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A Study On Cyanobacterial Biosensors For Detection Of Herbicides

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Abstract

A microbial biosensor combines a physical transducer and one or more microorganisms to produce a quantifiable signal that is proportionate to the quantity of analyses. Recently, a wide range of microbial biosensors for use in food, medicine, and the environment have been developed Microbial biosensors have numerous advantages in ecotoxicity testing. Microorganisms are generally cheaper to culture than higher organisms, and they can be produced in large batches, subjected to stringent quality control procedures, and freeze dried for storage. Cyano-bacterial biosensors for detecting herbicides represent an innovative application of biotechnology. These biosensors use cyanobacteria (blue-green algae) to sense the presence of herbicides, leveraging their natural biological processes to produce measurable signals. Various biological constituents, including enzymes, cells, and organelles, as well as luminous cyanobacterial biosensors that are taken into consideration in this review, have been immobilized on suitable transducer surfaces in biosensors designed for herbicide detection.

Key words: Ecotoxicity luciferase, Immunosensors, Biosenssors, Atrazine

Introduction

Worldwide pesticide usage was recently reported (Sharma et al., 2019). As many as 2 million tonnes of pesticides are used annually all over the world, with ca. 50 % herbicides, 30 % insecticides and 20 % fungicides, thus pointing out the intensive use of herbicides.An enzyme, antibody, tissue, organelle, or entire cell, for example, can be intimately associated with a particular biological recognition element (an electrical, thermal, or optical signal that can be converted into a numerical signal) on a transducer. Herbicide detection using biosensors based on photosynthesis and enzymes in cells and subcellular components (Sassolas et al., 2011). Because they are sensitive to environmental changes, including the presence of hazardous compounds like herbicides, cyanobacteria are the preferred type of bacteria. These organisms can be genetically modified to respond to particular substances by producing a detectable signal.

Different biological elements have been immobilized on an appropriate transducer surface in the biosensors developed for herbicide detection; these elements include aptamers, antibodies(Majdinasab et al.), and molecular imprinted polymers (MIPs) (Nageib et al., 2023), in addition to the enzymes and cells/organelles that are the subject of this review. The majority of biological elements (approximately 60%, of which are enzymes) used in biosensors for herbicide detection are undoubtedly enzymes and cells/organelles; immunosensors are also frequently cited among biosensors for herbicide detection (35%)(Jiang et al., 2008), while apt sensors and MIP-based biosensors are less developed biosensors.

The cyanobacterium's physiology and the uptake of luciferin, the substrate for luciferase, were taken into consideration while optimizing bioluminescence. According to bioassays, a unique luminous cyanobacterial biosensor has been created that can react to a variety of substances, such as various poisons and herbicide kinds.

2. Cyanobacterial Biosenssors

The most popular category of pesticides worldwide is herbicides. Concerns about their potential harm to human health and the environment are brought up by their extensive use. The low amounts of these contaminants, particularly in water samples, must be identified. Well-known analytical methods (HPLC-MS, GC-MS, ELISA tests) are accessible, but they are expensive, require large, cumbersome equipment, require operator training, and require sample pre-treatment. These methods are also very sensitive.

Biosensors are less selective and sensitive early warning systems that can be used in conjunction with other early warning systems. However, they enable direct sample detection on-site without the need for a step beyond dilution and are quick, affordable, and simple to use. The review is on biosensors that are based on enzymes and cells, or subcellular components. subcellular components (thylakoids, chloroplasts) and photosynthetic cells (algae, cyanobacteria) are also reported. The most often found herbicides are atrazine, diuron, 2,4-D, and glyphosate.

Enzymatic biosensors

It is well known that herbicides can disrupt a plant's metabolism by blocking particular enzymes. Since an enzyme can be inhibited by a variety of herbicides in addition to other compounds, which can result in problems with specificity, enzymes can be employed as biological recognition elements in biosensors based on this feature. Herbicides can get around the restriction on specificity by being utilized directly as substrates for enzymatic reactions. Not many biosensors, though, rely on this kind of direct detection.

