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REVIEW

Biocontrol of pathogens using a Sustainable Tool: Opportunities and Challenges

Biocontrol de patógenos mediante una herramienta sostenible: Oportunidades y retos

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ABSTRACT

Sustainable agricultural methods are essential to achieving the objective of ending world hunger because of the expanding global population. The agricultural sector is very concerned about both the Modern Environmental Health Hazards (MEHHs) which were troubles to Public Health (PH) caused by insect repellent experience, residue, with the rise in insecticide resistance. Today's farming methods rely on microbial bio-stimulants, which are safer and more productive than synthetic agrochemicals. In this respect, using microorganisms for BioControl (BC) that may stifle insects and phytopathogens is one of the most crucial methods for sustainable agriculture. Understanding these bacteria's role in promoting development as well as the management of the illness is essential since they are being used in the field as biopesticides or biofertilizers, with varied degrees of efficiency. For plant and insect pathogen analysis, we have used Biocontrol analysis. Through the use of advantageous microbes, substances, or healthy cropping practices, BC inhibits plant diseases, boosts plant immunity, and/or modifies the environment.

Keywords: Entomopathogenic Microorganism; Induced Systemic Response (ISR); Pest; Bio-Control Agents (BCA).

RESUMEN

Los métodos agrícolas sostenibles son esenciales para lograr el objetivo de acabar con el hambre en el mundo debido al aumento de la población mundial. El sector agrícola está muy preocupado tanto por los Peligros Modernos para la Salud Medioambiental (PAMS), que eran problemas para la Salud Pública (SP) causados por la experiencia de los repelentes de insectos, como por los residuos, con el aumento de la resistencia a los insecticidas. Los métodos agrícolas actuales se basan en bioestimulantes microbianos, más seguros y productivos que los agroquímicos sintéticos. En este sentido, el uso de microorganismos para el biocontrol (BC) que pueden ahogar a los insectos y fitopatógenos es uno de los métodos más cruciales para la agricultura sostenible. Entender el papel de estas bacterias en la promoción del desarrollo, así como la gestión de la enfermedad es esencial, ya que se están utilizando en el campo como biopesticidas o biofertilizantes, con diversos grados de eficiencia. Para el análisis de patógenos de plantas e insectos, hemos recurrido al análisis de Biocontrol. Mediante el uso de microbios ventajosos, sustancias o prácticas de cultivo saludables, el BC inhibe las enfermedades de las plantas, aumenta su inmunidad y/o modifica el medio ambiente.

Palabras Clave: Microorganismo Entomopatógeno; Respuesta Sistémica Inducida (ISR); Plaga; Agentes De Biocontrol (BCA).

INTRODUCTION

Modern agriculture is always changing and growing. New biotechnologies and agricultural practices are now being developed in response to the massive use of chemical pesticides and fertilizers in the 20th century, which enabled a significant rise in production. How to boost food production, particularly that which comes from plants, while conserving the environment is one of the key concerns in this context.[1] Biological control is an ecological and sustainable technique to maintain parasite numbers at a level that doesn't affect the ecosystem while bringing parasite populations down to an acceptable level, usually with the aid of hostile animals or natural living enemies. The main nematode adversaries in soil include several species, including microorganisms, toadstool, viruses, tardigrades, insects, mites, and nematodes that prey on other nematodes. These organisms include plant infections and pests. The prospect of recognizing and comprehending the many natural enemies of plant infections and pests opens up with the application of modern molecular and omic tools.[2] The phytopathogen clearance mechanisms used by the BC enzymes, it helps plants develop and survive. Pesticide opponents' manipulation and the environmental harm caused by improper agrochemical usage have resulted in significant changes in the public's perception of pesticide use in agriculture.[3] The potential future of microbial insect control, the creation of microbial insecticides, and the use of microbial control, which has seen both triumphs and failures were all discussed. According to the definitions, entomopathogens are used in all three forms of BC such as classical, conservational, and augmentative.[4] Figure 1 showed a schematic illustration of the infections that affect insects.

