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Agro-ecological approach for insect pest management in organic crops

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Abstract
Increasing awareness towards adverse effects of synthetic pesticides has played a key role in bringing organic farming to the forefront and consumers too preferring organic produce. Thus, sustainable organic approaches of IPM paved the path for ensuring reduced pest infestation in crops and minimising the effect of harmful chemicals in farm produce. Although the concept of IPM originated from traditional practices adopted by farmers which recently became famous as organic management strategies but the earlier documented principles and practices of IPM paved a way towards formulation of organic agriculture management practices. This review article presents various agro-ecological as well as specialised management approaches for insect pest management in crops emphasising on the crucial aspects in achieving the desired goals culminating at reduction of crop losses without causing any detrimental effect on the environment.

Keywords: IPM, model, organic, Uttarakhand

Introduction

World has witnessed the destruction caused to mankind due to excessive use of synthetic chemicals, whether non-agricultural or agricultural as described by Rachel Carson in her book "Silent Spring". With the discovery of dichlorodiphenyltrichloroethane (DDT) by the Swiss chemist Paul Muller in 1939 started period known as "the dark ages of pest control" but by the end of World War II, ill effects of synthetic pesticides became a concern. Thus, due to basically two factors i.e. development of resistance against insecticides and harm on non-target natural enemies, mainly laid the foundation for development of integrated pest management strategies [1]. First official major IPM program was Huffaker project took place in USA and alfalfa, citrus, cotton, pines (bark beetle), pome, stone fruits and soybean were selected as crops to be covered under this project spanning period from 1972-1978[2]. After Huffaker, the second largest IPM project started in USA which is known by an acronym CIPM, the Consortium for Integrated Pest Management [3]. In India maximum pesticide consumption has been reported in Green revolution era covering around 103 districts of some major agriculture belts from Punjab, Haryana, Andhra Pradesh and Western Uttar Pradesh [4]. While the official integrated management practices in India started from 1974, it was since ancient times Indians have been practicing ecological approach in insect pest management. In Rigveda and Atharvaveda one of the Indian primordial literatures various eco-friendly pest management practices have been quoted making use of either plant based or animal-based products. Under Operational Research Project integrated pest management research started in India in year 1974-75 on rice and cotton [5]. The concept of IPM is based on holistic approach with minimal or need based application of synthetic pesticides to tackle pests and diseases [6]. It has also been documented that organochlorines, carbamates, organophosphates, thiocarbamates, pyrethroids, triazoles, and triazines may cause thyroid disruption in birds, rodents, fish and amphibians, also biorationals may cause epigenetic and transgenerational effects in aquatic species[7],[8]. Hence, several researches conducted studies of ill effect of pesticide usage on environment and living organisms, and rising interest of humans in organically produced crops paved a way towards making ecological pest management approach need of the hour[9],[10]. Various IPM programs provided a framework for development of pest management in organic cropping system and supported indigenous technical knowledge of farmers, in India the area of organic farmlands increased from 40 thousand hectares in 2001 to approximately 19 lakhs hectares in 2018 (Source of data: FiBL survey https://statistics.fibl.org/). Present article tries to focus on how IPM is the stepping stone towards achieving goal of pest management in organic cropping system.

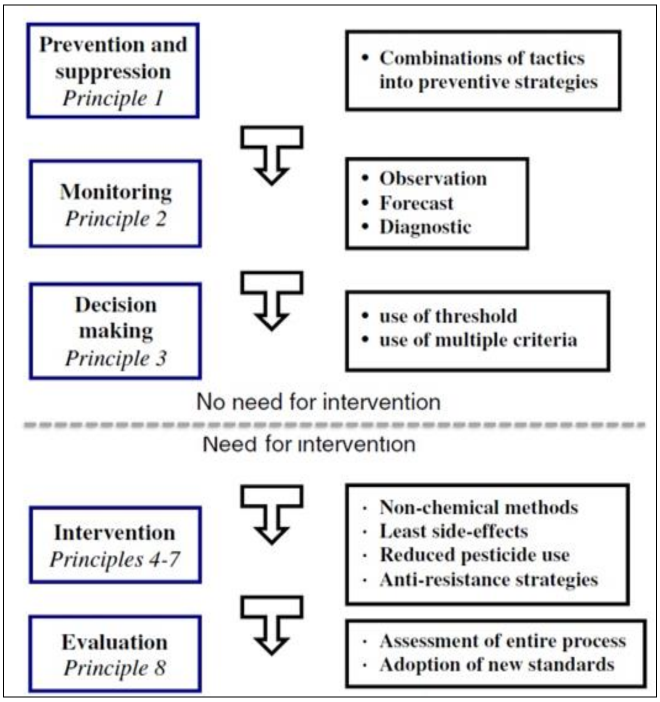

Fig 1: Sequence of eight principles of IPM
Source: Brazman *et al*. 2015

Principles of IPM

To ensure the logical decision making and for professional pesticide users, Framework Directive 2009/128/EC of European union legislation implemented logical sequence of eight principles for integrated pest management [11]. The eight principles are prevention and suppression; monitoring; decision making; non-chemical methods; pesticide selection; reduced pesticide use; anti-resistance strategies and evaluation respectively in sequence (Fig 1). Although, the IPM strategies vary according to the region and different countries have been adopting different IPM practices [12].

