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Review on biosafety regulations for efficient pest management under protected cultivation

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Abstract
The integrated pest management (IPM) is a method which employs a decision-based well-suited use of diverse methods for optimizing the management of all classes of pests in an ecological and environmentally safe. An alternative for chemical pesticides as important key elements of integrated pest management system like Many bio-control agents including, arthropod natural enemies, entomopathogens, botanicals and insect viruses. Biotechnology and can genetically modified organisms (GMOs) can contribute to the sustainable agriculture by the positive impact on food security from an attack of insects by placing these methods in a right place to enable full exploitation. Under protected cultivation, emphasis should always be on management of the pests rather than control of pests. Even if some insect-pests are noticed, we should not resort to harmful pesticides straight away, but should exploit other measures for managing these pest species with minimum pesticides applications. Naturally occurring biological control agents/biopesticides/botanicals/safer pesticides/ cultural control measures etc. should be used to manage the pests below ETL by causing specific biological effects rather than inducing chemical poisoning. Alternate pest control methods and the restricted use of pesticides can minimize the risk of pesticide usage. Pesticides can prove to be the most effective instruments in crop protection and if correctly used, their effect is fast and complete, which makes them applicable against nearly every pest. In this chapter, IPM for biosafety through eco-friendly pesticides is discussed.

Keywords: Banned chemical pesticides, bio pesticides, GM crops, Insect viruses

Introduction

In India, agriculture contributes about sixteen percent (16%) of total GDP and ten percent (10%) of total exports. Over 60% of India's land area is arable making it the second largest country in terms of total arable land. Indian agriculture has registered impressive growth over last few decades. The food grain production has increased from51 million tonnes (MT) in 1950-51 to 250 MT during 2011-12 highest ever since independence (Kekane, 2013) [3]. Green revolution has played an important role in increasing the agricultural production in the country which resulted in 135 tonnes of food grains, 23 million tonnes of oil seeds and 32 million tons of fibre crops per annum. During the last five decades, intensive agriculture utilizing green revolution technologies has caused tremendous damage to the natural resources that sustain it. Fresh water, quality soil, energy and biodiversity are all being depleted, degraded and/or polluted (International Food Policy Research Institute, 2016). The rate of increase in productivity of major cereal crops has also declined significantly. Consequently, the per capita availability of food grains has been declining of late. Thus, intensive high-input technologies may not be able to meet the human needs for food, feed and fibre in future. Large numbers of pests are attacking the crops both in field and storage. The crop losses due to insect pests were less in the pre-green revolution period as compared to those in the post-green revolution period and beyond, throughout the world in almost all the crops except cotton and rice. While decrease in crop losses to the tune of 6.8% was observed in rice, it contrasted with an increase of 1.5 and 4.2% in maize and wheat, respectively, in a comparison of traditional and modern agriculture (Benedict, 2003) [1]. There is wide scope to enhance crop productivity through effective suppression of pests. Pesticides play a major role in plant protection in the field and storage of agricultural produce. Pesticides are biologically active substance designed to kill the pest population by their toxic or deleterious effects. A number of new pesticides are being synthesized and introduced for use of various purposes. Their need in Indian agriculture and public health has been appreciated in protecting crops from insect pests and human health from vector born diseases.