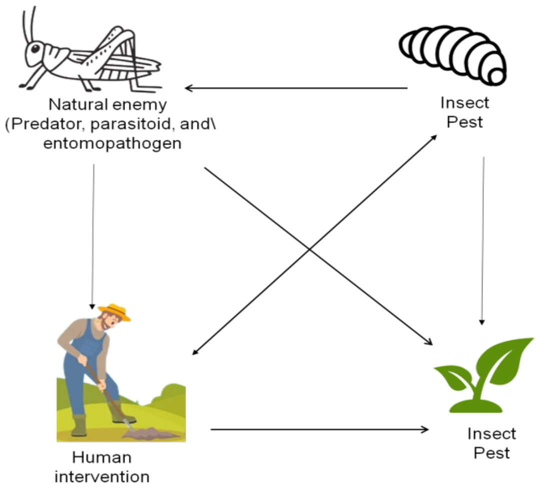

Figure 1. Schematic Representation of Insects Pathogens

Innovative sustainable farming techniques have emerged over the last ten years to enhance pest control, low energy consumption, as well as environmental and human safety. For instance, we have used Entomopathogenic Nematodes (EPNs) and Plant Growth-Promoting Rhizobacteria (PGPR). In addition to cultivating disease "Induced Systemic Resistance (ISR)", beneficial microbes may shield plants from pests and increase their ability to withstand abiotic stress. Plants may react to a variety of diseases with hormonal and metabolic changes without losing their fitness by recognizing the existence and activity of PGPR in the roots.[5] One of the few possibilities with promise may be the use of beneficial BC bacteria. These may assist the environment by battling diseases or actively opposing them, such as by producing antimicrobial chemicals. The capacity of helpful non-pathogenic rhizobacteria to prepare plants for Induced Systemic Resistance (ISR) against pathogens is also of important interest. Infection with a local plant pathogen might lead to systemic acquired resistance. Plants are more prepared thanks to this priming, which enables them to react to pathogen assault more quickly and powerfully.[6] Industry insiders believe that reduced crop protection methods might cause a drop in the world's food supply, which could result in famines in already fragile nations. In light of all of these factors, it is evident that using synthetic pesticides to control pests enables adequate production at a lower cost to please the market and the client. However, usage of these substances may have negative consequences on the environment's balance, non-target beneficial arachnids, insect pest resistance, bioaccumulation of toxic residues, tainted food, general environmental difficulties, and public health issues.[7]

Mantzoukas et al.[8] describes the BC capability of many EPFs, which may be exploited to develop fresh Integrated Pest Management (IPM) strategies. Maluta et al.[9] identifies the impacts of the entomopathogenic fungus Cordyceps fumosorosea on D. citri's probing behavior at various times after the fungus was sprayed on the insect. Aguilar-Marcelino et al.[10] provides an in-depth investigation of the prospective use of genetic techniques for biotech instruments that are helpful microorganisms for the treatment of plant diseases and pests. Sehrawat et al.[11] discusses the fluorescent insecticidal toxins, HCN, and biosynthetic regulation of antibiotics, by the conserved global regulatory GacS/GacA system, as well as prospective strategies to enhance cyanogenesis for better pest management. Peng et al.[12] discusses the most important advances of Plant-Pathogenic Fungi (PPF), as well as their pathogenic elements like "cell wall-degrading enzymes, toxins, growth regulators, effector proteins, and fungal viruses", with their benefits of Bio-Control Agents (BCA) and also used for weed, plant pesticides, and disease. Görg et al.[13] studies the "pathogenicity of Pandora sp. against the insect families Psyllidae , Triozidae's Cacopsylla pyri L., Cacopsylla pyricola, Cacopsylla picta, Cacopsylla pruni, and Cacopsylla peregrina species". Saha et al.[14] proposes a model to examine the impact of wild plant species on biologically based pest control strategies. Eads et al.[15] discusses the fungi's life cycles, flea virulence, commercial production, field use, ecological and safety factors, as well as their production and field use. Bamisile et al.[16] suggests that fungal endophytes might be used as an alternative to inorganic fertilizers to benefit crops. Branine et al.[17] summarizes the current knowledge on the ecology, evolution, mechanisms of insect and plant colonization of endophytic insect-pathogenic fungi (EIPF). They also discuss EIPF's practical applicability and provide ideas for other research fields. Elnahal et al.[18] employs microbial agents as biofertilizers, biopesticides, nano-biofertilizers, and NPS-biopesticides in agriculture has the potential to increase plant production and promote sustainable farming. Triterpene glycosides known as plant-derived saponins are produced by plant varieties from the families Leguminosae, Alliaceae, Asteraceae, Polygalaceae, and Agavaceae in their top as well as root tissues. Additionally, the biocidal effects of saponins and saponin-rich plant materials on phytoparasites and soilborne plant diseases have been documented.[19] The potential for using resistant cultivars, fungicides, or bactericides in addition to Bacillus-based BCAs, other BCAs, and bactericides or fungicides will be investigated in.[20] Pandit et al.[21] emphasizes diverse techniques for controlling plant diseases, kinds of plant pathogens, their modes of operation, and different BC strategies using a variety of microbes and their byproducts. Prashar et al.[22] covered biological plant pathogen management as a substitute for chemical control techniques, various BC products' market share has increased noticeably by 80 % in the last five years, according to the present market situation. Antibiotic production, intense competition for resources and niches in the rhizosphere, parasitism of the pathogen, and ultimately the development of systemic resistance in plants against diseases are examples of antagonistic behaviors that regulate and decrease soil-borne plant infections. Plant Growth Promoting Rhizobacteria (PGPR) can defend an extensive variety of plant varieties aligned with various plant diseases. Stenberg et al.[23] suggests that induced plant volatiles have an underutilized potential for biological control due to their many functions as signals, deterrents, and antimicrobial substances and that further breeding attempts should improve crops' ability to interact in tri-trophic ways. The mechanisms by which B. bassiana affects plant diseases are currently being studied, as well as whether endophytic colonization is an essential component of BC.[24] Nega[25] shows that plants grow when bioagents are present. Bio agents must be created in a way that promotes the survival and activity of the microorganisms they contain while not directly harming plants. In addition, the term biological control agent (BCA) refers to the organism that prevents the infection from growing. More generally, the utilization of natural compounds that have been extracted or fermented from diverse sources has also been referred to as biological control.

