruction in IPM. India adopted the concept of integrated insect control for use in protecting crops in 1985. Because biopesticides account for less than 2% of the farming market, IPM uptake has been slow.

2. EVOLUTIONARY TRENDS IN CHEMICAL-BASED PEST MANAGEMENT

Farmers used social practices like crop rotation, healthy crop variety, and adjustments to the sowing date to combat pests before the 20th century. "When it was discovered during World War II that DDT could kill insects, it sparked a dramatic shift in how pests were controlled. DDT was found to be safe for use around people, animals, and vegetation, and it eliminated 99.9% of all insect species. Businesses in India joined the fray after learning of the benefits of low application rates. It was well received by manufacturers, especially during the green era. The pesticide business responded to rising customer demand by quickly expanding its investigation of made organic compounds and other forms of pesticides. The chemical accountable for herbicides' unintended consequences, on the other hand, was Dichloro Diphenyl Trichloroethane (DDT). Herbicides comprising organophosphate (OP) and pyrethroids were then widely used by farmers, prompting the evolution of herbicide-resistant strains. Arsenic, mercury, lead, and copper were common components in insecticides. Pesticides are not only harmful to humans but also to creatures that eat pests. Restored bug populations can rapidly experience overpopulation and toxic tolerance if their native enemies are removed. Chemical pesticide use exacerbates the problem. Reduced output was the result of ineffective insect control. As more herbicides became available, their use soared. The damage they did to ecosystems and human well-being was also plain to see. Rachel Carson's landmark work Silent Spring, released in 1962, raised public awareness of these impacts. Because of the widespread, heavy, and constant application of insecticides, bug populations have undergone genetic shifts. Pests with built-in resilience to pesticides can be able to escape their impacts and perpetuate the gene by breeding with offspring. This increased the prevalence of pests that are immune to pesticides. Over 270 herbicide-resistant grass species and 150 fungicide-resistant plant diseases are predicted. Pesticide-resistant insects come in more than 500 species.

2.1 Intensive Agriculture and Pesticide Use in India

Since the beginning of the 1970s, India's yearly herbicide consumption has increased by 2.5 percent. Article [6] reports that the country generates 96,000 tonnes of technical-grade pesticides, of which roughly two-thirds are put to use in agricultural settings [7]. The production of sustenance was significantly increased by using cereal varieties with higher yields. To continue production, pesticide use increased from 5,700 tonnes in 1960 to 46,195 tonnes in 2000. Herbicides at a rate of 250 grams per acre are used in India, but their application is irregular [8]. Cotton, which accounts for only 5% of cultivated land, uses 50% of all agricultural pesticides. These herbicides are used to control insect pests and illnesses. Throughout its lifecycle, cotton receives between 15 and 20 different herbicide applications. Birthal and Jha [9] estimate that each cotton acre will require 3.75 kilograms of pesticides. Pesticides are used on rice at a rate of 17%. Extensive farming was the foundation of India's Green Revolution, a worldwide success story that enhanced the nation's overall level of food security. Intensive farming, on the other hand, has resulted in the emergence of new challenges, such as the wasteful and inefficient use of irrigation water, the depletion of genetic resources brought on by the substitution of a small number of high-yielding crop varieties for a diverse range of traditional crop varieties, and the improper management of essential inputs, such as chemical fertilizers and pesticides. Several different products are currently under attack from exotic pests. During the time of the green revolution, widespread farming drove an increase in pesticide application. (Fig. 1). Eighty percent of agricultural pesticides were insecticides in 1995–1996. This was followed by ten percent of fungicides and seven percent of herbicides. The use of insecticides decreased, while the application of herbicides and fungicides increased. In 2002-2022, insecticides constituted 60%, fungicides 21%, and herbicides 14%. Although the amount of pesticides used on an acre of land has diminished (as shown in Fig. 1), the amount of pesticides used on different products varies considerably (Table 1). Since the beginning of the 2000s, there has been a decline in the amount of pesticide used per acre. This is a result of increasing biological understanding as well as IPM initiatives made by state administrations (Table 2). By region, different pesticide use patterns exist." Because of the endeavors of the state governments, the Indian states of Andhra Pradesh, Karnataka, and Gujarat no longer make use of the majority of herbicides. Most food is consumed in Uttar Pradesh, Punjab, and Haryana [10].

