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BIOPESTICIDES: AN ALTERNATIVE TOOL FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

Indiscriminate and regular use of chemical pesticides has resulted in some undesirable effects on the environment and the overall sustainability of the environmental system. Due to the unbiodegradable nature of their constituent compounds, synthetic themselves chemical pesticides have severely affected both the biotic and abiotic components of the environment. They bio magnify themselves through food chain, causing serious health problems in human beings and other animals. Indiscriminate use of chemical pesticides also leads to development of resistant plant pathogen strains. There is an urgent need to adopt ecofriendly practices for safe and sustainable environment and protecting human health by reducing the use of toxic chemical pesticides. Ecofriendly approaches for sustainable agriculture are being practiced all over the world. Biopesticides are promising alternatives to chemical pesticides. Biopesticides are products and by-products of naturally occurring substances such as insects, nematodes, microorganisms as well as plants. Due to the high components of bioactive compounds and antimicrobial agents, microorganisms are the major sources of biopesticides. When applied in the right regimes, concentrations and appropriate frequencies, these biopesticides perform better than synthetic pesticides. Biopesticides controls pests by non-toxic mechanisms and in ecofriendly manner. Biopesticides are target specific, quickly decomposable and have little or no residual effects. They perform efficaciously with the flexibility of minimum application restrictions, and superior resistance management potential. Despite the many challenges facing the adoption of bio-based pesticides via integrated pest management (IPM), they still remain suitable alternatives to conventional pesticides. There are also studies on effectiveness of biopesticides under controlled environments and field conditions with varying results.

KEYWORDS: *Biopesticides, Chemical Pesticides, Sustainable Development, Integrated Pest Management (IPM).*

INTRODUCTION

Our global population is increasing at an exponential rate. A growing population will exacerbate climate change effects and further stress of food insecurity [1,2]. Climate change reduces agricultural yields and the nutritional value of staple crops, and it increases the prevalence and spread of diseases and environmental unsustainability. Providing ample food for the ever-growing global population is a challenge. But more important part is to produce this in a safe and sustainable manner. However Intensive agriculture provides sufficient food grains but current pest management strategy relies heavily on synthetic chemical pesticides. Chemical pesticides adversely affect beneficial organisms, leave harmful residues in food and cause environmental pollution, resulted in several undesirable effects on the environment, and the overall sustainability of the environment. Hence, the need of the day is to produce maximum from the decreasing availability of natural resources, without adversely affecting the environment [3]. The increased public concerns about the potentially adverse environmental effects associated with the use of synthetic pesticides, prompted search for the technologies and products based on biological processes to control the pests. Biopesticides are used to control agricultural pests and pathogens [4,5]. Synthetic pesticide-free agriculture is a demand of time, which can be a reality by the use and implementation of biopesticides-driven IPM. This can create a socially acceptable connection between agricultural food economic viability and environmental sustainability [6].

BIOPESTICIDES

Biopesticides are potential alternatives to synthetic pesticides. Biopesticides control pests through non-toxic mechanisms. They work in an eco-friendly manner. Hence, biopesticidesimposeless threat to the environment. Biopesticides are generally made from natural substances[7]. According to United Nations Food and Agriculture Organization standards, biopesticides are naturally occurring agents. Biopesticides include living organisms (natural enemies). They include animals such as insectsand nematodes[8], as well as plants such as Chrysanthemum, Azadirachta[9].Some microalgae (Chlamydopodiumfusiforme and Chlorella vulgaris) and cyanobacterial sources (Nostocpiscinale) produce biologically active antimicrobial compounds[10]. They have potential to act as biopesticides. Plants obtained Insecticidal proteins such as lectins and arcelinsare potentially active and a good approach for the production of insect resistant transgenic crop. Similarly hormones, insect growth regulators and pheromones are generally used as biopesticides[11]. Commercially, major sources of biopesticides are microorganisms such as bacteria and fungi. Sometimes genetically modified agents act as biopesticides[12].