The success to enhance agriculture productivity and production has been achieved through fertilizer responsive high yielding crop varieties with an over-emphasis for the use of agrochemicals for the control of pests and diseases and growing crops under protected environment. Protected cultivation of vegetables offers distinct advantages of quality, productivity and favourable market price to the growers. Vegetable growers can substantially increase their income by protected cultivation of vegetables in off-season as the vegetables produced during their normal season generally do not fetch good returns due to large availability of these vegetable in the markets. Off-season cultivation of cucurbits under low plastic tunnels is one of the most profitable technologies under northern plains of India. Walk-in tunnels are also suitable and effective to raise off-season nursery and off-season vegetable cultivation due to their low initial cost. Insect proof net houses can be used for virus-free cultivation of tomato, chilli, sweet pepper and other vegetables mainly during the rainy season. These low cost structures are also suitable for growing pesticide- free green vegetables. Low cost greenhouses can be used for high quality vegetable cultivation for long duration (6-10 months) mainly in peri-urban areas of the country to fetch commensurate price of produces. Polytrenches have proved extremely useful for growing vegetables under cold desert conditions in upper reaches of Himalayas in the country. However, insect pests and diseases are the major constraints in achieving higher productivity especially under protected cultivation where more favorable conditions prevail for the growth and development of insect pests and diseases. No doubt pesticides application can curtail the menace of insect pests but indiscriminate and injudicious use of chemical pesticides to suppress the pests during post green revolution resulted in fivefold increase in pesticides until 1990-91 over the quantity used in 1965-66 (Sharma, 2010 and Sood *et al.*, 2009) [5, 6]. In 2014-2020 about 60,599 MT technical grade pesticides were used in India (Table 1). An insecticide alone contributes 62.7 per cent of total pesticides used in India. Beside this the pest problems have been accentuated with the introduction or release of high yielding, input responsive crop varieties/hybrids. Besides, the high cropping intensity in protected cultivation gave boost to pest survival and further buildup of population. The climatic changes have also been instrumental in creating upheavals in pest fauna throughout the globe. These factors have led to the increase in pest populations and appearance of new pest especially under protected cultivation like tobacco caterpillar, whitefly, mites and nematodes etc. The pesticides being meant for killing the insect pests are basically toxic in nature and do not differentiate between target and non-target species of pests hence, their indiscriminate or injudicious use may be harmful to human being and environment. They are, therefore likely to cause acute and chronic adverse effects on human beings, cattle, pets, pollinator and environment. It is therefore, necessary to use them carefully so as to maximize the advantages and minimize the hazards associated with them. The public alarm raised about pesticides in 1960s has been translated into legislative control in form of Insecticides Act, 1968.The insecticide act regulates the import, manufacture, sale, transport and use of insecticides with a view to prevent risk to human beings, animals, environment etc. The rules framed under the Act are called the Insecticides Rules 1971 (WHO, 1971) [8]. Concerns of health and environment safety and availability of quality pesticides to farmers/vegetable growers are the important concepts behind this legislation. In India, the principal regulatory method is by a system of pre-marketing registration of pesticides including bio-pesticides and transgenic etc.

Biosafety is defined as application of knowledge, techniques and equipment to prevent personal, laboratory and environmental exposure to potentially infectious agents or biohazards or Biosafety defines the containment conditions under which infectious agents can be safely manipulated. Biosafety also include the prevention of large-scale loss of biological integrity, focusing both on ecology and human health as well as safe handling, transfer and use of living organisms modified through biotechnology. India is one of the few countries in Asia that has instituted biosafety regulations. How effective are these regulations? Are they well enforced? Doubts were raised when an institute under the Ministry of Agriculture was found to be violating biosafety guidelines. The website on Indian biosafety rules and regulations is to advice. Facilitate and regulate modem biotechnology work at different stages to achieve the objectives of protecting environment including human and animal health from the unintended adverse effects of GMOs and products.

Now an era of efficient crop production management technology has to be heralded and Integrated Pest Management (IPM) would be an important component of this technology. It involved use of eco-friendly approaches to suppress pest populations, which includes the use of bio rational (Biopesticdes also known as biological pesticides are certain type of pesticides derived from such natural materials as animals, plants, bacteria and certain minerals). Insect resistant crop varieties, safer insecticides, transgenic, etc. In the latest agriculture scenario of WTO, an increasing attention is required to be paid on low cost and quality production of agriculture produce.

The protected cultivation is an alternative to provide nutritional food to fast rate growing population and it likely to play a major role in improved quality production in future. But, on an average about 20 - 30 percent of crop loss is estimated due insect pests and diseases and damages are more in protected cultivation. The injudicious use of water, fertilizers and pesticides has created problems in the past in the form of pest populations and under protected cultivation crops are more prone to pests. It is important that the crops must be protected from various pests and diseases with due consideration of environment and health of human beings and live stocks. Use of toxic pesticides under protected cultivation may result in environment contamination (residue problems) and health hazards. The Biopesticides/GM plants are likely to play vital role under protected cultivation.