Agro-ecological approaches of integrated pest management

Behavioural Manipulation Methods

It has been observed that almost all the pest management methods in one way or the other involve behavioural manipulation of the pest. The behavioural manipulation is mainly divided into three principal methods i.e. i) behaviour of the pest, ii) means by which behaviour of the pest is manipulated and iii) methods by which behaviour of the pest is manipulated [13]. Attributes such as accessibility; definability and reproducibility; controllability; specificity and practicability determine the choice of stimulus for behavioural manipulation. Use of chemical, visual and mechanical stimuli dominates the methods used in manipulation of insect behaviour. Chemical and mechanical stimuli (mainly two classes tactile and acoustic) use predominates as compared to visual stimuli since impracticability of changing certain visual stimuli to effect, but effective in eliciting landing colour traps [14]. One of the most important examples of behavioural manipulation is use of methyl eugenol in Oriental fruit fly, *Dacus dorsalis* male eradication programme on the island of Rota [15].

Host-plant resistance

Plant resistance is defined as "sum of the genetically inherited qualities' that determine the ultimate degree of damage done to the plant by the herbivore" [16]. In integrated management practices resistant plant genotype is used in combination with other practices to reduce impact of insect pests [17]. Painter (1951) identified three categories of resistant genotypes *viz*., antibiosis (Adverse effect on the physiology and life history of insect pests), antixenosis or non-preference (reduce acceptance of host by pest) and tolerance (ability of a host to withstand injury by pest). This approach of pest management has been found to be very useful and since 1970s more than 500 arthropod resistant varieties have been developed [18]. Its use has been documented to be successful in Rice brown plant hopper, whiteflies, aphids etc; also, in USA production of sweet corn was possible after using *Helicoverpa zea* resistant corn varieties [19].

Biodiversity

Ecosystem complexity is generally associated positively with regulation of pests, though the effect is not always positive [20]. The effect of biodiversity was described by Root (1973) in his hypothesis which is famously known as 'root concentration hypothesis' while more recently it is often referred as 'bottom up trophic effect' [21].

Fig 1-2: The images are from a survey done in North-western Himalayan hills of Uttarakhand during 2019, Fig 2: Picture from fields of Gaai village of Pithoragarh district where fermers maintained biodiversity and thus very low infestation of insect-pests were observed. Fig 3: Picture from Bhujaan village of Almora district where due to monoculture of cauliflowers in fields of all the farmers, heavy infestation of Pieris and Spodoptera were observed.

The lack of intraspecific botanical variation and interspecific botanical diversity in monoculture agro-ecosystem is an important cause of pest outbreak by making host plants sensitive to pests [6]. A survey was conducted in different districts of Uttarakhand, India which is situated in north-western Himalayas, it was observed that the infestation of insects was severely high in areas with monoculture (Fig 2) while in areas where diverse agro-ecosystem was maintained the infestation of insect-pests was quite less (Fig 3). The push-pull concept is one of the most important examples of this approach, in contrary *Cosmoplitus sordidus* abundance increased and changed its diet to generalist when an alternative source was present in banana plantation [22].

Biorationals

Biorationals are substances which have low toxicity to non-target organisms such as Insect Growth Regulators (IGRs) and Semiochemicals [23] (Figure 4). IGRs are the hormones or chemicals produced in one part of the pest the affect other part and lead to abnormalities that impair normal growth and development of insect and affect its survival [24, 25]. IGRs that play a pivot role in pest management are Chitin synthesis inhibitors (CSIs), juvenile hormone analogues (JHAs) and anti-juvenile hormone analogues (Anti-JHAs).

Semiochemicals are signal chemicals which carry information between receiver and releaser [26], these are broadly classified into two categories *viz.*, pheromones (interaction between individuals of same species) and allelochemicals (interaction between individuals of varied organisms). Methyl eugenol, trimedlures, spinosads are some of the successful examples used as biorationals for organic crop pest management.