DEVELOPMENT

Biological Control

In the context of pest management, biological control (BC) is often used to describe the behavior of parasites, predators, or illnesses on a pest population that causes the population's numbers to fall below a threshold at which economic damage is inflicted. BCA also includes herbivorous insects and diseases that target weeds that constitute a problem. BC is a kind of natural control that may be used on any sort of creature, whether or not it is a nuisance and regardless of whether the BCA is naturally occurring, has been imported by people, or has undergone other modifications. For biological control to be successful, as opposed to chemical, cultural, and mechanical controls, part of a food supply (such as a pest) must be preserved. As a result, biological control alone cannot eradicate pests (figure 2).

Important Characteristics

- For those BCA that can live for many years and become self-perpetuating, they are often affordable and may be permanent.
- Intensity may range from low to high.
- It may be hampered by several pest control measures, particularly broad-spectrum insecticides.
- The effects of suppression are density-dependent; they are more pronounced when there are large populations of pests.
- Typically focused on a single pest and not all pests.
- Since BCAs are often slow-acting, there is frequently a lag between the expansion of the pest population

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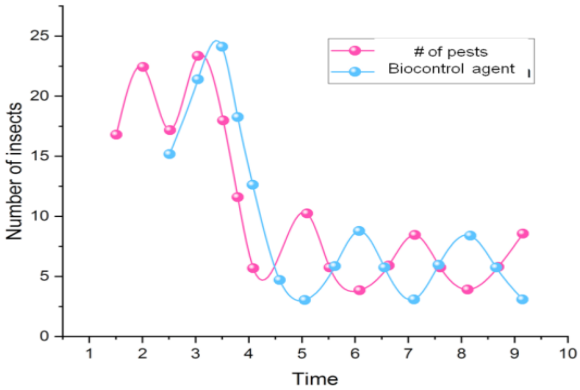

Figure 2. Biological Management

and its expansion.

- An excellent tool to include in an integrated pest management (IPM) strategy; it works well with cultural, mechanical, and certain chemical treatments.
- The perennial crops that can sustain a reasonable amount of pest damage, such as orchards and vineyards, rangeland, and field or feed crops, have seen the most success.