MOLECULAR MECHANISMS AND MODE OF ACTION OF BIOPESTICIDES

Depending on their type and chemical nature, biopesticides act in a variety of ways on enemies. Biopesticides attack or kill pathogens through specific mechanisms[13].Nicotine like insecticides functions by binding to acetylcholine receptors at nerve synapses. It is a major neurotransmitter. These binding causes impair normal nerve impulse activity resulting in failure of normal body functioning[14]. While Azadirachta like natural pesticides work either blocking the release of molting hormone (ecdysteroids) from the prothoracic gland or act as growth regulator by disrupting the mechanism of chitin synthesis. Sometimes they inhibit insect growth regulator and thus help to combat against infections. Some microbicides impair metabolic function. They generally disrupt the integrity of plasma membrane and thus inhibit the conidial formation.

The bactericides inhibit the process of protein synthesis, especially translation. They disrupt translation in numerous ways. In prokaryotes they bind to 50S ribosomal subunit and prevent peptide transfer mechanism. Further chain elongation process is blocked (such as blasticidin)[15]. In another mechanism of translation, 30S and 70S ribosomal subunit complexes are affected. Bactericides such as kasugamycin inhibit translation through interfere with the Binding of aminoacyltRNA to 30S and 70S subunits[16]. Sometimes they block the activity of peptidyltransferase. Some microbial biopesticides such as natamycin disrupt permeability of plasma membrane. As permeability disrupted, it cause leakage of substances such as amino acids and electrolytes and ultimately causes cell death. Similarlypolyoxins inhibit chitin synthase activityand polymyxins B disrupt the outer membrane of gram negative bacteria by displacing calcium and magnesium cations of the outer membrane resulting in cell death due to leakage of cell substances.

Some insecticides like avermectins and emamectin upon reaching nerve endings, release gamma-aminobutyric acid (GABA)[17,18]. This event causes GABA-gated Cl-ion channels to open. Hyperpolarization of nerve membrane potential occurs and it blocks the electrical nerve conduction. Similarly leakage of potassium ions from mitochondria may occur by the action of polynactins. Some herbicides like bilanafos work on the same pattern and inhibit the activity of glutamine synthase [19]. Inhibition of this enzyme resulting in buildup of ammonia and ultimately kill the plant due to impair photosynthesis. .

Bacterium B. thuringiensisact as GMO-based biopesticide. It produce delta endotoxins (Bt toxin). Whenever these endotoxins reached in the gut of insect, toxins are broken down into smaller toxins by the action of proteases[20]. Later in the midgut these bind to receptors. On binding with receptors, smaller toxins cause cell expansion. Later rupturing of cells get occurred and ion leakage start which ultimately lead to cell death.

Transgenes had a significant impact on plants against viral infection through an RNAi mechanism. Due to its increased sensitivity towards pests and pathogens, biopesticides are produced through this RNA interference technology (RNAi)[21]. RNAimechanism includes the expression of transgene dsRNA. Expressed gene induces virus resistance in plants. In a parallel mechanism it induces gene silencing. As intermediates Guide RNAs are formed. Guide RNAs are around 25 nt long. They guide target RNAs for their degradation. Small interfering RNA (siRNA) having silencing potential is formed from dsRNA of target transcripts (target RNAs) in plants[22]. RNA-dependent RNA polymerase RDR6 plays a significant role to degrade double-stranded RNA (dsRNA) of target transcripts. The enzyme responsible for degradation of dsRNA lies in RNase III domain. This domain is referred as Dicer. Now RNA-induced silencing complex (RISC) is recruited. Degradation of target transcript mediated byRISC[23].When dsRNA is completely degraded to siRNA, silencing potential developed, thus conferring resistance to the host.

To overcome the ill effects of pests and pathogens RNAi technology being proved a promising tool. Recently, RNAi technology is highly developed for oral application. In oral application artificial diet is being preferred. Recent investigations and researches proved the importance of this technology. Recently in 2017, a commercial variety SmartStax PRO maize was developed. This Smart Stax PRO maize is a genetically modified variety. This variety shows the expression of dsRNA against Snf7 gene of an insect pest western corn rootworm[24]. RNAi-mediated silencing mechanism is used now to control a number of plant pests and pathogens.