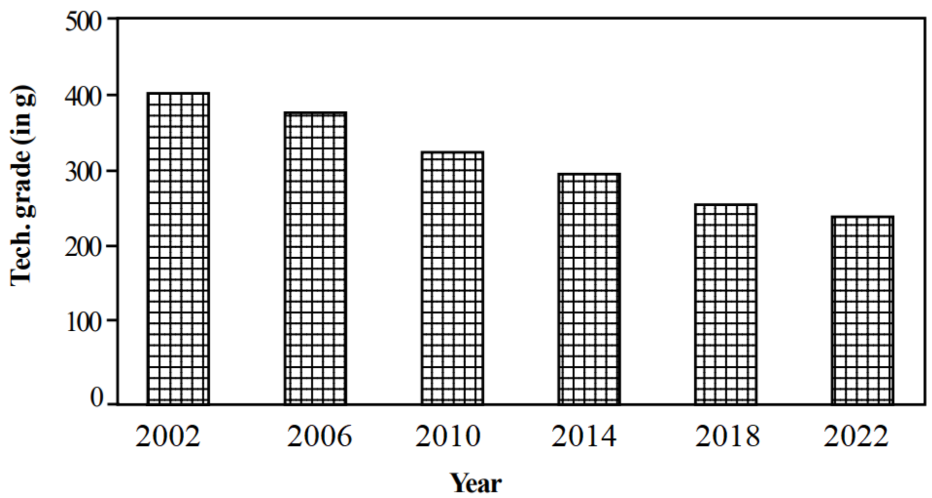

Fig. 1. Per ha pesticide use in India

Table 1. Pesticide consumption by major crops

Crop	Cropped area (%)	Pesticide (%)
Cotton	5	54
Rice	24	17
Vegetables & Fruits	3	13
Plantation Crops	2	8
Sugarcane	2	3
Others	64	5

Table 2. Total pesticide consumption by states

State	Total (Tones)	Percent
Uttar Pradesh	7459	16.15
Punjab	6972	15.10
Haryana	5025	10.88
Andhra Pradesh	4054	8.78
Gujarat	3646	7.90
Maharashtra	3614	7.83
West Bengal	3370	7.30
Karnataka	2484	5.58
Tamil Nadu	1685	3.65

3. SUSTAINABLE AGRICULTURE AND IPM

The problem of the "harmful impacts of pesticide use on the ecosystem can be mitigated through the practice of IPM. (cultural, resistant varieties, biological and chemical control) [11]. Since IPM needs the producer to have expertise in pest tracking and knowledge of pest dynamics, as well as the collaboration of the producers as a whole, it is more challenging to put into practice. There was a dearth of IPM tools in the 1960s when it was first advocated as a means of pest management. Rice, cotton, sugarcane, and veggie product IPM were all bolstered by studies performed in the 1970s.IPM was supposed to drastically reduce the use of pesticides without affecting farming production, but it has fallen short of those goals.