Challenges

The decline of certain chemical plant protection methods, such as soil chemical fumigants the emergence of novel invaders or insect strains that are resistant to pesticides, climate change, or dedicated monoculture are the entire factors to contain impacted this development of the Biological Control Field (BCF). Insect pests and infections are becoming more important due to increased food demand, certain chemical pesticides, including soil fumigants, have been withdrawn. Among these are increasing concerns over the use of synthetic chemical pesticides with their residues. Despite the benefits these elements have over conventional Crop Protection Measures (CPs), BCA is not yet ready to replace them. BCA often has a poor ability to adapt to the non-native environment. They also perform poorly against a wide range of illnesses and insect pests. It hasn't been used much as a consequence.

There are several substantial obstacles, including a lack of study on the efficacy, growth-promoting activities, a lack of physiological, molecular responsiveness of bio-agents, and inadequate bio-agent characterization. For instance, many PGPRs and biofertilizers are designed to be BCAs, but they have limited efficacy in non-native soils and habitats, little study has been done on their effectiveness and growth-promoting activities, and other issues. These biological agents' poor ability to manage disease or pests may be a result of their capacity to encourage plant development. The end users are perplexed by this product since they expect anti-pest activity from these items. The Promotion of Plant Growth is shown in figure 3.

Figure 3. Plant Growth Promotion

Growth-promoting chemicals and bio-control agents that exploit plant growth promotion. Seedling vigor, biomass output, improved germination, improved yield production, improved photosynthetic efficiency, and improved blooming are all growth-promoting factors. BCA includes:

- Siderophores are secreted to stop pathogens in the area from spreading.

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- Antibiotics and bioactive chemicals are synthesized.
- Pathogen-inhibiting enzymes are produced.
- Stimulation of the plants' systematic resistance Volatiles production.

As a result, they often are ineffectual, which harms the standing of Microbial BioControl Agents (MBCA). Strong management is necessary to make certain the effectiveness of biopesticide microorganisms, in addition, to avoiding their inappropriate use because plant protection commodities, even though many strains conflate the categories of biopesticides and biofertilizers. There are presently just a few BCA taxa, species, and strains that protect some soil-borne diseases, including "Trichoderma asperellum, T. atroviride, and T. harzianum, Gliocladium catenulatum, Pseudomonas chlororaphis, Streptomyces griseovirides, with the Streptomyces lydicus". Similar to this, only Bacillus frmus and Purpureocillium lilacinum BCAs have been approved for use in treating nematodes.

In addition to BCA's difficulties with cost and scalability, experts have had a difficult time creating a variety of BCA products. Since many alternatives based on fermentation or pheromones, be exclusive to produce, consumers lack the financial motivation to discontinue using well-known BCA-containing products. As a consequence, numerous businesses were investigating cutting-edge tactics to lower manufacturing expenses. Due to the low entry barriers and high market attractiveness of this sector, hundreds of organizations, ranging from major CP companies to various mid-tier firms, call the BCA along with bio-stimulants industries home. Due to the influx of venture money, a lot of new firms are created, but they typically lack the resources to set up shop, create their goods, and join the market. For each crop or illness in each zone, firms would need to carry out comprehensive, statistically significant efficacy experiments before registering a single strain for commercial use. This restriction has led to a shortage of goods in Europe and Asia for the biological management of insect pests and illnesses. Only a small number of these products have been given the go-ahead for usage by European farmers, as was previously mentioned.

Opportunities for Biological Control

A long-term, cost-effective, eco-friendly method of protecting crops from biotic stressors is biological control. To tackle plant diseases, progressive farmers increasingly adopt biologicals, including the protection and management of rare species of BC microbes. The most efficient biological management approach for conservation goals is based on the most important components of natural enemy ecology. Enhancing the efficiency of natural enemies may be accomplished in one of two ways:[1] changing the environment so that they gain an advantage against pests,[2] or reducing the harm that pesticides do to them. Additionally, it has been underlined how crucial biological control conservation is in less developed nations.

Over the last 50 years, a variety of microorganisms are effective against nematodes and soil-borne illnesses. The active components of at least one commercially available biopesticide are among them. Competition from artificial chemical fumigants, which, even though many of these strains are relatively new, are often more readily available, less expensive, have a greater range of activities, and are extremely powerful. Research on the effectiveness of MBCA as a defense against illnesses carried by soil has intensified since the prohibition of methyl bromide and other pesticides. These herbicides perform best when used in conjunction with other agronomic techniques or plant types that are resistant or tolerant. To eradicate plant diseases, MBCA employs direct antibiosis, hyperparasitism, resistance induction, and competition for resources and space. The biocontrol of plant pathogens is shown in figure 4.

