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QUORUM SENSING AND ITS ROLE IN PLANT PATHOLOGY

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INTRODUCTION

Quorum sensing (QS) is a bacterial cell to cell communication process that involves the production, detection, and sending signals in response to external environment. Bacterial cells communicate with one another using chemical signal molecules called autoinducers (AIs). The quorum-sensing function is based on the local density of the bacterial population in the immediate environment. Autoinducers accumulate in the environment as the bacterial population density increases, and bacteria monitor this information to track changes in their cell numbers and collectively alter gene expression. Most quorum sensing-controlled processes are unproductive when undertaken by an individual bacterium acting alone but become beneficial when carried out simultaneously by a large number of cells.

QS controls genes that direct activities that are beneficial when performed by groups of bacteria acting in synchrony. Processes controlled by QS include bioluminescence, bacterial growth, sporulation/proliferation, competence, antibiotic production, biofilm formation, environmental adaptation and virulence factor secretion.

HISTORY:

In 1970, the marine bacteria *Photobacterium fischeri* was found to secrete a chemical substance that controlled the luminescence of bacterial cells (Lerch, 1970). The bacterium releases autoinducers, that stimulate the bioluminescence system at a high bacterial population density. In the 1980s, scientists discovered the bioluminescence producing gene-Luminescence (lux) in *Vibrio fischeri*, and subsequently identified the autoinducer in *Photobacterium fischeri* as an N-(3-oxohexanoyl)-DL-homoserine. In 1994, Fuqua first proposed the concept of QS, in which bacterial phenotypes are regulated according to the concentration of chemical stimulus produced by individuals or colonies of bacteria (Fuqua et al. 1994).

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Mechanism of Quorum sensing:

Both gram-positive and gram-negative bacteria use quorum sensing, but there are some major differences in their mechanisms (Fig 1). Wide range of autoinducers were reported in different bacteria like Acyl-homoserine lactone (AHL), Autoinducing peptides (AIP), LuxS/autoinducer-2 (LuxS/AI-2), AI-3, diffusible signal factor (DSF), and *Pseudomonas* quinolone signal (PQS).