Biological control, ecosystem management, alterations to farming techniques, and the use of protected species are all components of IPM, an environmentally based approach for eradicating pests [12]. The NIFAP is responsible for the creation of IPM. Even if a technique is central to IPM, employing it to control a single organism is not IPM. Multiple insect-control methods are likely necessary to ensure secure yields in the long run. Pesticides can be used to eliminate or prevent the target organism, but only after an evaluation supported by tracking and sampling shows that they are necessary to avoid economic harm. The use of insecticides and other forms of pest control is carefully considered in light of their possible impacts on humans, animals, and the ecosystem. For farming sustainability to be achieved, conventional herbicides and funds must be traded for organic farm-grown components and knowledge to lower production costs without sacrificing output [13]. To keep agricultural outputs and farm income high without depleting available resources, the idea of sustainability depends on tried-and-true farming practices and utilizes a multidimensional strategy. Sustainable agriculture takes into account both short- and long-term consequences of human actions on the natural world and other living organisms. This method of farming integrates historical knowledge with cutting-edge scientific research to create cooperative, equitable, and environmentally responsible food production structures. Environmental harm is mitigated, the farming output is increased, economic success is increased both in the short and long term and quality of life is preserved by this systemic strategy [14]. The following are common components of environmentally responsible farming:

- Crop cycles that reduce weeds, disease, bugs, and other pest issues, provide different nitrogen sources, reduce soil runoff, and reduce farm chemical water pollution.
- IPM methods, such as sampling and tracking, the use of robust varieties, sowing timing, and organic pest controls, lower the need for chemicals.
- More mechanical/biological weed control, soil and water saving, and green manure use
- Safely using natural or manmade inputs.

4. TOOLS OF IPM

Monitoring: IPM depends on field monitoring to identify and locate harmful organisms and pests [15]. This information about pests and products helps select the most effective methods of pest management. Pheromone traps are significantly more effective than light and adhesive traps. Their insect specificity is helpful in IPM validations conducted on a broad scale in cotton, basmati rice, chickpea, and pigeon pea.

Pest-resistant Varieties: Breeding for pest resistance is a continuous process. Pests, particularly plant illnesses, adapt to their victims' changing environments [16]. Therefore, the transfer of genes can result in variations that are impervious to herbicides, pesticides, and other pathogens. To render cotton, maize, and potatoes poisonous to insect pests, a naturally occurring bacterium known as Bacillus thuringiensis, or Bt, is utilized. It is remarkable in its ability to control pests, but the scientific community is concerned about the increased selection pressure for resistance and the effects it will have on native wildlife that is not the intended target." However, there are many ethical, technological, and societal concerns surrounding this potentially useful technology.

Cultural Pest Control: It includes ways of generating food that minimize the impact of pests [17]. "The use of crop rotation, fallowing, manipulating planting and harvesting dates, plant and row spacing, and the destruction of old crop refuse are all cultural techniques that can be used to control pests. The use of cover crops, plants that produce pollen, and interplanting crops to provide a haven for beneficial insects are all important management methods. Cover crops, which are typically legumes or grasses, stop soil drainage and protect the soil from pests. The residue left behind by a cover crop is rich in nitrogen and organic matter, which are beneficial to the next harvest. When incorporated into the soil, brassica cover crops decrease the number of worm pests as well as wilt illnesses. Over ninety percent of plants can be controlled by rye and wheat leftovers. Cultural boundaries are set by pest biology and development.

Physical or Mechanical Controls: Based on the characteristics of the bugs. The Colorado potato insect can be physically controlled by setting traps for it in potato fields that have channels bordered with plastic [18]. Growers of pigeon peas give the plant a good shake to remove any Helicoverpa nematodes. Handpicking individual insects and other pests is the simplest form of pest management. In cotton and legume-producing regions, bollworm populations have decreased at both dead and active avian locations. Mulches and crop blankets are two additional methods that can be used to manage pests and insects.

Biological Controls: These include cultivating and preserving natural enemies of pests, such as insect predators, parasitoids, parasitic worms, fungi, and bacteria, as well as increasing their numbers [11]. IPM initiatives focus on preserving native natural adversaries and introducing non-native organisms with extreme caution. The majority of recipient plants employ parasitoids belonging to the Trichogramma genus. Trichoderma, Verticillium, Aspergillus, Bacillus, and Pseudomonas bacteria are all examples of biological control agents. These bacteria target and suppress plant illnesses.