Indeed, the issue of pest management in protected cultivation is assuming great importance as the insect pests are responsible for substantial crop losses. It is, thus, Imperative for us to develop appropriate bio-safety regulations for efficient pest management strategies especially for protected cultivations. At the same time development of new varieties having resistance/tolerance to the insect pests need to be aggressively addressed. In the recent years, use of chemicals is also reported to hasten the process of evolution of new strains or virulence leading to breakdown of resistance.

Over the years, spectaculars advancements have been witnessed in the field of insect pest management, with the focus on the pest management techniques, which helped in revolutionizing the agriculture scenario at the Global level. It has provided solutions to various agri-related problems; ensured need based plant protection of the main plant crops and reduced agriculture expenditure through judicious use of chemicals and pesticides.

The overuse and misuse of pesticides created many ecological problems like pest resistance, resurgence, outbreaks of secondary pests and contamination of the environment. Dr. M.S. Swaminathan coined the term 'evergreen revolution' in 1990 to emphasize the need for enhancing productivity in perpetuity without associated ecological harm.

In the view of second generation pest problems created by the green revolution technology, several pest management tactics were evolved and refined for crop protection including the crop of protected cultivation. Some of the major approaches include chemical pesticides, biological control agents, insect resistant varieties, biorational approaches and more recently the genetically modified (GM) or transgenic crops. Out of these the latter one ie genetically modified (GM) or transgenic crops require specific biosafety regulatory assessment process prior to their adaption in different countries.

Genetically modified (GM) or transgenic crops

Regulatory risk assessments are an important part of the introduction of insect resistant genetically modified (GM) crops (e.g., *Bacillus thuringiensis* [Bt] crops) into the environment to ensure the safe use of such products (DBT, 1998). In doing so, the regulatory assessment process can be clearly beneficial to integrated pest management (IPM) programs. In general, the regulatory framework for insect-resistant GM crops includes an assessment of the following: effects of the insecticidal trait on non-target organisms, other potential adverse environmental impacts, evolution of resistance to target pests, and environmental and agronomic benefits of the insecticidal trait.

Each country's regulatory system is dependent on the overall environmental risk management goals, relevant and available risk information, scientific capacity, and the available financial resources. A number of regulatory activities can help to ensure that new products such as *Bt* crops fit well within IPM programs:

- Evaluation of the environmental safety of new products, and their ability to enhance IPM
- Encouragement of the adoption of new technologies with improved environmental safety profiles.
- Adoption of an expedited regulatory review system.
- Encouragement and appropriate oversight of sustainable use of such products.

Governmental regulation of insect-resistant GM crops can also hinder IPM programmes under protected cultivations by creating significant barriers to the adoption of such technologies. Such barriers include:

1. Absence of functioning regulatory systems in many developing countries.
2. Meeting the obligations and understanding the various interpretations of international treaties, e.g., Cartagena Protocol on Biosafety.
3. Lack of public sector research to generate data supporting the safety of these crops.
4. Regulatory costs involved in the development and commercialization of novel products for small market sectors.

Regulations for genetically modified (GM) crops

- Regulatory risk assessments are an important part of the introduction of insect- resistant genetically modified (GM) crops (e.g., *Bacillus thuringiensis* [Bt] crops) into the environment
- To ensure the safe use of such products.
- The regulatory assessment process can be clearly beneficial to integrated pest management (IPM) programs.

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- Effects of the insecticidal trait on non-target organisms,
- Other potential adverse environmental impacts,
- Evolution of resistance to target pests, and
- Environmental and agronomic benefits of the insecticidal trait.

