Journal of Biofertilizers & Biopesticides
ISSN: 2155-6202

Brar et al., J Biofert Biopest 2012, 3:3
DOI: 10.4172/2155-6202.1000e103

Editorial Open Access

Biopesticides - Road to Agricultural Recovery

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The dawn of human civilization came with the need of producing and safe guarding food for sustaining current and future generation. The growth and development in living standards came with incessant changes in agriculture often based on novel introductions, ethical beliefs and the end users preferences. Agricultural intensification became a matter of concern in order to support the growing population and ensuring the per capita availability of food grains. Losses due to insects and pests are often hampering the agricultural production. Insect pests are a major constraint on production of many crops worldwide. Traditional reliance on agro-chemicals from decades has led to environmental pollution, toxicity, bio-magnification and the development of resistance. Hence several chemical pesticides, such as organochlorine and methyl bromide have been phased out. Increasing number of pesticide and fungicide resistant strains has become a matter of serious concern. The global consent to alleviate the use of chemical pesticides is gaining substantial importance in the perspective of the development of novel, benevolent, and sustainable crop protection strategies, such as the use of biopesticides.

One of the most insurgent contributions of science to the plant disease management is the development of Bacillus thuringiensis (Bt) based biopesticides and thereafter transgenic Bt crops. The growth and development of Bt based biopesticides in the past and future has covered an extensive area of research from dual culture to spacious arena of omics i.e., molecule to functional genomics. The genomic constitution of Bt conveys enthralling properties, such as an array of entomotoxin active against diverse insects against root dwelling pests, or larvae that after hatching rapidly burrow or bore into plant tissues. More to the point, the crops are frequently affected by different pests that are unable to be controlled by a Bt product alone. Bt crystal proteins are UV sensitive and degrade rapidly thereby losing their activity. Therefore, several applications are required through the entire growing season that invariably increases the cost of application. Technological advancements have led to the development of advanced Bt formulations that are more adaptive to harsh environmental conditions.

In our efforts to minimize the damage caused by insect pests, we have to acknowledge that pests cannot be efficiently managed by utilizing a single pest control agent. Several studies have shown that pest resistance to chemical pesticide and more recently to Bt has increased requiring new techniques to be applied to reduce the impacts of pests on crop production. While commonalities regarding the development of resistance to chemical and biological control agents remain to be determined, research suggests that both biochemical and genetic factors can contribute to this resistance. In the present context, the biopesticides have gained importance meticulously in permutation with Integrated Pest Management (IPM). It is therefore crucial to continue examining the potential of IPM to reduce the threat of pests on agro-ecosystems.

IPM is a technical and systematic concept which is now of inclusive implications. Elementary meaning of IPM is designing and implementing pest management practices while fulfilling the basic goals of farmers, consumers as well the governments in minimising the losses due to pests. It also curtails the risk of environmental pollution, human health hazards, whilst improving the agricultural sustainability. However, the philosophy of IPM is now widely acknowledged in the political as well as scientific community. Biopesticides as a key component of IPM has the potential to lessen the use of conventional pesticides to a great extent while improving the crop yields.

The key success of biopesticides lies in its impact on the target pest, market size, and variability of field performance, cost effectiveness, and end-user feedback. Technological challenges such as, fermentation, formulation development and efficient delivery system also affects the success of any biopesticide. In spite of the fact that Bt biopesticides have undergone extensive research, several formulations do not deliver effectively under field conditions. Integrated approach, i.e., the development of biopesticides that also supports sustainable agriculture can further strengthen its role in plant disease management. Adapting cost-effective fermentations, using conventional and simple adjuvants/additives, and efficient harvesting processes might lead to the development of high potent efficacious formulations that are also widely accepted. Activity spectrum, persistence, recycling and cost-effective formulation development needs to be addressed in order to establish the biopesticides in an international market particularly for the farming community. Recently, the concept and theories for using wastewater, wastewater sludge and other agro-wastes as a potential cost-effective technique for Bt formulations have become widely accepted and extensive research has been carried out in the past decade.

The emerging era of insect-resistant transgenic Bt crops also offers real prospects to provide a foundation for more sustainable, economically acceptable IPM with the integration of a range of non-chemical tactics and much less reliance on pesticides. Introduction of Bt transgenics for the last one and half decade, opened spectacular approach of introducing host plant resistance with magnificent socio-economic gain. With the increase in the search of crop species expressing different cry genes, the first generation of insect-resistant transgenic Bt crops will most likely increase. Nonetheless, pests tend to modulate their level of resistance either by loss or gain of functional approach and remain tolerant of the available Bt toxins. Transgenic plants expressing Bt toxins were among the foremost plant biotechnology products approved for commercial purpose. Nevertheless, it was implicated that Bt toxin might affect non-target organisms, such as predators or parasites and may lead to develop resistance owing to high selection pressure.

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Received May 13, 2012; **Accepted** May 15, 2012; **Published** May 17, 2012

Citation: Brar SK, Kaur S, Dhillon GS, Verma M (2012) Biopesticides - Road to Agricultural Recovery. J Biofert Biopest 3:e103. doi:10.4172/2155-6202.1000e103

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RNAi (post-transcriptional control mechanism) in the form of transgenic plants or a crop spray has a robust and selective effect on target gene expression that makes it a valuable tool for manipulating metabolic pathways to address above mentioned problems. The level of RNA silencing produced is considerably affected by constructing a suitable vector/expression system and delivery method. Vectors containing inverted repeats separated by an intron produce double-stranded RNA (dsRNA) or hairpin RNA (hpRNA) which effectively inhibits homologous gene expression at the RNA level. The specificity is sequence based and depends on the sequence of one strand of the dsRNA analogous to part or all of a specific gene transcript [1]. Fabricating dsRNA in RNAase III deficient E. coli strains and treating the plant with the extracted product as an alternative to RNAi transgenic plants has recently been accomplished [3]. Point to be emphasised here is that RNAi is a knockdown instead of knockout effect that suggests that total silencing does not takes place and the effect could be frequently ephemeral [2]. Although, it should not be an insuperable drawback to use this technique as under many circumstances yet, partial silencing of certain genes might result in irreversible negative and lethal effect on the insect.

Even though it is implausible that RNAi have an instantaneous effect on crop protection against lepidopteran and coleopteran pests, however Bt-based strategies propose a high degree of protection. The technology finds an appropriate place where Bt-based approaches is difficult to achieve such as, in the case of dipterans (flies) or where no effective Bt toxins are known, example sap-sucking homopteran pests (aphids, leafhoppers and whitefly). In order to target these phloem-feeding insect pests, in planta expression and transportation of dsRNAs in the phloem sieve elements is the primary requirement. Similar to any other control methods, risk assessment will be required to determine whether transgenic crops or RNAi technology as a form of pest control will be safe and probably create a new era in pest control. Therefore, an extensive research is required to introduce a feasible technology that is also readily acceptable and available to the entire farming community for plant disease management. At the same time, it should be cost-effective and self-sustainable to fit the changing trends of agro-ecological systems. Although there is an enormous possibility to control many pests, in agriculture and forestry through Bt based technologies, there is still some research required in terms that inculcates their efficiency across the globe under diverse agro-climatic and ecological conditions. It needs the inputs from the entire scientific community through the farming community, stake holders, and extension development officers, to share and exchange their paragon together on one platform. Therefore, it is necessary to disseminate the knowledge of pest management in an eco-friendly manner to the end users by propagating biopesticides which will bestow a sustainable future for the agriculture.

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