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Biopesticides for Integrated Crop Management: Environmental and Regulatory Aspects

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Introduction

To feed the ever-growing global population, we need to produce more food and livelihood opportunities from less per capita arable land and available water. Providing ample food is only the first part of challenge, the second and more important challenge is to produce this in a safe and sustainable manner [1]. Most of the cultivated crops/varieties have reached their yield plateau, hence protection of crops to harvest maximum is one of the ways to meet the increasing demands of food and to attain global food security on sustainable basis. There are about 67,000 pest species that damage agricultural crops, and a significant portion of agricultural inputs is required for pest management to protect the crop. Pesticides are extensively used in the intensive agriculture to control pests, diseases, weeds, and other crop enemies to reduce yield losses and maintain the product quality. Insect-pests management in high yielding varieties by extensive use of synthetic pesticides has certainly provided protection to crops; but it has also raised concerns about pesticide residues in the food and the environment [2]. This pest management strategy adversely affects even beneficial organisms, leave harmful residues in food, feed and fodder, and causes environmental pollutions. Human exposure to pesticides occurs primarily through contaminated food, feed and drinking water. Their adverse effects depend on toxicity of pesticides, method of application, the dosage applied, their adsorption on soil colloids, the weather conditions prevailing after their application, and how long the pesticides persist in the environment. Therefore, assessment of risks of pesticides either on human health or on the environment is not an easy and accurate process because of differences in the periods and levels of exposure, and the types of pesticides used. Hence, the need of the day is to produce maximum from the decreasing availability of natural resources without adversely affecting the environment.

Biopesticides and Integrated Crop Management

Biopesticides are formulations made from naturally occurring substances that control pests by non-toxic mechanisms and in an ecofriendly manner. They may be derived from animals, plants, micro-organisms and include living organisms, their products or byproducts which can be used for the pest management. Biopesticides are used primarily as preventive measures, so they may not perform as quickly as some synthetic chemical pesticides do. Biopesticides are generally less toxic than chemical pesticides, often target specific pests, have little or no residual effects hence pose less risks to human health, the environment and have acceptability for use in the organic farming. Biopesticides may be categorized into three major groups: plant-incorporated protectants (PIPs), biochemical, and microbial biopesticides. While microbial biopesticides use microorganisms (bacteria, fungi, viruses or protozoans) as active-ingredient, biochemical pesticides are naturally occurring substances from plants and animals. PIPs are produced naturally on genetic modification of a crop plant, such as Bt cotton. Such transgenic plant produces biodegradable protein with no harmful effect on animals and human beings, and thus curtails the use of hazardous pesticides. PIPs may be more effective and economical strategies in the developing countries to help produce more food, feed and forages in an environmentally safer manner [3].

Integrated Crop Management (ICM) is a pragmatic approach to crop production which includes Integrated Pest Management (IPM) focusing on crop protection. ICM is based on understanding the intricate balance between the environment and agriculture, and is a whole-farm approach in achieving a proper balance. Its basic components are crop management, nutrient management, pest management and ultimately financial management. One of the main objectives of ICM is reduction of external farm inputs, such as inorganic fertilizers, pesticides and fuel by means of farm produced substitutes. Although complete replacement of these inputs is not possible without significant loss of yields, but partial substitution of the inputs can be achieved by the use of natural resources. ICM assumes a broad palette of available disease and pest control methods, such as biological, cultural and physical controls, host plant resistance, and decision support tools. In recent decades, the focus on crop production has moved from yield to quality and safety, then more recently sustainability. ICM and IPM strategies combine a range of complementary methods to reduce pest populations below economic injury level while minimizing impacts on other components of the agro-ecosystem and environmental conditions of the area. While considering pest and disease management, the use of biological control methods is considered to complement physical and cultural methods. In ICM, synthetic pesticides are treated less as a blanket solution to crop protection and more as a tool to be used selectively in ways that complement other methods and thus minimize the chances of resistance development in pests. Evidences show that biopesticides can be valuable components of ICM for promoting sustainable agriculture. Biopesticides have gained lot of interest in the last decade particularly in view of the growing demands for organic foods.