Ways in which regulatory data requirements can be globally harmonized need to be considered to decrease the regulatory barriers for insect-resistant GM crops and comparable technologies. International organizations can play a key role in rationalizing regulatory systems; however, public sector research will also be needed to make sure that the risk assessment process is scientifically sound and transparent. Among the Countries 74% of the transgenic area sown is in industrialized countries and 26% percent in the developing countries. The country wise distribution of the transgenic area reveal that most of the transgenic area was occupied in USA (68%) and Argentina (22%) followed by Canada (6%) and China (3%). Rest of the Countries had less than one million hectare under transgenic crops.

Biocontrol agents and Biopesticides

Biological control agents have played a pivotal role in regulating pest populations. There have been 5634 recorded releases of 2119 species of entomophagous arthropods to control 597 pest species. In India, 163 exotic bioagents have been studied for utilization against crop pests and weeds. Of these, 69 species were recovered after releases, 4 provided partial control,4 substantial and 6 recurring benefits millions of rupees (Ramani *et al*., 2004) [4] Biopesticides (also known as biological pesticides) are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. For example, canola oil and baking soda have pesticidal applications and are considered biopesticides. Currently there approximately 175 registered biopesticide active ingredients and 700 products. Biopesticides fall into following three major classes (Koundal, 2001). However complete control was achieved in 212 cases and substantial control was obtained in 419 cases. In India total consumption of bio pesticides/plant based pesticides during 2014-20 (Table 3)

Microbial pesticides consist of microorganism (e.g a bacterium, fungus, virus or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pest (s). For example there are fungi that control certain weeds, and other fungi that kill specific insects. The most widely used microbial pesticides are subspecies and strains of *Bacillus thuringiensis* or Bt. Each strain of this bacterium produces a different mix of proteins, and specifically kills one or a few related species of insect larvae. Bt produces a protein that can bind to a larval gut receptor, thereby causing the insect larvae to starve.

Plant pesticides are pesticide substances that plants produce front genetic material that has been added to the plant. For example, scientists can take the gene for the Bt pesticidal protein, and introduce the gene into the plants own genetic material. Then the plant. Instead of the Bt bacterium, manufactures the substance that destroys the pest. Both the protein and its genetic material are regulated by EPA; the plant itself is not regulated.

Biochemical pesticides are naturally occurring substances that control pests by ion- toxic mechanisms. Conventional pesticides. By contrast, are generally synthetic materials that directly kill or inactivate the pest Biochemical pesticides include substances, such as insect sex pheromones that interfere with mating as well as various scented plant extracts that attract insect pests to traps because it is sometimes difficult to determine whether a substance meets the criteria for classification as a biochemical pesticide.

Biopesticide regulatory requirements

Although biopesticides are widely recognized as safer than chemical pesticides, they do have the capacity to reproduce, and many of the standard tests for chemical pesticides are irrelevant or difficult to apply. For instance, standard chemical pesticide registration requires a specific chemical test for the pesticide; the degradation products must be known, and soil persistence determined. For biological, complex characterization tests are needed for identification; degradation products cannot be defined precisely; and the microbe may be normally present in soil. Therefore, on one hand, attempts to apply rigid chemical pesticide regulations to biological agents delay implementation and raise the development cost of biopesticide products. On the other hand, regulations which are too slack, or non- existent, allow sub-standard products to appear on the market, undermining consumer confidence in biopesticides (Table 3). In India the Directorate of Plant protection and quarantine authorities designed registration guidelines for the registration of biopesticides. In America, the U.S. Environmental Protection Agency EPA has designed registration guidelines that are tailored to the unique features of microbial pesticides.

Bio-hazard evaluation

There are growing number of tested and accepted biological insect control agents belonging to diverse group such as bacteria, fungi and certain viruses etc. Some of them are registered in global market. Whereas the testing and large scale use of biological control agents would itself require the nominal course of approval from Directorate of Plant Protection and Quarantine under Ministry of Agriculture, the production testing and use of these genetically altered agents would be strictly governed by the rDNA guidelines and regulations of the Government of India. Violations and non-compliance including non- reporting of the R&D work in this area would attract the punitive actions provided under the Environmental Protection Act.

