THE ROLE OF BIOLOGICAL AGENT IN MODERN PLANT PROTECTION: GREEN APPROACH TO PEST MANAGEMENT

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Abstract. *In the current scenario surrounding agricultural sustainability, the incorporation of biological agents has turned out to be a major aspect in alleviating pressures from pests and diseases. Traditional chemical approaches, which are frequently marked by their harmful effects on the environment and the emergence of pest populations that are resistant, have compelled a transition towards more environmentally friendly methods. Biological agents, which include a wide variety of organisms ranging from helpful microorganisms to predators and parasitoids present novel solutions aimed at improving plant health and productivity. This shift in paradigm not only holds the promise of safeguarding biodiversity but also corresponds with global movements that advocate for decreased use of chemicals in agricultural practices. In the modern sphere of agriculture, the notion of biological agents incorporates an array of organisms, which encapsulates predators, parasitoids, pathogens, alongside beneficial microbes, that are utilized for the sustainable control of pests and diseases. These agents function via diverse mechanisms, such as predation, parasitism, or competition, thereby serving to decrease dependency on synthetic pesticides. The importance of these agents is accentuated by their varied roles in fortifying ecosystem resilience and fostering biodiversity. Research illuminates the requirement for a strong biological basis to formulate efficient non-chemical interventions, which ultimately seek to tackle significant pest dilemmas. In addition, the incorporation of multifunctional plants within cropping systems not only strengthens pest management practices but concurrently improves overall agricultural output. Hence, the delineation of biological agents bears considerable importance, since their proficient application has the potential to foster more sustainable agricultural methods that are in line with the shifting global benchmarks for environmental responsibility.*

Keywords*: plant protection, biological, green, pest, agents, approaches*

INTRODUCTION

The trajectory of plant safeguarding methodologies can indeed be traced posteriorly to the antecedent agricultural practises, wherein an emphasis upon innate components established the groundwork for contemporary strategies. Originally, agriculturists relied upon manual methodologies to tackle pests, inclusive of practices such as crop rotation and intercropping, which served to bolster biodiversity as a natural bulwark against infestations. As time progressed, the emergence of chemical interventions drastically altered pest management paradigms; however, this transition frequently disregarded the pivotal function of ecological equilibrium. Sustainable methodologies have started to gain prominence, advocating for agroecology as a schema that honours and reinstates natural diversity whilst simultaneously boosting productivity (CLEMENTS ET AL., 2011). Consequently, the historical backdrop profoundly influences the contemporary dialogue regarding the incorporation of biological agents within plant protection, positing a call for a congruent balance between innovation and ecological sustainability (ȘMULEAC ET ALL., 2022).

The inclusion of biological agents within the realm of sustainable agriculture holds considerable importance for advocating an environmentally friendly method to pest management. Such agents, encompassing beneficial microorganisms alongside natural predators, play a substantial part in sustaining ecological balance and bolstering soil health, hence diminishing reliance on synthetic pesticides. The interaction among a variety of organisms nurtures a robust farming system, a concept bolstered by discourse pin-pointing the necessity for

research into the amalgamation of multifunctional plants that may augment agricultural productivity whilst addressing pest issues through natural means. Moreover, the formulation of decision-support instruments can facilitate the application of these biological strategies, as underscored by contemporary research that has suggested a multi-tiered approach to organic research, unveiling optimistic results from experimental assessments of crop protection methods (BELLON ET AL., 2010). As practices within agriculture undergo transformation, the importance of water and irrigation are crucial, grasping and employing these biological agents will prove vital for the attainment of sustainable and efficacious farming systems, thereby emphasising their indispensable function in contemporary plant protection (ȘMULEAC ET ALL., 2023).

Grasping the underlying mechanisms by which biological agents' function has paramount importance for their successful integration into contemporary plant protection methodologies. Such mechanisms may encompass direct confrontations with plant pathogens or the fortification of the plant's inherent defensive capabilities. To illustrate, microbial agents could synthesize metabolites that serve to impede pathogen proliferation or activate immune responses within the plant. Moreover, naturally occurring compounds sourced from medicinal flora have attracted notable interest due to their radioprotective properties, revealing an additional dimension of biological interaction that could potentially be utilised within agricultural frameworks. Evidence suggests that these indigenous herbs exhibit substantial efficacy against a variety of stressors, thus elucidating their complex mechanisms in augmenting plant durability (CHOONG ET AL., 2014). In addition, the utilisation of these agents corresponds with sustainable agricultural paradigms, proffering an environmentally friendly substitute to synthetic chemicals, which frequently jeopardise ecosystem integrity (DAVISON ET AL., 2004). Consequently, a thorough comprehension of these mechanisms serves not only to guide their application in plant protection but also to bolster broader sustainability objectives within the realm of agriculture and international dissemination through foreign languages implemented also in agriculture (PAȘCALĂU ET ALL., 2023).

