Article ID 240204042

Biopesticides Production and its Quality Assurance

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Biopesticides, defined by the US EPA, are a category of pest control agents derived from natural sources. These encompass three main types:

- Living Organisms: Natural enemies like predatory insects, nematodes, and beneficial microbes that directly target pests.
- Natural Products: Extracts from plants and insect pheromones that disrupt pest behaviour without directly killing them.
- Genetically Modified (GM) Plants: Plants engineered with added genes to resist pests or diseases. These are also known as Plant-Incorporated Protectants (PIPs).

Advantages of Using Biopesticides in Agriculture

Biopesticides are an important tool in sustainable agriculture. They help farmers to produce food safely and efficiently without harming environment.

There are many advantages in using biopesticides in agriculture. They are more selective than chemical pesticides, making them less likely to harm beneficial insects and other animals. They are also often more effective in the long run. Biopesticides are an important tool for farmers as they tend to break down more quickly in the environment and pose less risk to human health.

Keeping in view the enormous potential of biopesticides, it was felt necessary to know the practical ways to ensure quality assurance of biopesticides produced in our country. The overwhelming advantages of bio-pesticides are their high selectivity to target pests and safety to non-target and beneficial organisms. They are amenable to bio-intensive pest management and ideally suited for organic niche products including export-oriented commodities. They can also be tailored to IPM programmes for increased efficacy, higher yield and lower chemical load. They are renewable, sustainable, offer an improved impact profile, and reduce pesticide residues. In 2007 National Farmers Commission has strongly recommended the promotion of biopesticides for increasing agricultural production, sustaining the health of farmers and environment. It also included the clause that biopesticides would be treated at par with chemical pesticides in terms of support and promotion. Further research and development of biological pest control methods must be given priority and people in general and agriculturists in particular must be educated about the handling and use of such control measures (Ansari et al., 2012; Copping, 2009).

The first recorded registration of a microbial pesticide was in the USA in 1948. In India, interest on bio-pesticides begun sporadically with entomopathogenic fungi in 1910. The development of wide-spread insecticide resistance in cotton in 1980s led to revival of interest on baculoviruses (Mukhopadhyay, 1987). During last three decades, some noteworthy advancements have been made for effective management of pest and diseases using biopesticides (Mukhopadhyay, 1996). The State Agricultural Universities are also producing biopesticides themselves and are advising companies in production. The Krishi Vigyan Kendras are also engaged in the promotion of local production of microbial pesticides

Current Scenario

There are about 1400 biopesticide products being sold globally. The United States of America consumes maximum biopesticides (40%) of the global production followed by Europe and Oceanic Countries (20% each). Despite the promising impacts of biopesticides, the Indian biopesticide industry is growing at a very slow pace. In India, biopesticide production is currently dominated by antagonistic fungi and bacteria such as *Trichoderma* spp. and *Pseudomonas fluorescens*, but the production of nucleopolyhedrosis viruses (NPV), granuloviruses (GV), and entomopathogenic fungi are also established and expanding (Rabindra, 2005; Singh et al., 2012). In 2008, three larger private companies reported the following total production values: 187 metric tonnes (MT) of *Trichoderma harzianum*, 23 MT of *Trichoderma viride*, 15 MT of *Pseudomonas lecanii*, 28 MT of Beauveria bassiana, 30 MT of *Verticillium lecanii*, and 25 MT of *Metarhizium anisopliae*. As of early 2013, there were approximately 400 registered biopesticide active ingredients and over 1250 actively registered biopesticide products (Rabindra, 2005). In total, at least 410 biopesticide production units have been established in India, 130 in the private sector (Singhal,

2004). Botanicals In India, products based on four plants are registered under the Insecticides Act, 1968. These include pyrethrum (*Chrysanthemum* sp. ex. *cinerariaefolium*, coccinium etc.), neem (*Azadirachta indica* A.*Juss*), nicotine (*Nicotiana* sp., for export only) and citronella oil (*Cymbopogon nardus*). Among these, neem pesticides are of maximum current interest, being in maximum demand all over the world. Macrobials and Microbials Pesticidal organisms are applied by inundative or inoculative means. Macrobials include parasitoids and predators which are mass released and the microbials such as bacteria, fungi, nematodes, protozoa, viruses, etc. are applied directly or as formulated products. Key macrobials in use are exemplified by parasites such as Trichogramma and predators such as Coccinellids. Sex pheromones are available commercially for cotton bollworms, sugarcane borers, brinjal fruit / shoot borer, diamond back moth, rice yellow stem borer, rhinoceros beetle and red palm weevil. Out of total biopesticides used in our country, the genus *Trichoderma* alone occupies 60% of their market share. Recent reports on *Trichoderma* and its genome from different parts of the world including India have clearly demonstrated its role as "multifunctional fungal plant symbiont" to enhance plant growth, productivity and plant disease management (Harman, 2011; Mukherjee et al., 2013).