Chemical Controls: Pesticides are used to keep the number of pests at a level that is not financially damaging, even in cases where other methods of pest management are ineffective [12]. Pesticides are both manufactured by humans and extracted from plants. Many manufactured poisons are the product of human ingenuity. These are not only economical but also quick and simple to employ. Herbicides should only be used as a last resort in IPM initiatives because of the damage they cause to the environment. The most effective pesticides are those that have the least negative impact on the environment and other organisms. New pesticides that are gentler on the environment are currently being developed and approved for use. Pesticides in this category are those that have a limited lifespan or that only have an effect on one or a few specific species.

When evaluating economic barriers, it is assumed that most plants can withstand insect damage. There have been many studies conducted to determine agricultural and insect damage boundaries, but all of them have been unsuccessful. In an IPM plan, chemical measures are not implemented until the pest's detrimental ability is getting dangerously close to the economic barrier. Botanical pesticides can be made using a variety of different processes. Examples include raw ground plant foliage, products derived from plants, and chemicals derived from plants. Ingredients such as pyrethrum, neem, tobacco, garlic, and Pongamia are all examples of botanicals. Botanical pesticides are broad-spectrum. Because of their rapid decomposition, botanicals cause less damage to the environment than other types of waste. It is now secure to travel." These can be produced on farms themselves.

4.1 Approaches for IPM Implementations

At a number of the research locations, the effectiveness of IPM products was superior to that of the producers' practices. IPM helped cut down on hazardous waste releases. IPM not only increased the number of natural enemies, but it also reduced pollution and the use of pesticides [13]. It is possible to integrate the management of major illnesses and pests.

(i) Breeding new varieties with built-in resistance,
(ii) Evolving efficient methods of pest control through pest surveys and monitoring, and
(iii) Preserving and bolstering naturally occurring enemies, such as parasites, carnivores, and illnesses carried by insects, as a biological method for controlling pests. IPM is a cost-effective method for controlling major pests that affect rice, cotton, legumes, and sugarcane, among other crops. The sugarcane Pyrilla and top borer, the coffee mealy bug, and other lepidopterous pests of cotton, tobacco, cocoa, and sugarcane, amongst others, have all been successfully controlled by agents of biocontrol. The technology for mass-producing biocontrol agents such as Trichogramma, Chrysoperla, Heliothis, and Spodoptera nuclear polyhedrosis viruses has proven to be very successful.

Both Indian academicians and field employees are aware of the negative impacts that pesticides can have, as well as the concept of economic boundaries [14]. “The Indian Department of Biotechnology provides financial support to the State Agricultural Universities and other research organizations in India to develop and manufacture biopesticides and biocontrol agents. Recent years have seen the establishment of several new biopesticide manufacturing facilities as well as improvements made to existing plant protection research centers. Therefore, India is employing a greater number of biopesticides and biocontrol agents, but this is still not sufficient. Biopesticides are more cost-effective than conventional pesticides. They are safe for the environment and don't contain any toxic chemicals. The market for biopesticides is estimated, which can be found in the IXth Five-Year Plan. The numbers seem unattainable to achieve without a strategy that is mission-oriented. Farmers don't appear to have much knowledge about biopesticides and biocontrol agents. IPM only applies to one percent of the 143 million hectares of fertile territory in two thousand five hundred of the six lakh cities. Produce, check, and move forward with the development of location-specific IPM components [15].

4.2 Major Obstacles

The greatest method for protecting produce from pests is IPM, but farmers hardly ever use it [16]. The greatest threat to IPM is still pesticides. To have a successful implementation strategy, it is essential to identify the dissemination obstacles it faces.