Biopesticides and Environmental Issues

Although pesticides are developed through very strict regulatory processes to function with reasonable certainty and minimal impact on human health and the environment, increasing public concern about the potential adverse effects of synthetic agrochemicals prompts search for the technologies and products safer for the environment. Moreover, due to the problems of pesticide resistance and withdrawal of some pesticides for either regulatory or commercial reasons, a fewer chemical pesticides are available in the global market. Hence, ICM approach needs to be deployed to counteract degradation of the agro-ecosystem due to the ongoing intensive agriculture. This would include the use of

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biofertilizers, biopesticides, IPM, soil and water conservation practices, biodiversity conservation etc. [4].

A better understanding of genes from micro-organisms and crop plants has allowed isolating genes effective against particular pests, and they are being deployed to control insect pests and diseases of crop plants. Benefits of the use of biopesticides in agriculture and public health programs are considerable. They do not have residual effects which is a matter of significant concern for consumers, particularly in case of fruits and vegetables. When used as a component of IPM, efficacy of biopesticides can be equal to the conventional pesticides. Interest in biopesticide is gaining because of its advantages associated with environmental safety, target-specificity and efficacy in very small quantity, natural decomposition and suitability in IPM. Thus, biopesticides are one of the promising alternatives to manage environmental pollutions. They can replace some of the hazardous chemical pesticides. Though potential of biopesticide for promoting sustainable agriculture has been known for years, it has gained interest in view of the growing demands for safe and healthy organic food. Although use of agrochemicals is indispensable to meet the ever growing demands of food, feed and fodder, opportunities do exist in selected crops and niche areas where biopesticides can be used as a component of IPM. Increasing demands for residue-free crop produce, growing organic food market and easier registration than chemical pesticides are some of the key drivers of the biopesticide market.

There are rising concerns for conservation of biodiversity and threats to some of the endangered species, set against the requirement to increase agricultural production without excessive reliance on chemical pesticides. Development of biopesticides has largely followed a chemical pesticide model that does not exploit fully the favorable biological properties of the biological agents. While there is commercial pressure from the manufacturing side to develop products, based on a single strain that are broad spectrum in order to control a range of pests on different crops and may not be endemic to the areas of application; the environmentalists want narrow spectrum products based on strains from the area of use. To reconcile these divergent demands, biopesticides in the market have been maintained at minimal negative impact, if any, on the environment.

Biopesticides for Organic Farming

Organic produce perhaps does not mean to be pesticide-free or chemical-free. In fact, under the laws of many countries, organic farmers are allowed to use a wide variety of biochemical sprays and powders on the crop. If pesticide is to be used in the organic farming, it must be derived from natural sources and must not be synthetic chemical in nature. It is also important that the biopesticides must be applied using equipment that has not been used to apply any synthetic chemicals and the land used must not had any treatment with synthetic chemicals in the past three years. Primarily different agricultural practices, such as crop rotation, cover crops, disease resistant varieties and good seed bed preparation etc. are used to control pests and diseases in organic farming. However, these practices are not always sufficient to protect crops from losses. Hence, organic farmers turn towards biopesticides to ensure and enhance quality of their organic products. The biopesticides that can be used by organic farmers include microbial and biochemical pesticides only.

Biopesticides represent just 1% of the global market for agrochemicals. Ninety per cent of the microbial biopesticides are derived from just one entomopathogenic bacterium, *Bacillus thuringiensis*. As of early 2013 there were approximately 400 registered biopesticide active ingredients, and more than 1250 registered biopesticide products [5]. Data on microbial biopesticide agents from Agriculture and Agri-Food Canada and the US Environmental Protection Agency (EPA) indicates that more than 200 products are being sold in the US, compared to only 60 comparable products in the EU. There are several reasons why adoption of biopesticides has been higher in the US than elsewhere. US has a separate Biopesticides and Pollution Prevention Division which promotes the use of biopesticides as components of IPM programs and coordinates the Pesticide Environmental Stewardship Program. This voluntary program forms partnerships with pesticide users in order to reduce the potential environmental hazards and health risks associated with pesticide usage and implements pollution prevention strategies. EPA tests biopesticides for safety but not for efficacy, as efficacy testing may result in higher cost of biopesticides than chemical pesticides [5].