Bacterial agents

Three main groups of bacteria *viz. Bacillus popilliae, B. thuringiensis* and *B. Sphericus* have been the subject of extensive studies. Off these, *B. thuringiensis* particularly H-14 strain has been found to be most promising for the control of larvae of Lepidoptera, mosquitoes and black flies. The protein crystal toxin (endotoxin) of these bacilli acts as potent gut poison on ingestion by the larvae.

Insect viruses as control agents

Virus diseases have been reported from more than 800 species of insects and mites. Major groups of virus pathogens of insects are (i) *Heliothis zea,* (ii) *H. virescens* (iii) *Lymantria dispar Div*) *neodiprion sertifier* (v) *Orgyia pseudot-sugata* (vi) *Dendrolimus* are produced on an industrial scale.

The bio-hazard evaluation of promising viral agents which are naturally occurring entomopathogens should include the following:

1. Elaborate tests conducted in the laboratory as well as under greenhouse conditions to understand potential physiological and/or genetically hazards for non-target organisms.
2. The safety measures for large scale application of such products would require very careful evaluation since the combination of two or more types of biocides may affect the target organisms particularly those which are beneficial. For example genus *Apis* which plays an important role in pollination of oil seeds, legumes, vegetables, forage and food crops.
3. The characteristics of baculovirus that is more useful for identification is the profile produced by cleavage of the viral DNA with bacterial restriction endonucleases. Such techniques should be used to screen all production batches which should be preferably purified before release.
4. The purified virus should be formulated in such a way that its stability both on the shelf and field is satisfactory.
5. The biological activity of the propagation should be measured by reproducible and effective bio-assays to measure the responses of larvae expressed in standard activity units which can be related to the activity of the other batch.

Recombinant Insect viruses

Autographa California nuclear polyhedrosis virus (AcNPV) is a registered insecticide in USA and is also now gaining importance for being employed as recombinant vector. The recombinant technology could be extended to the construction of noval AcNPVs with genes of *B. thuringiensis* b- endotoxin and insect neuropeptides for greater effectiveness. Thus baculovirus recombinant vector containing 6-toxin of *B. thuringiensis* and insect neuropeptides could be of immense use in planning overall strategy for insect control.

Risk Assessment

The assessment of potential risks arising from the introduction of microorganisms into environment is made according to the three major criteria of familiarity, control and effects. Upon evaluation of these three criteria, a proposed introduction can be field tested according to established practices or it can be assigned to one of the three levels of concern low, moderate or high uncertainty. If an introduction does not satisfy the familiarity criteria, it is evaluated with respect to our ability to control the organism’s persistence and dissemination and the microorganism’s potential for significant adverse effects. This is categorized with moderate and high uncertainty category depending upon the potential of the adverse effects. Therefore, any attempt at genetically altering, improving changing the host range, target specificity, differential pathogen toxicity, toxic agent productivity, factors affecting safety and efficiency new formulations leading to newer uses of these biological control agents and related organisms and their products derived through genetic alteration would require the application of rDNA safety guidelines and regulations.

Recombinant DNA safety guidelines

India is one amongst very few countries in the developing world to have laid out detailed biosafety guidelines for organisms. The guidelines are prepared by the Recombinant DNA Advisory Committee constituted by DBT, Govt of India which is responsible for the development in biotechnology in the country (DBT, 1998). The recombinant DNA Safety guidelines are based on the three tier system involving

- Institutional Biosafety Committee (IBSC)
- The Review Committee on Genetic Manipulation (RCGM)
- The Genetic Engineering Approval Commitee (GEAC)

The IBSC is established at every institution engaged in research on genetically engineered organisms. The RCGM and GEAC closely monitor the field experiments involving transgenic before their commercialization is contemplated.

The RCGM is the national committee functioning under the DBT and has the function of reviewing the approval of ongoing R&D projects on GMO undertaking field visits of the sites of experimental facilities and issuing clearance for import/export of vectors, germplasm etc. needed for experimental working, training and research. Based on the recommendations of the RCGM, trials permits are issued by the DBT. Environmental safety including human health, gene flow etc. are required to be investigated before commercialization.