- Low awareness and innovativeness of extension personnel and target groups
- Inadequate interaction between research and extension agencies
- Problem of timely and adequate supply of quality inputs, including biocontrol agents and biopesticides
- Complexity of IPM vs simplicity of chemical pesticides
- Pesticide industry dominance
- Lack of location-specific IPM modules for many crops

4.3 Essentials for Implementation

- Measurement, evaluation, and publicizing of IBM's effects; availability of site-specific IPM modules that are ecologically sound, economically viable, and socially acceptable;
- High participation from the intended audience; a strategy for disseminating
- IPM across a wide geographic area;
- The elimination of barriers to IPM's spread.

Natural predators of pests must be preserved and cultivated further [17]. Because of their ability to be renewed, reversed, and maintained over time, botanicals and biopesticides are the most effective options for sustainable IPM.” Therefore, bio-agents, biopesticides, and vegetation should be given top priority to maintain the natural equilibrium and control pests.

5. THE FUTURE OF IPM IN INDIA

Agrochemicals boost our health and ensure that our food supply is secure [18]. “The danger to farming output and human health, however, arises from their improper use. There has been a decline in the population of helpful insects, which serve as natural hunters of bothersome insects, and an increase in the population of insect pests that are resistant to toxic pesticides. What effect they will have on human and environmental well-being, in the long run, is still unknown. More secure options using plants and animals as pesticides have been created by the scientific community as a direct response to these dangers. They are supposedly as efficient as potentially harmful pesticides. When used in tandem with synthetic pesticides, these are highly successful in keeping pests at bay in a variety of experiments. To reduce the use of chemical pesticides, boost farm profits, protect the environment, and lessen the negative impact on human health, India has developed and implemented a large number of IPM programs in research, extension, and education since 1985. These initiatives have been implemented in the realms of study and teaching. Pesticides weren't used as much, especially after the 1990s. Agricultural security and safety are also major foci of this study's investigation. Traditional chemical pesticides are no longer an option for controlling pests and reducing related costs. Pesticides are useless against many bug pests. New bug pests have appeared because their native enemies have disappeared. These show that using a lot of chemical pesticides raises the cost of insect control and decreases the income farmers make from their crops. Biopesticides and other possible alternatives can prove useful. The plant and disease communities have produced a wide variety of tools. Due to issues like low economic viability, limited shelf life, delayed impact, and incompatibility with chemical pesticides, many of these have not been placed into commercial production. The brief store life, lack of resistance to chemical pesticides, and higher cost of Trichogrammachilonis and Crysoperlacarnea mean that they are not commonly used in industrial agriculture or fields despite their efficacy. Plant-based pesticides have a slower rate of action. This is the sort of technical issue that needs to be looked into. Crop security relies on the modification of microbes that are resistant to plant pests. It is unclear what long-term effects genetically engineered products like cotton and rapeseed mustard will have on the ecosystem and humans. Genetic resilience can help with the control of pests, according to some data.

5.1 Public-Private Sector Interface

The majority of public sector advancements are not implemented by private businesses because of the short shelf life and unpredictable nature of bug behavior [19]. The majority of biopesticides are produced by public companies. These makeup less than 2% of the total market for pesticides. The insecticide is biased towards chemical treatments and considers biopesticides to be a threat to the chemical industry. Pesticides and biopesticides are in direct competition. In the short term, the use of biopesticides results in lower profits than the use of chemicals. However, the use of biopesticides is required to capitalize on the growing concern among consumers around the world regarding the quality of their food and the state of the environment. Nevertheless, a biopesticide enterprise on a smaller scale that makes use of local resources and maintains quality control has enormous potential.

5.2 Economic Feasibility

IPM is considered by scientists to safeguard food from bugs and other pests [20]. Experiments under controlled conditions lend credence to the claims, but testing in the field is necessary to demonstrate commercial feasibility. It is well recognized for the positive effects it has on both the environment and well-being. On the other hand, farmers in developing countries pay no attention to environmental or health concerns. If it generates the same amount of financial benefit as the technology they currently use, then they will embrace it. Evidence of the project's economic feasibility is scant. IPM, on the other hand, can be just as profitable as pollution management. Therefore, extensive field experiments on farms are required to demonstrate the economic feasibility of IPM in the field.” Therefore, research in both the biological and social sciences needs to be incorporated.