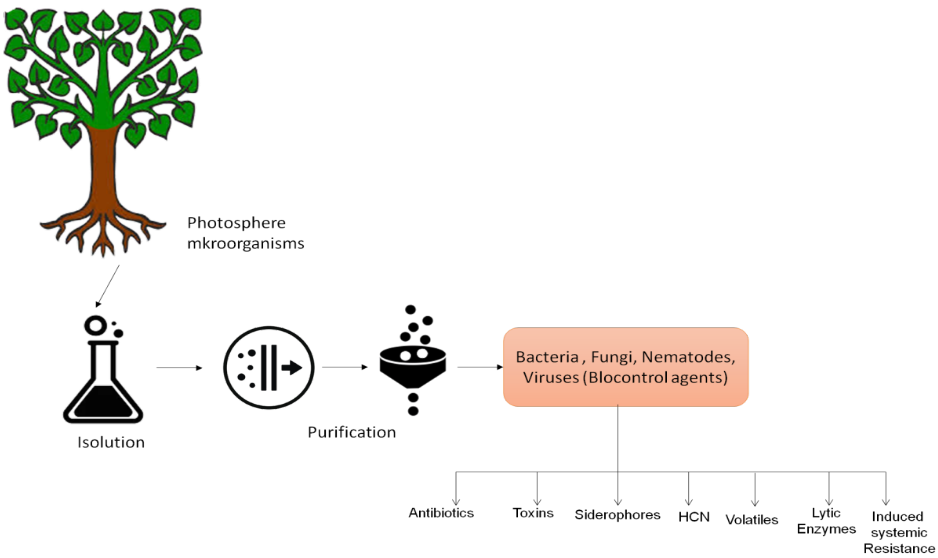

Figure 4. BC of plant pathogen

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Researchers are also looking at how ISR, a mechanism that increases plant resistance to illnesses, involves non-pathogenic beneficial rhizobacteria. After infection with a plant pathogen, systemic acquired resistance (SAR) may emerge. Some microbes, such as those from the Bacillus, Pseudomonas, Acinetobacter calcoaceticus, Azotobacter, Azospirillum, Mesorhizobium, Bradyrhizobium, and Burkholderia species, proceed as bio-stimulators in produce indole-acetic acid, nitrogen fixation, siderophore, and 1-amino cyclopropane.

Additionally, soil and plant microbiomes may serve as BCA, nutrient-assimilation aids, inoculants, assist in the protection of plants from pathogens and pests, or both. To support the survival of beneficial bacteria, certain soil additives may be necessary. Perhaps "probiotics" can be found to sustain the health of plant microbiomes.

Priorities for Investigating BCA

Research on basic biological principles, notably in the areas of taxonomy, ecology, and behavior, has greatly improved BCA research, selection, and risk assessment techniques. Certain unresolved issues in the area of BC, such as the ineffectiveness of plant-associated MBCA, the absence of a thorough knowledge of a pathogen's biology, with the epidemiology of the ensuing illness, delay the growth of disease as well as pest management approaches. consequently, while examining novel issues in the area, scientists and researchers must keep the following goals in mind to build an eco-friendly bio-control method.

Concentrating on a new generation of BCA that is highly compatible with other control techniques, more productive in fermenters, effective, long-lasting, and able to be kept at room temperature.

- Standardization of BCA methods for spotting pests and diseases that propagate via soil.
- Population genetics study offers chances to better comprehend how biological control's influence may be maximized.
- To improve MicroBiological Control (MBC), this may include several genus species or different strains of the same genus and specie.
- By comprehending how effective MBCA is against additional soilborne illnesses outside those listed on the labeling and their prospective users with carriers that may improve survival in soil, it can be used to determine the substance's environmental safety.
- New desired properties, including pesticide resistance, may be inserted into biological control agents that might otherwise have unwanted characteristics by researching cutting-edge genomic methods like Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) genome restriction.
- The use of MBCA together with other management techniques as a component of IPM methods
- Simplify and lower the cost of BCA production by using low-cost BCA carrier substrates or fermentation processes.
- It is essential to assist and encourage companies to register microbiological goods that comply with the concept of low-risk compounds to safeguard food and decorative crops from diseases.