GEAC function under the Department of Environment as statutory body for review and approval of GMO & their products in research and development of environmental release and field application. Following the GEAC clearance, the applicants are to seek the clearance of the ministry of Agriculture (MOA) that in turn installs procedures of the All India Coordinated Trial (AICT) through the Indian Council of Agricultural Research (ICAR). The final clearance of the transgenic crop varieties/microorganisms for agricultural use shall be accorded by the MOA, through its well established wing of assessment. The GEAC based on the information generated elsewhere by the applicant or through the RCGM mechanism in India may accord approval of the applicant to proceed further for AICT. The regulatory agencies in India, have so far done an excellent job of formulating detailed guidelines for GMO field experiments. There is however an immediate need to ensure that the guidelines on GMO and biopesticides as well advertised to increase public awareness on the subject and to ensure that technology is well received.

Chemical pesticides

In sustainable agricultural production, various methods of pest management played an important role. However, significance of chemical pesticides as one of the component of IPM, in increasing agricultural productivity cannot be denied. Reduction in problems associated with use of chemical pesticides under protected cultivation can be achieved with judicious use of pesticides, development of safer molecules, effective insecticide resistance management, pesticide quality management, enhanced use seed treatment, effective pesticide application technology, pesticide monitoring mechanism in lights of SPS issues, enhanced use of ICT for pest forecasting and forewarning. In most countries, before a pesticide product can be marketed and used to manage a pest problem, the product must be registered with a government agency responsible for regulating the sale, distribution and use of pesticide products. Initially, registration of pesticide products was required to protect the consumer from fraudulent claims and limited attention was given to the impact of the product on consumer safety or the environment. As awareness of the potential impact of pesticides on the user. the consumer, and the environment developed, the registration of a pesticide products became the predominant method for regulating the use of a pesticide products. As requirements for registration of pesticide products expanded, the product label became the bottom line of the registration process. Every specific statement on the label had to be supported by evidence that no adverse effect would be caused to man or the environment if the product was used according to instructions specified on the product label.

Regulation of Pesticide Applicators

Although a pesticide product may be approved to control a specific pest problem on a given host crop or site, problem still occur if the applicator does not follow the instructions specified on the label or fails to use sound judgment when exceptional situations occur. As a result, it has been recognized over time that distribution and use of some pesticide products need to be restricted to applicators or users having the training or expertise to use the pesticide product in a manner that no adverse harm will occur to man or the environment. Regulating applicators of pesticide products includes two steps: (l) pesticide products designated for restricted/banned use (Table 2) must be labeled accordingly during registration process, and (2) a system of pesticide applicator training and certification must be implemented to insure that only trained applicators are granted a license to purchase and use pesticide products labeled for restricted use.

- **Regulations for approved uses of pesticide registered under the Insecticide act, 1968:** The Insecticide Act. 1968 and Rules, 1971 regulate the import, manufacture, sale, transport, distribution and use of insecticides with a view to prevent risk to human beings, animals, and environment. The Registration Committee (RC) constituted under section 5 of the Act register pesticides considering the data submitted by the applicant on different parameters such as Chemistry, Bio-efficacy, Toxicity, Packaging & Processing scrutinized by the secretariat of CIB & RC to ensure efficacy and safety, approve the label claims for control of different pests of crops. Such approval is granted by the RC after considering various parameters on safety and efficacy of product. So far RC has approved 225 pesticides for use against various pests on different crops and vectors in India. The approved label claims for these registered pesticides under the Act are available at the website www.cibbre@nic.in. While recommending the pesticides under protected cultivation due consideration must be given to label claims to avoid any legal risk.
- **Recommended uses of Insecticide Fungicides Herbicides by States on agricultural/horticultural**

crops: At State level, the State agriculture/ Horticulture Department/ state Agriculture Universities recommend package of practices for the control of pests in different crops. Based on the information gathered from various states, it has been observed that a large number of pesticides, recommended by the states, are not approved by the RC. A list of crop wise pesticides recommended by the states which are approved/ not approved by RC has been compiled by the Directorate of Plant Protection, Quarantine and storage.