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5.3 Area-wide Adoption

IPM-protected area data is scarce. “Only 1% of the total planted area gets IPM inputs, according to estimates based on output data for bio pesticides [21]. Farmers lack biopesticides and knowledge. Farmers are risk-averse and oppose IPM because it's new. As mentioned, many biopesticides are slow-acting and chemical-sensitive. Pest control needs shared action because pests are harmful to common property resources. Chemicals near IPM crops limit its efficacy. Biopesticides' technical features require community engagement to maximize their potential. Individualism dominates present efforts. Community involvement will shape IPM's future. An incentive system for community pest control farms is needed. Panchayats and NGOs can help advance IPM.

5.4 Agricultural Extension

Agriculture in India is supported by a robust network of development services [22]. On the other hand, it has not been adapted to meet the rapidly changing technological needs of the producers. There is frequently a dearth of knowledge on the part of extension employees regarding the IPM inputs in terms of the technological characteristics, application rates, and methods of application of these inputs. Despite the significant attempts that have been made over the past few years to educate extension employees in IPM, the necessary skills have not yet found their way down to the farmers. It is necessary to create a system of rewards and sanctions to be applied to expansion employees [23].

5.6 Regulations

Biopesticides are regulated like standard pesticides. Registration is tedious and expensive [24]. Small businesses are encouraged to produce biopesticides. Agricultural pesticides number over 150. India sells many pesticides that civilized nations ban. Biopesticides have unique licensing standards. Given their environmental and health benefits, biopesticides should have looser licensing requirements. Ban toxic pesticides to boost the biopesticide business.

5.7 Food Security and Quality

Recently, the policy made ensuring food stability a top priority [25]. This can be eliminated if sufficient carbohydrates are consumed. Several years ago, it was anticipated that a reduction in the use of pesticides would hurt the production of both food and non-food crops. This can pose a risk to the safety of our food supply. New evidence, on the other hand, indicates that a reduction in pesticide use might not affect agricultural production. The level of food safety awareness is growing, particularly among consumers with more disposable income." The amount of worry will increase. The use of IPM increases both the protection of food and the environment.

6. CONCLUSION

Food production that is founded on ecological principles is essential because conventional farming that relies on petrochemicals cannot continue. The application of biotechnology makes this a reality. The use of biological techniques is the most obvious and environmentally favorable alternative to the use of pesticides. The company has not yet made use of the insecticidal and growth-inhibiting properties that many different kinds of plants possess. Farmers who practice holistic planning have a better chance of turning a profit while managing biologically complicated agricultural systems. IPM initiatives require a significant investment of time, money, tolerance, adaptability, long-term and short-term preparation, and commitment. The research supervisors are responsible for their education as well as communicating with the marketing and research employees about the various agricultural activities. This helps with integrating the strategy. IPM could benefit from measures taken by the government. The federal government and state governments need to change insect control by making pesticide control less attractive. This can be accomplished through changes in the law, regulations, and budgetary policies. The Indian Council of Agricultural Research (ICAR) and the Department of Agricultural Research and Education within the Ministry of Agriculture are the organizations that provide funding for IPM. The Indian Council of Agricultural Research and the Indian government have made it a top priority to come up with secure and effective solutions to the problem of preventing unacceptable losses caused by insect pests, plants, and illnesses.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Satpathy S, Gotyal BS, Ramesh Babu V. Impact of climate change on insect pest dynamics and its mitigation. Conservation Agriculture and Climate Change. CRC Press. 2022;107-118.
2. Dara, Surendra K. The new integrated pest management paradigm for the modern age. Journal of Integrated Pest Management. 2019;10(1):12.
3. Dar, Showket A, et al. Insect pest management in organic agriculture-A Fast Growing Approach of 21st Century. International Journal of Agriculture, Environment, and Sustainability. 2021;3(1):1-6.
4. Pretty Jules, Zareen Pervez Bharucha. Integrated pest management for sustainable intensification of agriculture in Asia and Africa. Insects. 2015;6(1):152-182.