Agricultural Consumption of Pesticides Worldwide

From 1990 to 2020, the use of insecticides in agriculture rose largely steadily. More than 2,7 million metric tons of pesticides were consumed globally in the latter year, an increase of more than 57 percent from 1990. Figure 5 depicts the number of pesticides used in agriculture.

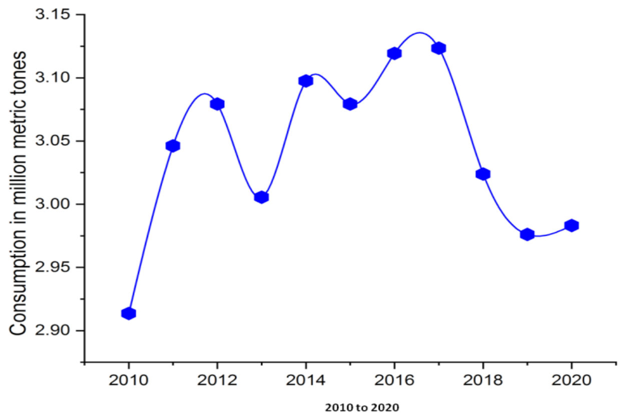

Figure 5. Agricultural Consumption of Pesticides

While pesticides may be useful for boosting agricultural yields and reducing insect populations, it is crucial to remember that their usage can also have adverse consequences on ecosystems, human health, and animals.

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To reduce these possible hazards, it is crucial to properly monitor and supervise their usage.

CONCLUSION

Researchers believe a comprehensive strategy of resilience and responsiveness is necessary to properly comprehend the effective BCA and their combined effects on enhancing pathogenesis and cytotoxicity. Furthermore, effective crop protection management techniques and a grasp of environmentally friendly technology are crucial for organic and sustainable farming. Scholars are thus invited to provide papers or reviews that address the abovementioned challenge, and possibilities, with aims for BCA research. We also invite scholars to present articles or reviews on the following subjects: how plants manage the defensive mechanisms of Bio-Control Microorganisms (BCM); how helpful bacteria interact with plants while depriving them of their benefits.

REFERENCE

1. Lahlali R, Ezrari S, Radouane N, Kenfaoui J, Esmaeel Q, El Hamss H, Belabess Z, Barka EA. Biological control of plant pathogens: A global perspective. Microorganisms. 2022;10(3):596.

2. Aguilar-Marcelino L, Mendoza-de-Gives P, Al-Ani LKT, López-Arellano ME, Gómez-Rodríguez O, Villar-Luna E, Reyes-Guerrero DE. Using molecular techniques applied to beneficial microorganisms as biotechnological tools for controlling agricultural plant pathogens and pests. In: Molecular Aspects of Plant Beneficial Microbes in Agriculture. Academic Press; 2020. p. 333-349.

3. Singh G, Kapoor T, Kaur H. Current Status and Future Perspective on Enzyme Involving in Biocontrol of Plant Pathogen. J Res Appl Sci Biotechnol. 2022;1(1):12-17.

4. Lacey LA, Grzywacz D, Shapiro-Ilan DI, Frutos R, Brownbridge M, Goettel MS. Insect pathogens as biological control agents: back to the future. J Invertebr Pathol. 2015;132:1-41.

5. Ab Rahman SFS, Singh E, Pieterse CM, Schenk PM. Emerging microbial biocontrol strategies for plant pathogens. Plant Sci. 2018;267:102-111.

6. Regaiolo A, Dominelli N, Andresen K, Heermann R. The biocontrol agent and insect pathogen Photorhabdus luminescens interact with plant roots. Appl Environ Microbiol. 2020;86(17):e00891-20.

7. Sabbahi R, Hock V, Azzaoui K, Saoiabi S, Hammouti B. A global perspective of entomopathogens as microbial biocontrol agents of insect pests. J Agric Food Res. 2022;10:100376.

8. Mantzoukas S, Eliopoulos PA. Endophytic entomopathogenic fungi: A valuable biological control tool against plant pests. Appl Sci. 2020;10(1):360.