Biopesticides and Policy Issues

Recognizing the ill effects of chemical pesticides such as pesticide resistance, pest resurgence, outbreak of secondary pests, pesticide residues in the produce, soil, air and water resulting in human health hazards and ecological imbalances, most of the countries have amended their policies to minimize the use of chemical pesticides and promote the use of biopesticides. However, biopesticides are still largely regulated by the system originally designed for chemical pesticides. This has created market entry barriers by imposing burdensome costs on the biopesticide industry. Though for effective utilization of biopesticides several technological and policy gaps have been identified, they need to be addressed properly. Policy measures need to be strengthened in order to reduce excessive use of chemical pesticides and to promote the use of biopesticides. In addition, there are certain technical difficulties in making biopesticides more applicable. Inconsistency in efficacy of biopesticides, degree of stringency of regulation, quality control, scientifically sound use packages, and well defined role in IPM are some of the aspects which need consideration and improvement.

The challenge is to develop a regulatory system able to balance the broadly defined costs and benefits of biopesticides compared with synthetic pesticides. In the European Union, a greater emphasis on IPM as part of agricultural policy has led to innovations in the way that biopesticides are regulated [6]. In fact biopesticides have potential role in IPM, and by combining ecological science and post-genomics technologies there are possibilities to improve biopesticides efficacy. The newer biopesticides may bring with them new regulatory and economic challenges that must be addressed jointly by social and natural scientists, policy makers and the industry. Given that existing factors in the policy network are primarily orientated towards chemical solutions, how can change be brought about?

Policy network theory extensively used in the analysis of agricultural policy suggests that networks are good at managing incremental change, but tend only to innovate in conditions of crisis or exogenous shock. One of the major obstacles in promoting biopesticides as alternative to chemical pesticides is that biopesticides are hampered by their lack of profile which reflects the weakness of the supporting policy network. Lack of integration in the network in terms of form, quality and frequency of interaction may be a key factor. Relative immaturity of the policy network, limited resources and capabilities, and lack of trust between regulators and producers are some of the serious problems. Lack of resources impact the way in which issues are framed. Even the Committee for Environment, Public Health and Food Safety of the European Parliament referred organic farming, crop rotation and GMOs as alternatives to the chemical pesticides. Better understanding

of the mode of action of biopesticides, their effects and regulatory issues that arise in their adoption may help further to raise their profile among the public, policy-makers and hence enable them to realize their contributions to sustainability.

It is also believed that biopesticides may be less vulnerable to genetic variations in plant populations that cause problems related to pesticide resistance. Mostly their use is not overly complicated, however application of some biopesticides may require training and knowledge of pests/pathogens against which they can be used successfully. As with any pesticide, proper timing of application is essential to ensure efficacy of biopesticides. Biological pesticides are expected to provide predictable performance, and they must do so in an economically viable manner for their better acceptability and adaptability. To be readily acceptable by the end users, biopesticides must be efficient in controlling the targeted pests. Deployed appropriately, biopesticides have potential to bring sustainability to global agriculture for food security. However, training on production and quality control to manufacturers, and organizational training to extension workers and farmers to popularize biopesticides may be essential for better adoption of the technology. As environmental safety is a global concern, we need to create awareness among the farmers, manufacturers, government agencies, policy makers and the common men to switch-over to biopesticides for pest management requirements.

The Journal of Biofertilizers and Biopesticides, an open access international peer-reviewed journal, is playing important role in dissemination of the acquired knowledge on biofertilizers and biopesticides, among the researchers, policy makers and the end users. The efforts made by the OMICS Publishing Group towards publication of open access journals and organizing international conferences on such pertinent issues generate awareness among the researchers, farmers, environmentalists, policy makers and the general public.

The views expressed herein are those of the authors only. It may not necessarily be the views of the institution/organization the authors are associated with.

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