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Bacterial Bioluminescence: Significance in Agriculture

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Bioluminescence bacteria are wonderful organisms which produce light and lives in either symbiosis or in free living form. These organisms are having number of application in the field of agriculture. Bioluminescence is the production and emission of light from a living organism. The most important genera comprising bioluminescent bacteria are *Vibrio, Photobacterium, Xenorhabdus* and *Photorhabdus*, which when grown on artificial media glows in dark. They can be used as biocontrol agents, biosensors and also having major role in preparation of genetically modified plants which having capacity of auto luminescence.

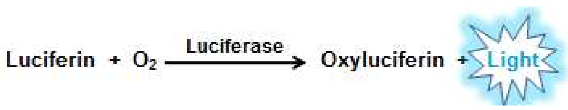
Introduction

The word bio luminescence is combination of greek word Bios meaning living and latin word lumen meaning light. So bioluminescence can be defined as the production and emission of light from a living organism. Bioluminescence organisms produce light as an outcome of a chemical reaction occurring either inside or outside the cells. Sometimes the bioluminescence is misunderstood as fluorescence. The difference between the bioluminescence and fluorescence is the basic mechanism. In bioluminescence the organism itself produce light by their own whereas in fluorescence the organism absorbs light and reemit the same. So both the terminologies are different and must not be mixed.

General Mechanism

Key components involved in bacterial bioluminescence are as follows:

- **Luciferase:** It is the enzyme that catalyse reaction between luciferin and oxygen
- **Luciferin ($FMNH_2$):** In case of bacteria the luciferin is $FMNH_2$ that acts as substrate for luciferase enzyme
- **Auto-inducer (3-oxohexanoyl-homoserine lactone):** It induces the expression of *lux* operon genes to switch on the luminescence reaction in bacteria
- ***Lux* operon:** Genes encoding key components of bacterial bioluminescence are grouped as *lux* operon



Genetic basis of bacterial bioluminescence

The genes that control luminescence bacteria are grouped in lux operon which is an inducible operon. It is active when the concentration of homoserine lactose is high; when a high concentration of bacteria is present. The *lux* operon has the sequence luxCDABE. Wherein *lux*A and *lux*B code for the subunits of the enzyme luciferase. *Lux*CDE code for enzymes that convert fatty acids into aldehydes which are needed for the reaction to proceed. *Lux*I is responsible for the production of the autoinducer protein, homoserine lactose. When the concentration of homoserine lactose is high, it reacts with the protein produced from the operon, the regulator, luxR. This results in increasing the association of RNA polymerase to the promoter region of the first operon and eventually producing luminescence. Induction of bioluminescence reaction is dependent on quorum sensing of inducer by regulator gene lux R. Induction of a quorum-sensing genes need accumulation of a secreted small molecule called an **autoinducer** Homoserine lactone. At a certain extracellular concentration, the secreted autoinducer reenters cells binds to a regulatory molecule, which in the case of bacteria is LuxR. The LuxR-autoinducer complex then activates transcription of the luciferase target genes that confer bioluminescence.

Applications of bioluminescence bacteria in Agriculture

Biocontrol of phyto-pathogens

Bioluminescent bacteria can be used as biocontrol gents against wide range of phyto-pathogens including insects, nematodes and fungi. Most common bioluminescence bacteria for biocontrol include *Xenorhabdus* spp and *Photorhabdus* spp. which lives in symbiosis with entomopathogenic nematodes *Hetrorhabdis* and *Steinerema*. Entomopathogenic nematodes are known for their potential for insect pest control but the actual role is played by symbiotic bioluminescence bacteria. Bioluminescence bacteria show two types of interaction with their hosts. Within nematodes they live in mutualism wherein they live within the EPN and multiplies within the gut of nematodes without harming the nematode. As the nematodes infect the insect they will show pathogenic interaction with insect host and kill the insect and allows multiplication of nematodes within the insect body.

Bioluminescence bacteria as biosensors

- Biosensors are living organisms that are exploited for their ability to sense and report changes in their surroundings.
- The scientists that are working with these biosensors are using colonies of live bacteria that have a luciferase (Lux) gene tethered to another gene that is activated during an environmental change. When the change causes the native gene to be activated, the luciferase gene is also activated and light is produced, physically signalling the change.
- The key to the system lies in the special protein found on the surface of the bacterial cell wall.
- This special protein can be tailored to cause the bacteria to respond to different environmental cues.
- This is accomplished by mutating the surface protein producing gene.

Mechanism of bioluminescence biosensor

Toxic compound binds with surface modified receptor proteins which will activate normal bacterial response as the gene gets activated the luciferase cascade gets activated as it is linked with the normal gene which results in bioluminescence. So, as there is accumulation of pollutant within the environment the bioluminescence bacteria respond towards them by showing bioluminescence.

Bioluminescence bacteria for development of autoluminescent plant

Transformation of plants with bioluminescent genes from bacteria will provide us auto luminescence plant which can be used as streetlight or household lights.

Scientist have created an autoluminescent tobacco plant by integration of *lux* genes from *Photobacterium leiognathi* in to chloroplast genome of tobacco plant

Recent research & development in India on *lux* operon

- *Plutella* and *Helicoverpa* are showing resistant to transgenic to some extent in view of this problem the futuristic transgenic crop will be based on *cry* + *lux* gene (multiply gene stacking technology) in chloroplast expressing new generation plant are under way to

develop by ICGEB (international center for genetic engineering and biotechnology), New Delhi.
- *Gus* genes are commonly used as marker for transgenic crop but presently *lux* genes are being promoted as reporter gene.

Conclusion

Emission of light by biological system is known as bioluminescence due to reaction between luciferin and oxygen mediated by luciferase enzyme regulated by inducible *lux* operon. Most familiar bioluminescence bacteria for biocontrol include *Xenorhabdus* spp. and *Photorhabdus* spp. which live in symbiosis with entomopathogenic nematodes *Hetrorhabdtis* and *Steinernema.* which attract insect by emitting light and producing various toxins thereby inhibiting phyto-pathogenic insects, nematodes and fungi. Genetically engineered bioluminescence bacteria very well employed as biosensors for monitoring pollution of soil and water as well as generate autoluminescent plants. Efforts are required to explore novel genera of bioluminescent bacteria useful in agricultural sector. Biology and Genetic engineering should join hands to explore bioluminescent bacteria for development of biosensors to monitor soil, water and air pollution as well as detoxification of the contaminant from the polluted sites. Research is to be focused to introduce bioluminescence genes in to ornamental plants and road side trees which can light up houses as well as streets with saving in electricity and environment.