9. Maluta N, Castro T, Lopes JRS. Entomopathogenic fungus disrupts the phloem-probing behavior of Diaphorina citri and may be an important biological control tool in citrus. Sci Rep. 2022;12(1):7959.

10. Aguilar-Marcelino L, Mendoza-de-Gives P, Al-Ani LKT, López-Arellano ME, Gómez-Rodríguez O, Villar-Luna E, Reyes-Guerrero DE. Using molecular techniques applied to beneficial microorganisms as biotechnological tools for controlling agricultural plant pathogens and pests. In: Molecular Aspects of Plant Beneficial Microbes in Agriculture. Academic Press; 2020. p. 333-349.

11. Sehrawat A, Sindhu SS, Glick BR. Hydrogen cyanide production by soil bacteria: Biological control of pests and promotion of plant growth in sustainable agriculture. Pedosphere. 2022;32(1):15-38.

12. Peng Y, Li SJ, Yan J, Tang Y, Cheng JP, Gao AJ, Yao X, Ruan JJ, Xu BL. Research progress on phytopathogenic fungi and their role as biocontrol agents. Front Microbiol. 2021;12:670135.

13. Görg LM, Eilenberg J, Jensen AB, Jensen AH, Gross J. Pathogenicity against hemipteran vector insects of a novel insect pathogenic fungus from Entomophthorales (Pandora sp. nov. inedit.) with potential for biological control. J Invertebr Pathol. 2021;183:107621.

14. Saha S, Samanta G. Modeling of insect-pathogen dynamics with biological control. Math Biol Bioinform. 2020;15(2):268-294.

15. Eads DA, Jaronski ST, Biggins DE, Wimsatt J. Insect pathogenic fungi for biocontrol of plague vector fleas: A review. J Integr Pest Manag. 2021;12(1):30.

16. Bamisile BS, Siddiqui JA, Akutse KS, Ramos Aguila LC, Xu Y. General limitations to endophytic entomopathogenic fungi use as plant growth promoters, pests, and pathogens biocontrol agents. Plants. 2021;10(10):2119.

17. Branine M, Bazzicalupo A, Branco S. Biology and applications of endophytic insect-pathogenic fungi. PLoS Pathog. 2019;15(7):e1007831.

18. Elnahal AS, El-Saadony MT, Saad AM, Desoky ESM, El-Tahan AM, Rady MM, AbuQamar SF, El-Tarabily KA. The use of microbial inoculants for biological control, plant growth promotion, and sustainable agriculture: A review. Eur J Plant Pathol. 2022;162(4):759-792.

19. D'Addabbo T, Laquale S, Lovelli S, Candido V, Avato P. Biocide plants as a sustainable tool for the control of pests and pathogens in vegetable cropping systems. Ital J Agron. 2014;9(4):137-145.

20. Jacobsen BJ, Zidack NK, Larson BJ. The role of Bacillus-based biological control agents in integrated pest management systems: plant diseases. Phytopathology. 2004;94(11):1272-1275.

21. Pandit MA, Kumar J, Gulati S, Bhandari N, Mehta P, Katyal R, Rawat CD, Mishra V, Kaur J. Major biological control strategies for plant pathogens. Pathogens. 2022;11(2):273.

22. Prashar P, Kapoor N, Sachdeva S. Biocontrol of plant pathogens using plant growth-promoting bacteria. In: Sustainable Agriculture Reviews: Volume 12. Springer; 2013. p. 319-360.

23. Stenberg JA, Heil M, Åhman I, Björkman C. Optimizing crops for biocontrol of pests and disease. Trends Plant Sci. 2015;20(11):698-712.

24. Ownley BH, Pereira RM, Klingeman WE, Quigley NB, Leckie BM. Beauveria bassiana, is a dual-purpose biocontrol organism, with activity against insect pests and plant pathogens. In: Emerging Concepts in Plant Health Management 2004. APS Press; 2004. p. 255-269.

25. Nega A. Review on concepts in biological control of plant pathogens. J Biol Agric Healthcare. 2014;4(27):33-54.

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Writing - proofreading and editing: Suhas Ballal, Kratika Pathak, Shweta R. Sharma.