- **Draft recommendations of for pesticide use in India:** A one-day Workshop was organized by the Ministry of Agriculture, Department of Agriculture & Cooperation (DAC) on "Approved Uses of Pesticides in Agriculture" on August 30, 2010 at NASC Complex, Pusa, New Delhi wherein the officers of DAC; Directors of Agriculture and Horticulture of State Governments; Directors and Scientists of ICAR Institution and State Agriculture Universities (SAUs); representative of Tea Board, Spices Board and Coconut Board; and representatives of Associations of Pesticide Industry participated. Participants deliberated on the issues related to presence of pesticide residues in various food commodities vis-à-vis recommended and non-recommended use of pesticides in agriculture. There was appreciation on the need for scrupulously adhering to uses approved by the Registration Committee as the same were approved after scrutiny of technical data. After detailed deliberations, following recommendations were crystallized for taking remedial measures:
  1. ICAR Institutes, Commodity Boards, SAUs and Agriculture Departments of all States would review their recommendations on uses of pesticides on various crops to bring them in alignment with the uses as approved by the Registration Committee under the Insecticides Act, 1968. The revised recommendation arrived at be made available to the Directorate of PPQ&S, Faridabad.
  2. The registration for expansion of label claims including usage on minor crops should be done on fast track.
  3. ICAR Institutes, Commodity Boards, SAUs and Agriculture Department of all States may ensure that every new use of pesticide in agriculture should have approval of the registration Committee before they recommend it to farming community for adoption.
  4. State Department of Agriculture and Horticulture should take corrective action, including creation of awareness among farmers, to ensure freedom of Agricultural Commodities from residues especially those of non-approved pesticides.
     a. Review uses of pesticides which have been approved by Registration Committee long ago.
     b. Broaden the crops covered in monitoring pesticide residues.

Awareness may be created through extensive use of print, audio and visual media, preferably in regional languages, about

- Benefits of using pesticides as approved by the Registration Committee;
- Adverse effects of non-approved uses of pesticides;
- Repercussions of not observing the waiting periods; and

Harmful effects of treating the food commodities with pesticides just before harvest or at the time of marketing

1. Education/training programmes may be organized by the Central and State Governments wherein package of practices, prepared strictly in consonance with the uses approved by the Registration Committee, should be circulated among the farmers; including in Farmer's Field Schools.
2. Proactive role needs to be played by the members of Pesticides Industry in popularizing the use, strictly as approved by the Registration Committee among farmers not only at the time of market development but also at the time of label expansion.
3. Website of the Registration Committee displaying registered pesticides and their approved uses may be updated regularly (within 30 days of the issue of the Certificate of Registration or letter of endorsement).
4. Every State Department of Agriculture may display their recommendations in conformity with approved uses of registered pesticides on its website, preferably in regional language for the convenience of users.
5. Training programmes may be initiated through National Institute of Plant Health Management (NIPHM) for sensitization of ICAR/SAU/State Government/Pesticide Industry functionaries on approved usage of pesticides.
6. Establish pesticide investigational labs in certain States to analyze adulterants/contaminants in bio-pesticides.

Table 1: Consumption of Chemical Pesticides in India

Year	Quantity in MT Tech. Grade
2014 – 2015	56,268
2015 – 2016	56,720
2016 – 2017	58,634
2017 – 2018	63,406
2018 – 2019	59,670
2019 - 2020	60,599

Table 2: List of banned pesticides: the government has shortlisted 27 insecticides for prohibition on 14 May, 2020.