In the quest for farming practices that are sustainable, the utilisation of biological control via predation and competition has evidently surfaced as a crucial tactic for managing pests. This methodology capitalises on the intrinsic interactions among organisms, thereby potentially diminishing the dependence on chemical pesticides. An illustrative example is found in the role of predatory soil mites, which have indicated potential in managing invasive species of thrips, as delineated in up-to-date investigations that showcase their ability to keep pest populations at levels that can be deemed acceptable (BERETTA ET AL., 2024). Moreover, the competition among varying species for resources may augment the effectiveness of biocontrol; this is especially noticeable in ecosystems characterised by diverse species interactions that bolster resilience against outbreaks of pests. The multifarious functions of amphibians within ecosystems further illustrate the significance of biological agents, playing a role not only in regulation but also in supporting services that enhance the health and productivity of plants (BABBITT ET AL., 2014). Hence, the integration of such biological agents into contemporary strategies for plant protection serves a dual purpose: it alleviates the pressures from pests while also fostering a state of ecological equilibrium and sustainability but also international guidance for both individuals and companies, due to the translation of all the results and actions into a foreign language (PAȘCALĂU ET ALL., 2023).

MATERIAL AND METHOD

As a student in the final year of bachelor's in Plant protection, at the Faculty of agriculture, the topic is very important for me, and we used the analysis method, based on our background and also on the research undertaken in the last years of studies. Consequently, a

varied assortment of biological entities assumes a pivotal position in current methodologies for plant protection, serving as substitutes for chemical pesticides. It is particularly noteworthy that these entities are amenable to classification into multiple categories: advantageous microorganisms, including bacteria and fungi, which contribute to the mitigation of plant ailments, and entomopathogenic organisms that specifically target certain pest populations. Investigative pursuits indicate the promise of naturally occurring products stemming from these entities in bolstering plant resilience against stressors, encompassing both diseases and pest infestations, thereby allowing for a diminished dependence on synthetic pesticides. To illustrate, numerous natural herbs have demonstrated considerable radioprotective attributes, implying their potential in shielding plants from assorted stress agents (CHOONG ET AL., 2014). Furthermore, holistic methodologies for pest management endorse the amalgamation of diverse biological entities, which nurture an equilibrated ecosystem. Such approaches not only augment agricultural output but also advance the cause of sustainability, exemplifying the necessary transition towards more environmentally benign interventions in pest management (ANDREASEN ET AL., 2013). Through these methodologies, biological agents emerge as crucial partners in the domain of modern agronomy.

A varied assortment of advantageous microorganisms holds significant importance in promoting plant growth and well-being, acting as essential partners in the realm of sustainable agriculture. This cohort of microorganisms encompasses nitrogen-fixing bacteria, mycorrhizal fungi, alongside a multitude of plant growth-promoting rhizobacteria, all of which play a role in the acquisition of nutrients, bolstering disease resistance, and enhancing overall plant vitality. They forge intricate interactions within the rhizosphere, thereby aiding in nutrient cycling and curtailing soilborne pathogens through methods such as competitive exclusion and the synthesis of inhibitory compounds. As elucidated in numerous studies, the tripartite interplay amongst plants, these beneficial microorganisms, and pathogens is capable of markedly impacting plant health, especially when subjected to the strains of biotic stress (ALABOUVETTE ET AL., 2009). Moreover, national, but also international communication (PAȘCALĂU ET ALL., 2024) and modern agricultural methodologies are becoming increasingly reliant on these biological agents to cultivate integrated pest management strategies that favour ecological equilibrium over the utilisation of synthetic chemical inputs. This shift accentuates the effectiveness of beneficial microorganisms in nurturing resilient agroecosystems while concurrently addressing the urgent demand for sustainable methodologies in pest control.

RESULTS AND DISCUSSIONS

The efficacy of pest management is significantly reliant on comprehending the complex interrelations that exist between insect predators, parasitoids, and their prey in agroecosystems. The notion of biological control, mainly through these indigenous enemies, not solely diminishes pest populations but also nurtures resilience within ecosystems. Adaptability is a significant characteristic displayed by insect predators and parasitoids, which allows them to flourish alongside numerous crops, encompassing genetically modified (GM) variants that possess the capability to substantially transform the pest landscape. For example, the adoption of insect-resistant GM crops impacts not just the pests targeted, but also the related biological control agents by altering the availability of both prey and non-prey resources.

In addition, through the function they serve in sustaining ecological equilibrium, these natural enemies are capable of alleviating secondary pest outbreaks, which aids in the formation of a sustainable Integrated Pest Management (IPM) framework This interplay exemplifies the prospects of employing biological agents to bolster both agricultural productivity and the health of the environment within contemporary strategies for plant protection (VOCCIANTE ET ALL., 2022).