Whole cell-based biosensors

The cyanobacterial biosensor is suitable for detecting herbicide residues in groundwater or soil because it has parts-per-million sensitivity. It also offers information on the herbicide's bioavailability in environmental samples, making it environmentally relevant.

Thylakoid membranes found in the chloroplasts of plants and cyanobacteria are the source of light-dependent photosynthesis, which oxidizes water to O2, producing NADPH and indirectly ATP. The photosynthetic electron transport (PET) chain is made up of two photosystems, photosystem I (PSI) and photosystem II . PSII is made up of a reaction center and A-chlorophyll, a photosynthetic pigment that can absorb photons and use their energy to excite electrons produced by water oxidation.

Thylakoids and chloroplasts

Several studies have proposed the isolation of organelles (such as chloroplasts), subcellular components (such as thylakoids), or even PSII particles as a potential alternative to whole cell-based biosensors for the detection of photosynthetic herbicides.

. The preferred detection technique in all of these methods is amperometry, and the use of preparations including cellular or subcellular elements allows for intimate coupling between the transducer (electrode) and the biosensing element, improving sensitivity. photosynthetic materials and in particular to PSII a great potential for various biotechnological applications . Intact cells, chloroplasts, thylakoid membranes or PSII particles can be used as biological material for the development of bioassays for herbicide detection. (Maly et al. 2020)

Tissues: plant tissue-based biosensors that have been reported to detect herbicides are based on potatoes or apples, which are well-known for having high PPO contents. Thus, atrazine might be detected based on PPO activity suppression. These biosensors have a low sensitivity but a long lifespan due to their great stability.

Bioluminescent

A new bioluminescent cyanobacterial strain was produced by chromosomally marking a representative freshwater cyanobacterium, Synechocystis sp. strain PCC6803, with the luciferase gene luc (derived from the firefly Photinus pyralis). Optical density and bioluminescence measurements were used to assess the successful expression of the luc gene throughout the growth of Synechocystis sp. strain PCC6803 cells. Optimizing bioluminescence involved taking into account the cyanobacterium's physiology as well as the ingestion of luciferin, the substrate of luciferase. Bioassays revealed the development of a unique luminous cyanobacterial biosensor that reacted to a variety of substances, including various herbicide kinds and other poisons.

(Shao,.at al., 2002). Some bioluminescence based biosensors and effects are liated in the Table-1

Table-1 EC_{50}s of Cu, Zn, and 3,5-DCP for a range of bioluminescence-based biosensors

Biosensor	Cu (mg liter−1)	Zn (mg liter−1)	3,5-DCP (mg liter−1)
Synechocystis sp. strain PCC6803 (luc + luxAB)	0.24	0.88	23.39
Pseudomonas fluorescens 8866 (luxCDABE)	0.30	0.10	4.82
Pseudomonas putida F1 (luxCDABE)	0.17	0.04	5.55
Pseudomonas fluorescens 10586s (luxCDABE)	0.09	0.09	NAc
E. coli HB101 (luxCDABE)	1.4	0.15	18.5

Conclusion

Herbicide and other environmental toxins can now be detected using biosensors, which are becoming a significant and promising modern instrument. The use of biosensors in conjunction with conventional analytical techniques should not be overlooked. (Arkhypova et al.), 2023. Indicating the potential presence of harmful materials in a sample, they can serve as quick and affordable early warning screening tools. More accurate, time-consuming, and expensive conventional methods if needed.

An entirely novel sort of luminous cyanobacterial biosensor has been created that can react to a variety of substances, such as several herbicide kinds and toxicants that are not herbicides. The rates at which distinct herbicide kinds impair bioluminescence vary. Comparing this approach to alternative herbicide toxicity detection techniques as photosystem-based whole-cell and tissue biosensors (Schafer et al., 1994)

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