ISBN: 978-81-19149-80-3

11. IPM: An Approach towards Sustainable Pest Management

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Abstract:

Integrated Pest Management (IPM) is a holistic and sustainable approach to managing pests, aiming to minimize the reliance on chemical pesticides while effectively addressing pest-related challenges. This strategy combines various techniques and strategies, considering the ecological, economic, and social aspects of pest management. The fundamental principles of IPM involve identifying and monitoring pests, establishing acceptable pest levels, implementing a range of control methods, and involving stakeholders in decision-making processes. The key components of IPM encompass cultural practices, biological controls, physical and mechanical measures, genetic approaches, and judicious use of chemical controls. IPM offers numerous benefits, including environmental sustainability by reducing the ecological impact of pest control, economic advantages through cost savings and increased productivity, enhanced human health and safety by minimizing pesticide exposure, and the prevention of pesticide resistance. Additionally, IPM contributes to the development of sustainable agricultural systems and compliance with regulatory requirements. Ultimately, IPM represents a promising approach towards achieving sustainable pest management, fostering ecological equilibrium, and safeguarding both ecosystems and human well-being.

Keywords:

Integrated Pest Management, environmental sustainability, pesticide resistance, sustainable pest management

11.1 Introduction:

Integrated Pest Management (IPM) is an environmentally sustainable approach to safeguarding crops by employing a decision support system for the careful selection and integration of pest control tactics. This strategy is founded on a comprehensive cost/benefit analysis that takes into account the economic, societal, and environmental impacts, as outlined by Kogan in 1998. Both the Food and Agriculture Organization of the United Nations (2005) and the European Union (EU Framework Directive 2009/128/EC 2009b) have defined IPM as the incorporation of all available methods of plant protection, followed by the integration of appropriate measures to deter the proliferation of harmful organisms.

The objective is to maintain the use of plant protection products and other interventions at levels that are economically and ecologically justified, while also minimizing risks to human health and the environment. Crop protection, which encompasses the management of plant diseases, weeds, and other pests, plays a pivotal role in steering agriculture towards more environmentally sustainable farming systems in the 21st century. The integrated management of weeds, pests, and diseases, facilitated by crop protection, is particularly crucial. Pesticides serve as a vital tool for farmers and growers, enabling them to achieve economically viable yields of marketable crops that meet the requirements of the supply chain.

11.2 The Origin of The Concept:

Integrated Pest Management (IPM) emerged as a response to the challenges posed by the widespread use of broad-spectrum insecticides, such as DDT. Entomologists at the University of California pioneered this new approach, known as integrated control. The primary objective was to address issues like secondary pest outbreaks and pesticide resistance.

The key innovation of IPM was the integration of biological and chemical control methods, with chemical control serving as a supplementary tool to biological control. Fundamental concepts like the "economic injury level" and "economic threshold" Stern *et al.,* (1959), forming the basis for decision-making in pest control. Over time, the concept of integrated control expanded to encompass a broader range of control measures, including cultural and mechanical methods. Contributions from researchers such as Franz (1961), van den Bosch (1962), and Smith and Huffaker (1973) played a significant role in the development and advancement of integrated control. Particularly, biological control gained prominence within IPM, recognizing the benefits of utilizing natural enemies to regulate pest populations.

11.3 Principles of Integrated Pest Management:

A. **Definition and Concept of IPM**: Integrated Pest Management (IPM) is an ecological approach that focuses on managing pests by integrating multiple strategies while reducing reliance on chemical pesticides. This approach recognizes the significance of comprehending the biology, ecology, and environmental interactions of pests in order to develop effective pest management strategies Reuveni *et al*., (1998).

B. Pest Identification and Monitoring: Accurate identification and monitoring of pests are fundamental steps in IPM. By identifying the pest species and understanding its life cycle and behavior, targeted control measures can be implemented. Regular monitoring helps to assess pest populations, determine thresholds, and make informed decisions regarding intervention.

C. Thresholds and Decision-Making: In Integrated Pest Management (IPM), thresholds are defined as the point at which pest populations or damage levels warrant the implementation of control measures. The establishment of economic and ecological thresholds plays a crucial role in optimizing the utilization of control strategies and minimizing unnecessary interventions. Decision-making within IPM takes into account a range of factors, including economic feasibility, environmental impact, and social acceptability.