S. No	Pesticides	Decision of Central government
1.	Acephate	Endocrine disruption in public domain, no report of resurgence could be traced in public domain, banned in 32 countries, toxic to honey bees etc.
2.	Atrazine	Incomplete bio-efficacy data submitted i.e. study on leaching, endocrine disruption in public domain, banned in 37 countries, toxic to aquatic organism including fish etc.
3.	Benfuracarb	Carcinogenic impurities, highly toxic via in- halatory exposure, reprotoxic effects observed in rat and rabbit, ground water contamination etc.
4.	Butachlor	Incomplete bio-efficacy studies submitted, prone for leaching, toxic to aquatic organism including fish etc.
5.	Captan	Endocrine disruptor, toxic to aquatic organism including fish etc.
6.	Carbendazim	Foetoxic and tetratogenic, it is a active component of Benomyl (already banned in country), toxic to pregnant women and presence of toxic impurities, resistance to many fungal sp. etc.
7.	Carbofuran	Extremely toxic, a red triangle pesticide belonging to class 1b, toxic to honey bees, aquatic organism and birds, its 50%

		formulation already been banned in country
8.	Chlorpyriphos	Product of organophosphate and is a neurotoxic and has been banned for household in USA and European Union, eco toxic, health hazard to children and infants etc.
9.	2,4-D	Conc. of dioxin content, as it is carcinogenic, etc.
10.	Deltamethrin	Comments for use in public health should be sought from national vector borne disease control programme (NVBDCP), Toxic to aquatic organism etc.
11.	Dicofol	Highly toxic to aquatic organism, contamination of DDT and its metabolites etc.
12.	Dimethoate	It is a organ phosphorus compound and is highly toxic etc.
13.	Dinocap	No bio-efficacy and residue data has been submitted by stakeholders, tetratogenic concerns with the product, toxic to aquatic organism etc.
14.	Diuron	The product falls under category 2 of European union prioritization of endocrine disrupting chemicals, toxic to aquatic organism etc.
15.	Malathion	Falls under Category 2 of European union prioritization of endocrine disrupting chemicals, eco toxic etc.
16.	Mancozeb	Level of Ethylene Thio Urea, (ETU) is a concern from toxicity point of view, toxic to aquatic organism etc.
17.	Methomyl	Extremely toxic a red triangle pesticide, toxic to honey bees, silk worms birds and aquatic organisms, Falls under category 2 of European union prioritization of endocrine disrupting chemicals etc.
18.	Monocrotophos	Also, extremely toxic red triangle pesticides, toxic to honey bees, silk worms birds and aquatic organisms, Falls under category 2 of European union prioritization of endocrine disrupting chemicals, banned in 112 countries etc.
19.	Oxyflurofen	Alteration in blood parameters causes anaemia haemolytic consequences and in liver, toxic to aquatic organism and carcinogen etc.
20.	Pendimethalin	Incomplete toxicity data submitted, causes thyroid follicular cell adenoma, toxic to aquatic organism etc.
21.	Quinalphos	High acute mammalian toxicity and is an organo phosphorus compound and highly toxic to aquatic organism etc.
22.	Sulfosulfuron	Development of resistance in the target weeds in Punjab, Haryana and Uttarakhand etc.
23.	Thiodicarb	Highly mammalian toxicity, Methomyl is a metabolite, toxic to aquatic organism and honey bees etc.
24.	Thiophanat emethyl	Carbendazim is an active component of Thiophanate Methyl and Benomyl, toxic to earthworm etc.
25.	Thiram	Metabolites M1 and NDMA is a concern, risk to birds, toxic to aquatic organism etc.
26.	Zineb	Falls under category 2 of European union prioritization of endocrine disrupting chemicals, Level of Ethyelene Thio Urea (ETU) is a concern from toxicity point of view, toxic to aquatic organism etc.
27.	Ziram	Also falls under category 2 of European union prioritization of endocrine disrupting chemicals, toxic to aquatic organism etc.

Table 3: Consumption of Bio Pesticides in India

Year	Quantity in MT Tech. Grade
2014 – 2015	4,855
2015 – 2016	5,834
2016 – 2017	6,802
2017 – 2018	6,710
2018 – 2019	6,772
2019 - 2020	7,345

Conclusions

- So far no plant levels available for protected cultivation in India.
- There is still no provision of registering the biocontrol agents in Indian.
- The microenvironment under protected cultivation is different than the open environment.
- Volatile compounds may behave different manner under protected cultivation.
- No pesticide/ GM plant should be prescribed without plant levels to avoid any legal complicacy.
- There is need to develop separate plant levels /biosafety regulatory measures for protected cultivation.

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