Microalgae Chlorella vulgaris is able to tolerate ammonium levels effectively in wastewater. Antibacterial activity of Chlorella vulgaris against several phytopathogens in wastewater such as Xanthomonascampestris, Rhizoctoniasolani[25], and Pseudomonas syringae has been proved to be effective.

ADVANTAGES OF USING BIOPESTICIDES

Based on natural products or living microorganisms, biopesticides are good pest management agents. Biopesticides are effective in very small amounts. Biopesticides control yield loss and do not compromise with the quality of the product. Generally biopesticides are quickly decomposable. They have very little residual effects. Comparing to synthetic pesticides, biopesticides are inherently less toxic. They are target specific and generally affect only the target pest. Biopesticides are not deleterious to non target organisms. Biopesticides are generally used to control agricultural pests and pathogens. Crop damage can be preventing by the use of genes or metabolites from these biocontrol agents. Biopesticides are pollution free. The pollution problems that are caused by the use of conventional pesticides can be completely avoided by biopesticides. Biopesticides work in an eco-friendly manner so maintain environmental sustainability[26]. Hence biopesticides showed enough potential to replace synthetic pesticides for pest management programs and so can be efficiently used in sustainable agricultural practices. At present biopesticides are used as a very important integral component of IPM programs. On the account of this fact, use of biopesticides is gaining momentum now a day.

DOWNSIDES OF BIOPESTICIDES

Despite the usefulness, biopesticides have not been used as widespread level as expected. A number of reasons may be behind the fact.

- Biopesticides are of high specificity. Biopesticides are effective only against target pests and pathogens. Generally farmers are not interested to use biopesticides[27].
- Biopesticides are costly and cumbersome. They are not available for every pest or pathogen.
- Biopesticides have limited field efficacy. It is due to the regional variations climatic variations in soil conditions, soil types, humidity and temperature etc. That is they have greater susceptibility towards the adverse environmental conditions.
- Biopesticides are sensitivity towards the fluctuations in humidity and temperature. Due to this sensitiveness they have short shelf life.
- To use them effectively, high level of knowledge be required by the grower.
- Biopesticides have high cost of production and shorter persistence.

CHALLENGING TASK AND MANAGEMENT

A mandatory system of regulations was originally developed for synthetic pesticides. This system also regulates biopesticides industry. This system imposes burdensome costs on the biopesticide industry and creates a market entry barrier. Although share of biopesticides to the global market is less than synthetic pesticides yet biopesticides market is expected to grow a CAGR of 15.1% during the forecast period (2022-2027)[28]. Therefore in order to promote the use of biopesticides, the policy measures must be strengthened[29]. However, biopesticide application is not complicated but to make biopesticides more effective and applicable, some technical difficulties should be removed. To apply successfully, there may require training and knowledge programs about pests and pathogens. By comparing with chemical pesticides, an important challenging task is to develop a balance between the costs and benefits of biopesticides. Another challenging task is in promoting the biopesticides as it lack the profile. This showed a condition of weak policy network. Relative policy network is immature[30]. There is a lack of trust between producers and regulators. Some other serious issues include limited resources and capabilities. To raise the profile between the public and policy-makers, a better understanding of regulatory issues and mode of action of biopesticides and their effects should be employed[31].

CONCLUSIONS

Regarding present scenario of the world, environmental safety is a global issue. Farmers and society are regularly and consciously leaning towards safety rather than yield. Biopesticides also have acceptability for use in integrated pest management. Biopesticides have tremendous potential in ensuring environmental sustainability. There should create more awareness among the common farmers to adoption and employ mentation of biopesticides. There is a need to enhance the market size of biopesticides and accessibility of biopesticides to the local farmers in order to reduce the use of chemical pesticides.

To protect the crop plants and other farms from invading and infecting pests, our agricultural sector can be greatly improved by employing biopesticides. In order to develop safe and sustainable agriculture new technologies like RNAi based technology has been proved effective and a good alternative to chemical based control methods. This is a need of present world to work on new and reliable technologies for an ecofriendly sustainable environment.

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