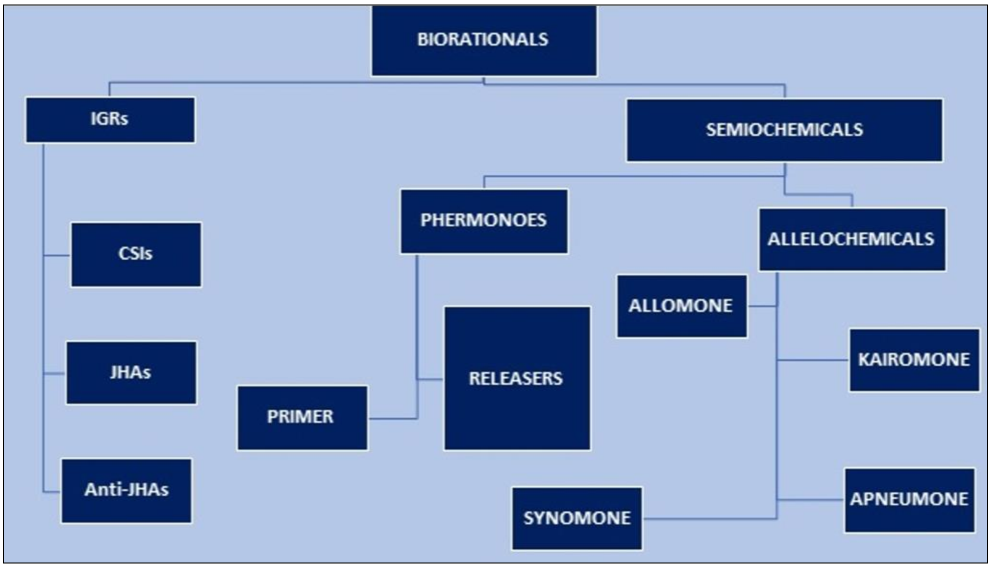

Fig 4: Broad categorization of Biorationals

Biological control

Predators, parasitoids and pathogens are used to reduce the impact of damage caused by pests in biological control[6]. There are three options to adopt biological control practices *viz.*, classical biological control, conservation and augmentation, which are self-sustaining among themselves [27]. Major group of predators belong to order Hemiptera, Neuroptera, Diptera, Coleoptera, and Hymenoptera, the Arachnida; while parasitoids are majorly present in order Hymenoptera and Diptera. Pathogen belongs to biocontrol agents which cause diseases and include fungi, bacteria, nematodes and viruses. Attributes which make them famous for ecological management practices are its high success rate, cost effectiveness and environmental safety. While increase in biodiversity is known as bottom up trophic effect, the use of biological control is described as 'top-down trophic effect' or Enemies hypothesis [21]. In a study annual biopesticides sale of 2009 was compared to data of 2017 and it was found that the sales increased from 2.4% in 2009 to 5% [28] and the benefits were estimated to be around U.S.$4.5 billion annually in 2008 in the US [29]. *Bacillus thuringiensis* is one of the most successful pathogenic biocontrol agents while *Trichogramma sp.* earned a remarkable success as egg parasitoid.

Botanicals

Botanicals have been used since ages and its description has been reported Indian vedic literatures, apart from this modern research literatures are also available for its use against field pests [30, 31] as well as storage pests [32, 33]. Selection of botanicals depend upon the criteria of national organic standard organisations and thus narrowing the options available for botanicals like azadirachtin and pyrethrin.

Wyss's model for insect pest management in organic agriculture ecosystem [34]

Wyss *et al*, (2005) proposed strategy for arthropod pest management in organic ecosystem by dividing the management practices in four phases [35]. The first phase strategy covers traditional farm practices which are in use since ages and implemented in the initial stages of planning of any organic ecosystem. Cultural practices such as crop rotation, soil management, non-transgenic host plant resistance, farm/field location are some of the common but significant since these practices make crop unavailable to pest with the help of proper understanding of pest biology. In second phase ecological engineering approaches as intercropping, trap cropping, mulching, complex biodiversity has to be explored so that crops can be made unacceptable to pest and enhance natural enemies' survival. The International Federation of Organic Agriculture Movements (IFOAM) supervise the guidelines for management practices for organic production adopted in third and fourth phase. Inoculative and inundative biocontrol strategies were used in third phase after conservation already progressed in second phase of pest management strategies [36]. In the last and fourth phase of management strategies application of biological and mineral origin pesticides were used in addition to pheromones and repellents which acts as agents for mating disruption and physical barriers respectively. Although there are certain limitations in each phase but new researches may supplement the model and will provide a clear understanding of the scale of effect.

IPM synergizing organic cultivation

However, there is wide difference in pest management in organic agriculture and IPM like for the use of synthetic pesticides, where only a narrow range of botanicals or biorationals are acceptable for organic agriculture but in IPM a decision-based use of pesticides is its basic principle [37]. According to IFOAM (2014) organic producers must rely on biological, cultural and mechanical methods of insect-pests management, thus making IPM an essential step for simplifying goals of achievement for organic agriculture [38].

Conclusion

Rising concern about adverse effects of chemical synthetic pesticides on human health and environment playing an important role in seeking the public eye towards organic produce consumption. Although organic farming and agro-ecological ways of management are not new to our rich vedic culture where the role of cow dung, cow urine, buttermilk, mustard, sesame, garlic, ginger etc has been elaborated in Sanskrit mantras. But green revolution introduced high demanding crops and abrupt shift towards synthetic management practices which created unprecedent conditions such as resistance among pests, resurgence and adverse effect on non-target organisms. Today the world is adopting organic farming practices, so is the management practices applicable for organic certification of crops. Researchers all over the world are working on the potential of organic management to replace conventional synthetic management practices, but this is time when workers from different frontiers should come together to work collaboratively towards achieving goal of sustainable organic farming practices.

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