Constraints in Commercial Venture

Despite the progress in establishing a microbial insecticide supply, the scale of biopesticide use in India still remains relatively small in comparison to chemical pesticides. Awareness of microbial products amongst farmers is poor, despite active IPM promotion and training. Much of the current production is sold to government agencies for distribution to farmers in IPM programmes, but distribution system for biopesticides is underdeveloped in many areas (Rabindra, 2005). Constraints that limit commercial investment in developing new biopesticides are listed below:

(i) Many biopesticides have high levels of selectivity. Although, it is of great benefit in terms of not harming other natural enemies and wildlife, but it implies low profit potential.

(ii) Unlike conventional chemical pesticides which have a large cost-cutting market, the drive to adopt biopesticides by farmers will need higher initial investment.

(iii) For fruit and vegetable crops, consumers' acceptance is as important as yield when it comes to making a profit. Due to long period of use, farmers have achieved scale economies in pesticide use as a result of 'learning by doing' but with the limited practical experience with biopesticides, they are averse taking risk leading to low level of adoption

Innovative Approaches for Biopesticide Market

The current system for biopesticide development and regulation borrows heavily from the chemical pesticide model. This approach overlooks the unique advantages of biopesticides, such as their ability to persist, reproduce, and even promote plant growth. However, the chemical model offers valuable insights for improving biopesticide formulation, packaging, and application.

Microbial biopesticides, with their diverse mechanisms of action and poorly understood properties, require a flexible regulatory framework that incorporates expert judgment. This flexibility is crucial to account for the inherent "intra- and inter-specific variation of microorganisms and their constituents" (Mensink and Scheepmaker, 2007).

Despite having nearly 500 registered biopesticides in India, quality control remains a significant challenge. Strengthening registration procedures, licensing practices, sample collection methods, and law enforcement at the state level is essential for ensuring the quality and effectiveness of these products

- Over 1 lakh registration certificates exist (including biopesticides) with no re-verification mechanism.
- Over 1300 manufacturing licenses issued (including 500 for biopesticides) lack a system to verify active businesses.
- Market surveys confirm quality concerns, especially with new producers.

Concern About Spurious Biopesticides

Spurious biopesticides, essentially fake products with no real active ingredients, are a major concern in India. These are distinct from misbranded or substandard products. Despite regulations requiring monitoring and inspections, a lack of manpower allows manufacturers to exploit loopholes. This results in an estimated Rs. 500 crore annually loss to farmers using ineffective products (Mukhopadhyay, 1994).

Quality Assurance (QA)

Definition "The maintenance of a desired level of quality in a service or product, especially by means of attention to every stage of the process of delivery or production". "A planned and systematic pattern of all

the actions necessary to provide adequate confidence that a product will conform to established requirements. Most of the biochemical pesticides products suffer from photo-, thermo-, hydro- and (or) bio-lability resulting in their poor shelf and (or) field lives. Similarly, the organisms which are inundatively released in the fields need to acclimatize to environmental conditions. The purity of their nuclear cultures has to be ensured to minimize consumer risk. The purity and viability of BCAs must be assured irrespective of the method of rearing and multiplication either on their natural or substitute hosts or other artificial diets.

QA system must be robust in increasing variability in the rearing of natural enemies such as long-term storage of the host, sex ratio, culture maintenance during summer and winter, cannibalism, crises of contamination, high prey density, behavioural changes, loss of vigour, etc. and these criteria must find due accounting in the quality certification. Microbial consortia-based products are claimed for their multi-functional benefits (Jain et al., 2013). Such QA for such consortia needs careful calibration in terms of cultural methods and their microbial composition in the product cycle. In formulated forms, suppression of metabolism and provision of survival factors are important approaches for improving shelf life.

Pheromones are highly sensitive and sophisticated dependent as they are on their stereoisomeric purity. Quality and quality assurance statements must factor them in the product cycle, including their kinetics of release. Quality assurance statement on botanicals must ensure that the formulations are standard and stable products that comply with the shelf life requirement. Unlike a chemical pesticide mostly with a single active ingredient, botanical pesticides harbour a host of active ingredients making their analysis cumbersome and tedious more so in formulations. While making the QA certification, one must ensure that non-interference of auxiliaries in the analysis has been taken care of. A quality product to the maximum satisfaction of the consumers has to be watchword of any production system. Quality must, therefore, be ensured at all costs (Parmar, 2010).

Awareness Creation

Most of the farmers in the country do not have sufficient and clear knowledge on the use of biopesticides. In order to educate farmers, educating and training extension workers is most important. This can be done through demonstration trials on the farmers' fields, as seeing is believing. An intensive publicity programme can be done through media like TV/ Radio, seminars, exhibitions and write ups in local newspapers. Proactive role needs to be played by the 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. Consumer awareness on the various aspects of biopesticides such as product quality, use, active ingredients, etc. through various government, non-government and private agencies needs to be created.

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