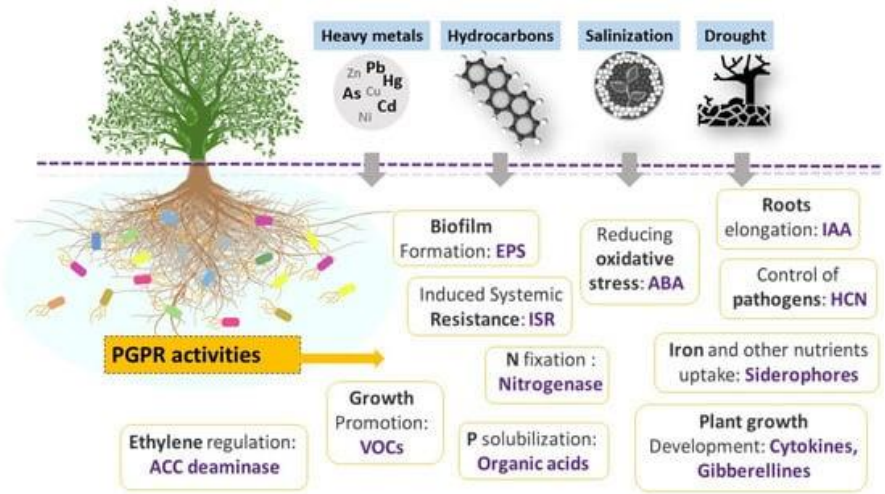

Fig. 1. The Role of Plant Growth-Promoting Rhizobacteria (PGPR) (https://www.mdpi.com/2076-3417/12/3/1231, Vocciante et all., 2022

The employment of plant growth-promoting rhizobacteria (PGPR) within the realm of agricultural methodologies constitutes a noteworthy progression in the sphere of sustainable crop stewardship and safeguarding. Through the augmentation of plant development by means of diverse mechanisms, which may include the secretion of growth hormones and the enhancement of nutrient assimilation, PGPR play a critical role in elevating yield and the overall vitality of plants. Moreover, their function in the suppression of diseases is of great importance; these advantageous microorganisms can directly counteract phytopathogens via the emission of antimicrobial substances, while simultaneously inducing systemic resistance within the plants, thus fortifying their inherent defensive systems against various biotic pressures (ADHIKARI ET AL., 2023). This dual capacity not only diminishes the dependence on chemical pesticides but also encourages a more integrative approach to agriculture, resonating with the increasing demand for ecologically sound farming methods. In conclusion, the amalgamation of PGPR is a promising tactic for the enhancement of food security, underscoring their considerable potential within contemporary plant protection paradigms (ABD EL-MAGEED ET AL., 2022).

CONCLUSIONS

The utilisation of biological agents within contemporary plant protection signifies a crucial development in agrarian methodologies, tackling both ecological sustainability and economic practicality. These agents proficiently manage pests and diseases in a manner that bolsters plant vitality without the adverse effects linked with synthetic chemicals. The amalgamation of biological control approaches holds notable importance in areas grappling with severe food insecurity, such as Sub-Saharan Africa, where postharvest losses surpass 50%.

This scenario accentuates the necessity for the advancement of sustainable, effective agricultural methods that leverage biological agents, ultimately aiding in the enhancement of food security and environmental governance amid an ever-challenging global situation. Current scholarly investigations into biological agents are establishing a hopeful benchmark for sustainable practices in the protection of plants within forthcoming agricultural frameworks.

These biological entities present a feasible substitute for synthetic chemical pesticides, which are encountering mounting regulatory examination due to apprehensions regarding environmental impact and issues surrounding resistance. Recent collaborative pursuits between researchers from China and Denmark underscore the promise of formulating comprehensive methodologies for pest management that amalgamate biological control strategies, thus emphasising the essential nature of a multidisciplinary approach. In addition, recent advancements in molecular diagnostics, notably those employing PCR-based methodologies, allow for the exact identification of plant pathogens even at very low inoculum thresholds, thereby enabling prompt and effective biological measures.

This emerging context suggests that the incorporation of biological agents, supported by robust scientific inquiry, has the potential to transform pest management practices, thus enhancing the resilience and efficacy of agricultural systems while also addressing public and ecological apprehensions related to traditional techniques. The various and changing challenges arising from climate change, pest resistance, and diminishing biodiversity are necessitating a collective effort directed towards innovative agricultural practices that utilise the capabilities of biological agents. The present research underscores the effectiveness of these agents; however, a considerable disconnect persists between academic revelations and their actual application within farming systems. To effectively bridge this gap, a multipronged methodology is essential; this should encompass not merely thorough scientific examination of the precise mechanisms and advantages of biological agents, but also extensive educational initiatives directed at farmers.

Additionally, it is imperative for policymakers to promote incentives that inspire the adoption of these sustainable methods, thereby ensuring a transition away from conventional practices that depend heavily on chemical inputs. The mobilisation of resources for broad-ranging field trials and workshops can significantly improve farmer participation, ultimately fostering a transformation in agricultural practices that places equal emphasis on ecological sustainability as well as productivity. Responding to this urgent call to action will be crucial for the robustness of future food systems.

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