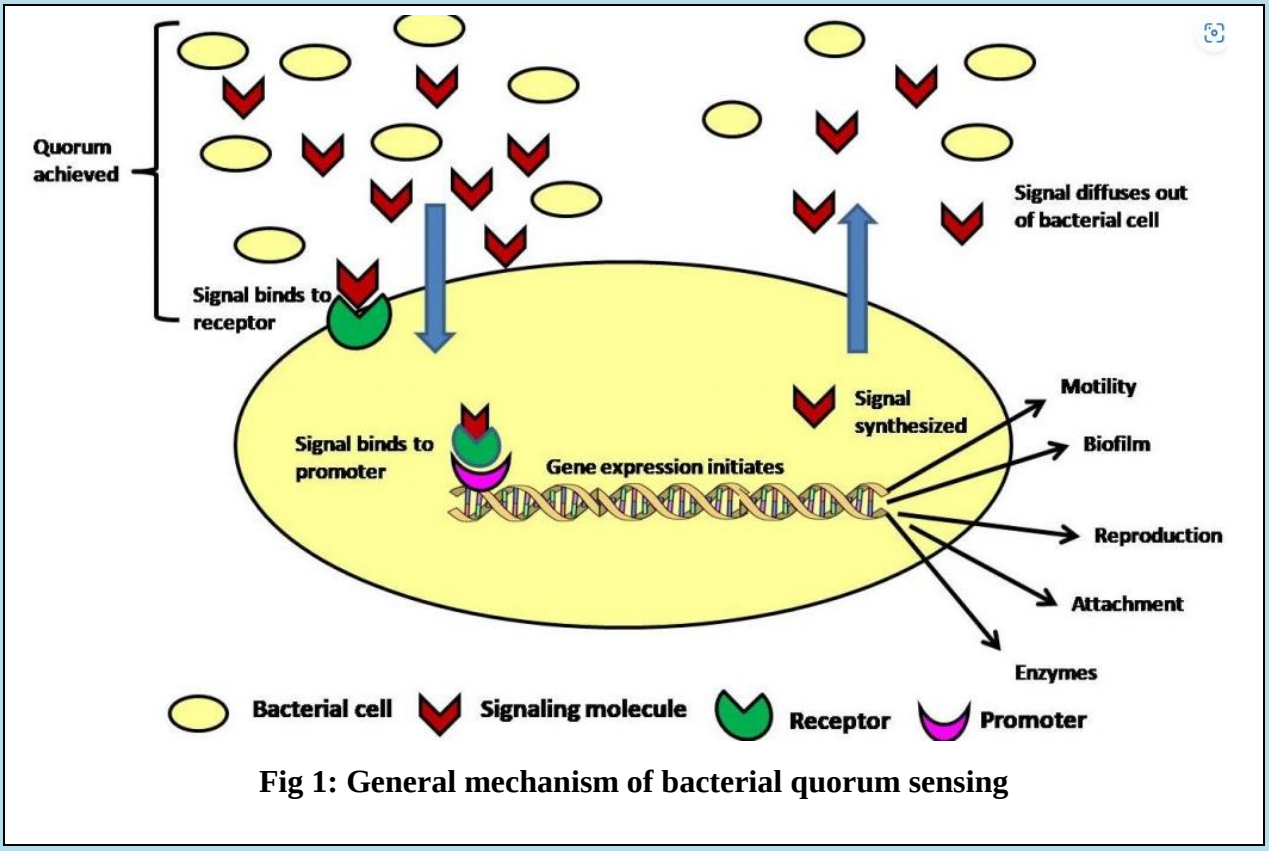

Fig 1: General mechanism of bacterial quorum sensing

Gram-positive bacteria:

Gram-positive bacteria uses autoinducing peptides (AIPs), as signalling molecules. When the concentration of the AIP is high in the external environment, it binds to membrane-bound two-component histidine kinase receptor. It autophosphorylates, and passes phosphate to a cytoplasmic response regulator activates transcription of the genes and finally shows its responsible activity. Another possible mechanism is that, AIPs are transported back into the cell cytoplasm where they interact with transcription factors to modulate the transcription factor's activity and, in turn, modulate gene expression changes (Monnet and Gardan, 2015).

Gram-negative bacteria:

Gram-negative bacteria produce N-acyl homoserine lactones (AHL) as their signalling molecule. These signalling molecules (AHL) do not need additional processing, and bind

directly to transcription factors to regulate gene expression (Fuqua et al., 2001).

Role of Quorum sensing in Plant Pathology:

Quorum sensing controls various processes like biofilm formation, production of virulence factors, bacterial growth and proliferation, competence, siderophore production and antibiotic resistance (Fig 2) which directly or indirectly helps in pathogenesis of bacteria in causing bacterial diseases.

Biofilm Development:

Biofilm is a special structure formed by bacterial colonies adsorbed on the surface of inert or active materials in order to adapt to the living environment. It is composed of extracellular matrix such as polysaccharides and proteins. The process of biofilm development is triggered by environmental signals, when bacterial colonies are aggregated in high enough densities, and those require flagella to successfully approach a surface, adhere to it, and form the biofilm. Biofilms protects the bacterial colonies from biotic or abiotic threats, which is huge problem in controlling bacterial plant diseases. Bacterial populations use QS to control biofilm formation, which provides members of the population superior access nutrients and thus enables them to out-compete non-biofilm-producing neighbors (Bogino and Oliva, 2013). *V. cholerae* is an typical example of integrating QS and biofilm formation during its pathogenic life cycle (Watnick et al. 2001)

Production of virulence factors:

A virulence factor is expressed by a pathogen to influence the growth and colonization of pathogen on the host. For many bacterial plant pathogens, a LuxI type protein synthesizes the Quorum sensing signal molecules to be sensed by a receptor protein; then, the formed adduct will interact with specific DNA sections in the QS regulon to activate the expression of virulence factors. The expressed virulence factors include the production of biofilm, cell wall degrading enzymes (PCWDE), and phytotoxins (Von Bodman et al., 2003).

Competition:

Competition are common in bacterial communities, which strongly affect the results of bacterial diversity. The luxR and its homologues can respond to AHLs signals in the community, identify competitors, and regulate biofilm formation, luminescence, release of virulence factors, toxin production, swimming capacity, and expression of protease activity genes, etc., and reduce interference by interfering with competition (Doekes et al. 2019).

Siderophore production:

Quorum sensing (QS) allows organisms to alter gene expression based on cell density to express siderophore production.