D. Integrated Control Strategies: IPM utilizes a diverse range of control strategies to effectively manage pests. These strategies encompass cultural control practices such as crop rotation and habitat manipulation, biological control methods involving the use of predators and parasites, physical and mechanical controls including traps and barriers, genetic control approaches such as the sterile insect technique and the cultivation of resistant plant varieties, and the careful and targeted application of chemical control methods. By employing this comprehensive array of strategies, IPM aims to address pest issues while minimizing the reliance on chemical pesticides.

E. Stakeholder Engagement and Education: IPM recognizes the importance of involving stakeholders, such as farmers, policymakers, and the general public, in the decision-making process. Stakeholder engagement helps in fostering a collaborative approach and promoting the adoption of IPM practices. Education and outreach programs play a crucial role in raising awareness about IPM principles and methods.

11.4 Components of Integrated Pest Management:

A. Cultural Control Practices: Cultural control practices involve modifying agricultural practices to create unfavorable conditions for pests. Examples include crop rotation, diversification, intercropping, and the use of resistant varieties. These practices disrupt pest life cycles, enhance biodiversity, and reduce pest pressure.

B. Biological Control Methods: Biological control methods utilize natural enemies, such as predators, parasitoids, and pathogens, to suppress pest populations. This component of IPM involves the conservation and augmentation of beneficial organisms through habitat manipulation, release programs, and provision of alternative food sources Nomikou *et al., (*2001), Urbaneja *et al.,* (2007), Sani *et al., (*2020).

C. Physical and Mechanical Controls: Physical and mechanical controls physically prevent pests from reaching crops or remove them from the environment. Examples include the use of insect-proof nets, traps, barriers, and mechanical removal methods. These measures can be targeted and minimize the reliance on chemical pesticides Shah *et al*., (2019).

D. Genetic Control Approaches: Genetic control approaches involve the use of genetically modified organisms (GMOs) or traditional breeding techniques to develop pest-resistant cultivars. This component of IPM focuses on enhancing the natural resistance of crops to pests, reducing the need for chemical interventions Mishra *et al.*, (2016).

11.5 GM Crops as A Route for Delivery of Sustainable Crop Protection:

Modern agriculture, with its vast monocultures of lush fertilized crops, provides an ideal environment for adapted pests, weeds, and diseases. This vulnerability has implications for food security: when new pesticide resistant pest biotypes evolve, they can devastate crops. Even with existing crop protection measures, so sustainable ways of preventing these losses are needed. Development of resistant crop cultivars can make an important contribution. Resistance based on single genes does not protect against the full spectrum of pests, weeds, and diseases, and is more likely to break down as pests evolve counter-resistance. GM (genetic modification) techniques greatly facilitate transfer of genes and thus provide a route to overcome these constraints. Effective resistance traits can be precisely and conveniently moved into mainstream crop cultivars. Resistance genes can be stacked to make it harder for pests to evolve counter-resistance and to provide multiple resistances to different attackers. GM- based crop protection could substantially reduce the need for farmers to apply pesticides to their crops and would make agricultural production more efficient in terms of resources used (Land, energy and water). Resistance based on single genes does not protect against the full spectrum of pests, weeds, and diseases, and is more likely to break down as pests evolve counter-resistance

- **Chemical plant protection in conventional crop production:** Conventional crop production on most farms typically relies on the use of mineral fertilizers and chemical plant protection products (PPPs). Mineral fertilizers provide crops with ample nutrient supply, while PPPs are employed to combat harmful bacteria, fungi, animal pests, and weeds. The integration of mineral fertilizers, chemical plant protection, and modern high-yield crop varieties enables the current intensive crop production system, characterized by tight crop rotations and monocultures. This combination of inputs and practices facilitates maximum productivity in conventional agriculture.

11.6 Major Recurring Themes of Sustainability in Crop Protection:

A. **Are current crop protection practices sustainable:** Do we believe that complete sustainability is achievable? Are integrated crop protection and sustainability symbiotic or antagonistic? That crop protection is of critical importance to any food production system, now or in the future; that the way in which we protect our crops today has significant implications for future generations.
B. **The concept of sustainability:** "Development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs "emphasizes intergenerational factors but is vague in relation to the key elements of either present or future needs. Land quality, natural heritage, rural populations, energy and rural infrastructure as critical elements of sustainability. Most of these elements are also important when assessing future crop protection needs in any agricultural system.
C. **The biological roots of sustainability:** Biological control, chemical-based conventional crop protection, landscape management, and pest, weed, and disease forecasting all rely on and contribute to our functional comprehension of the biological processes that regulate interactions between organisms, which farming practices aim to manage. The challenges encountered in promoting biological control

through the utilization of soil-borne plant pathogens highlight the significance of this approach. It emphasizes the necessity for holistic crop protection strategies to be rooted in a profound understanding of the ecology of the organisms involved. Moreover, it underscores the importance of pursuing various advancements in crop protection to effectively address these issues.