5. Taylor RAJ, et al. Climate change and pest management: Unanticipated consequences of trophic dislocation. Agronomy. 2018;8(1):7.
6. Abrol, Dharam P, Uma Shankar. Pesticides, food safety, and integrated pest management. Integrated Pest Management: Pesticide Problems. 2014; (3):167-199.
7. War, Abdul Rashid, et al. Impact of climate change on insect pests, plant chemical ecology, tri-trophic interactions, and food production. International Journal of Clinical and Biological Sciences. 2016;1(02):16-29.
8. Fitt, Gary, Lewis Wilson. Integrated pest management for sustainable agriculture. Integrated pest management: principles and practice. Wallingford UK: CABI. 2012;27-40.
9. Zayan, Sahar Abdou. Impact of climate change on plant diseases and IPM strategies. Plant Diseases-Current Threats and Management Trends. IntechOpen; 2019.
10. Khan, Zeyaur, et al. Push-pull: Chemical ecology-based integrated pest management technology. Journal of Chemical Ecology. 2016;42:689-697.
11. Nawaz, Ahmad, Jam Nazeer Ahmad. Insect pest management in conservation agriculture. Conservation agriculture. 2015; 133-155.
12. Sharma, Hari C, Chandra S Prabhakar. Impact of climate change on pest management and food security. Integrated pest management. Academic Press. 2014;23-36.
13. Gvozdenac, Sonja, et al. Impact of Climate Change on Integrated Pest Management Strategies. Climate Change and Agriculture: Perspectives, Sustainability and Resilience. 2022;311-372.
14. Skendžić, Sandra, et al. The impact of climate change on agricultural insect pests. Insects. 2021;12(5):440.
15. Chidawanyika, Frank, Pride Mudavanhu, and Casper Nyamukondiwa. "Biologically based methods for pest management in agriculture under changing climates: challenges and future directions. Insects 2012;3(4):1171-1189.
16. Pareek, Abhishek, et al. Impact of climate change on insect pests and their management strategies. Climate Change and Sustainable Agriculture. 2017;253-286.
17. Masood, Nasir, et al. Insect pest management under climate change. Building Climate Resilience in Agriculture: Theory, Practice and Future Perspective. 2022;225-237.
18. Fand, Babasaheb B, Ankush L Kamble, Mahesh Kumar. Will climate change pose a serious threat to crop pest management: A critical review. International journal of scientific and Research Publications. 2012;2(11):1-14.
19. Corrêa, Alberto S, Erick MG Cordeiro, Celso Omoto. Agricultural insect hybridization and implications for pest management. Pest Management Science. 2019;75(11):2857-2864.
20. Bajwa Ali A, et al. Impact of climate change on biology and management of wheat pests. Crop Protection. 2020;137: 105304.
21. Huang, Shou-Horng, Ching-Huan Cheng, Wen-Jer Wu. Possible impacts of climate change on rice insect pests and management tactics in Taiwan; 2010.
22. Dent, David, Richard H Binks. Insect pest management. Cabi; 2020.
23. Murrell, Ebony G. Can agricultural practices that mitigate or improve crop resilience to climate change also manage crop pests?. Current Opinion in Insect Science. 2017;23:81-88.
24. Ladányi M, L Horváth. A review of the potential climate change impact on insect populations- general and agricultural aspects. Applied Ecology and Environmental Research. 2010;8(2):143-152.
25. Das DK, Jitendra Singh, Vennila S. Emerging crop pest scenario under the impact of climate change–a brief review. Journal of Agricultural Physics. 2011;11: 13-20.