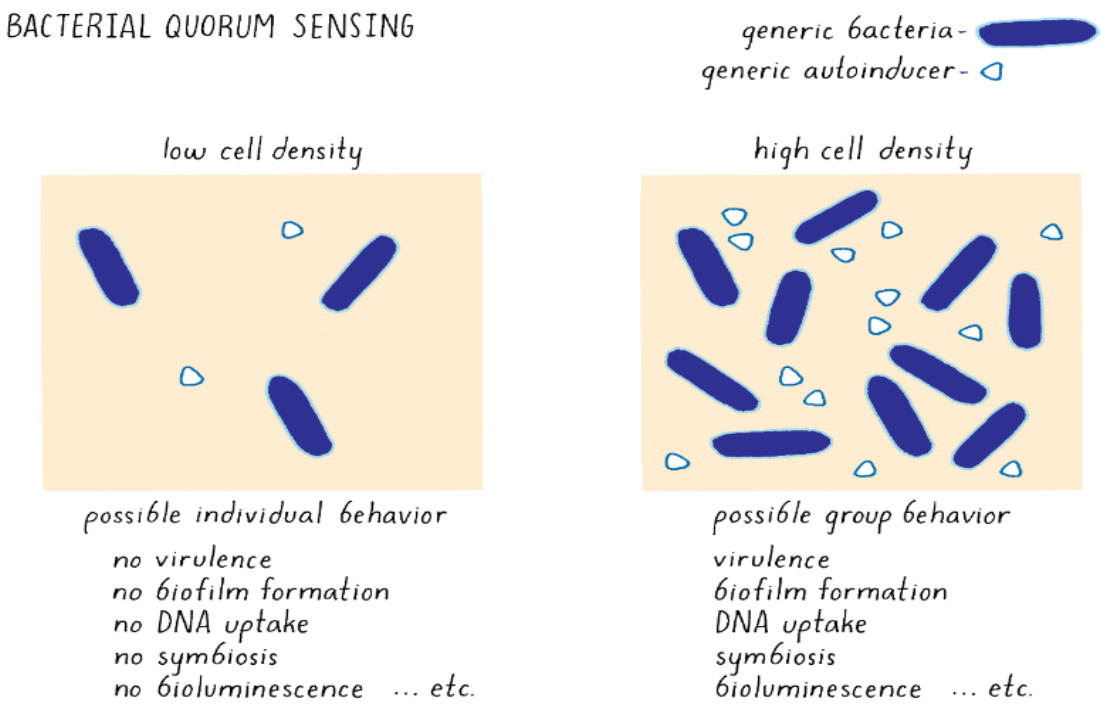

Fig 2: Quorum Sensing: Density dependent communication of bacterial cells regulating various processes

V. harveyi reported to use a single QS- and Fe-repressed gene cluster to produce both cell-associated siderophores (amphiphilic enterobactins) as well as several soluble siderophores. QS allows *V. harveyi* to exploit "knowledge" of its population size to avoid unnecessary siderophore production (MC Rose et al., 2018)

Antibiotic Resistance:

The QS system plays an important role in the formation of bacterial antibiotic resistance mechanisms by regulating the formation of biofilms and the direct regulation of drug efflux pumps. The development of antibiotic resistance has aggravated the difficulty in prevention of bacterial diseases (Saurav et al., 2016).

All these QS processes including biofilm formation, virulence factor production, antibiotic resistance, creating tough task in preventing plant diseases. Therefore, recently disruption of quorum sensing network in pathogenic bacteria is being looked upon as potential therapeutic target. One such disruption technique is quorum quenching (QQ) in which QQ molecules either decrease or completely inhibit the synthesis of signalling molecules. The other potential strategy being used is usage of structural analogues of QS receptor. However, the phenomenon of QS does not have a negative

side only as incase of beneficial rhizospheric microbes this trait is a boon for them.

CONCLUSIONS:

It is concluded that quorum sensing is an universal bacterial language which responds in group behavioural pattern. By understanding the quorum sensing role in plant pathology helps in developing disruption technique to inhibit quorum sensing among the bacteria by using quorum quenching or use of quorum antagonist microbes will help a lot in tackling various plant diseases caused by bacteria. Thus, this “chit-chat” among bacteria still holds many secrets which will help in addressing many problems which still lie unanswered.

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