D. Anticipation and sustainability: Most of the agrochemicals which are applied to our crops are wasted, because they are either applied to give protection against "pest" outbreaks which do not occur, or because they fall on a non-target area. With hindsight, chemicals could have been saved by making applications only to pest or disease outbreaks which developed to levels of economic significance. Anticipation also involves the development of new technologies and modifications to existing technologies so as to meet changing needs. There is likely to be for some time a continued development of conventional types of chemical control agents, together with more novel strategies, such as a stimulo-deterrent diversionary strategy, where semio-chemicals are used to modify behaviour and, as a consequence, give protection.

E. Experimentation on sustainable farming systems: Sustainable methods of crop protection will be based upon a better understanding of ecological principles, especially inter-specific interactions. Where either interactions or scale are important, a systems blueprint derived as the sum of information from a series of targeted studies, i.e., the effects of single bio-control agents, will be unsuccessful. Only studies which include the monitoring of whole systems will provide information which draws upon the full range of complexities.

11.7 Benefits of Integrated Pest Management:

A. Environmental Sustainability: A key advantage of IPM is its strong commitment to environmental sustainability. In contrast to conventional pesticide-centered approaches, IPM strives to minimize the reliance on chemical pesticides and instead prioritizes long-term pest management strategies. This approach significantly reduces the detrimental effects on ecosystems, non-target organisms, and water sources. By fostering ecological balance and biodiversity, IPM plays a crucial role in preserving the overall health of agricultural and urban ecosystems.

B. Economic Advantages: IPM can lead to economic benefits for farmers, agricultural industries, and society as a whole. While initial implementation of IPM practices may require investment in training, infrastructure, and monitoring, the long-term cost savings are significant. IPM reduces the need for frequent pesticide applications, leading to lower input costs for farmers. Moreover, by minimizing crop damage and yield losses, IPM contributes to increased productivity and profitability. Additionally, IPM can reduce pesticide residues, improving market access for farmers and ensuring consumer confidence in the safety of agricultural products.

C. Human Health and Safety: The emphasis on reducing dependence on chemical pesticides within IPM has significant implications for improving human health and safety. Pesticides have been linked to numerous health risks, ranging from acute poisoning to chronic illnesses and developmental disorders. By adopting alternative pest management strategies like biological controls and cultural practices, IPM mitigates the exposure of farmers, workers, and communities to hazardous chemicals. This approach also reduces the likelihood of pesticide residues in food, thereby safeguarding consumer health. Additionally, IPM advocates for the use of less toxic and more selective pesticides, enabling targeted control while minimizing harm to beneficial organisms and pollinators.

D. Reduced Pesticide Resistance: Conventional pest control methods often rely on the repeated use of chemical pesticides, leading to the development of pesticide resistance in target pests. In contrast, IPM employs a diverse range of control strategies, including biological controls and cultural practices, which can help prevent or delay the onset of resistance. By integrating different pest management tactics, IPM reduces the selective pressure on pests, making it more challenging for them to develop resistance. This enhances the long-term effectiveness of pest control measures.

E. Sustainable Agricultural Systems: IPM aligns with the principles of sustainable agriculture by promoting the use of integrated and ecologically sound pest management practices. By reducing reliance on chemical inputs, IPM supports the development of resilient and sustainable agricultural systems. It encourages the preservation of natural resources, soil health, and biodiversity, thereby fostering long-term productivity and environmental stewardship.

F. Compliance with Regulatory Requirements: IPM aligns with regulatory frameworks and policies that aim to minimize the environmental and health risks associated with pesticide use. Many countries have implemented regulations and guidelines promoting the adoption of IPM as a preferred pest management strategy. By adhering to these requirements, farmers and industries can ensure compliance and maintain their market access both domestically and internationally.

11.8 Conclusion:

The integration of crop protection and production aims can result in systems based on ecological principles and which optimize resource use. The role of native organisms and natural processes to regulate weeds, pests and diseases should allow a use of crop protection materials which is both more targeted and less extensive. Such systems will be more sustainable.

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