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Unveiling the Influence of Quorum Sensing on Plant Growth

R. Sowmiya
Assistant Professor (Agronomy), Vanavarayar Institute of Agriculture, Pollachi, Tamil Nadu, India
*Corresponding Author: sowmiagro94@gmail.com

In recent years, the exploration of quorum sensing mechanisms beyond microbial communities has unveiled intriguing interactions in unexpected realms of biology. Particularly intriguing is its influence on plant growth—a phenomenon that challenges traditional boundaries of interkingdom communication. Quorum sensing, originally identified in bacteria for coordinating collective behaviors, appears to wield a profound impact on plant developmental processes and stress responses. This paper delves into the emerging insights about basic quorum sensing and their influence on plant growth.

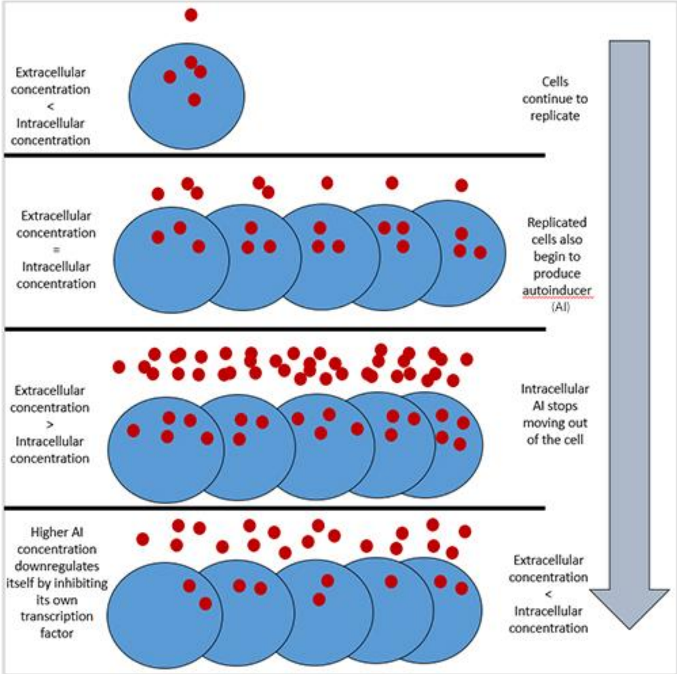
Quorum sensing

There exist two primary categories of bacteria differentiated by their cell wall composition and attributes: gram-negative and gram-positive. Throughout their reproductive cycle, individual bacteria produce molecules known as autoinducers (AI), which serve as chemical signals facilitating communication among bacteria.

In gram-positive bacteria, autoinducers are peptide-based and necessitate active transport through the peptidoglycan cell wall using the ATP-binding cassette (ABC) transporter system. In contrast, gram-negative bacteria generate autoinducers known as acyl-homoserine lactones (AHLs), which can passively diffuse through their thinner cell wall.

In both scenarios, autoinducers are released from individual cells upon their production. As bacterial reproduction progresses, the number of cells producing autoinducers increases, leading to a rise in the extracellular concentration of these molecules. Eventually, this concentration reaches a critical threshold where it becomes energetically unfavorable for more autoinducers to exit the cells, causing their intracellular concentration to accumulate. Once this intracellular concentration reaches a certain level, autoinducers bind to their respective receptors, initiating signaling cascades that modulate the activity of transcription factors and thereby influence gene expression. This regulatory mechanism of gene expression mediated by autoinducers is known as quorum sensing.

Quorum sensing serves to regulate cell density by modulating gene expression crucial for survival during the transition from log to stationary phase in dense cultures, as well as in natural environments such as soil, food, or within a host (Gracias and McKillip, 2011). Different bacterial species exhibit varying abilities to perceive and respond to distinct signals. This communication mechanism enables individual bacteria within colonies to synchronize and execute collective functions such as virulence, conjugation, competence, biofilm formation, bioluminescence, and sporulation (Goto et al., 2000). Quorum sensing involves the direct or indirect activation of receptor proteins by autoinducers (AIs) (Graumann, 2012), leading to the upregulation or downregulation of specific genes. The fundamental principles underlying all quorum-sensing processes include: (1) production of AIs by the bacterial species, (2) detection of AIs by membrane or cytoplasmic receptors, and (3) establishment of a positive feedback loop driven by AIs (Rutherford and Bassler, 2012). In many bacteria, changes in gene expression also involve the downregulation of autoinducer synthesis, contributing to a negative feedback loop.



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Influence of QS on plant growth

Root growth

The presence of AHL molecules elicited a change in root morphology as one of its responses. Interestingly, the morphological reaction to multiple

AHL molecules appears distinct from that triggered by a single AHL. Specifically, AHL variants such as the short-chain C6 and C8 homoserine lactones (HSLs) were found to enhance root length (Von Rad et al., 2008). Moreover, AHL presence has been associated with increased root length and plant biomass in wheat and barley crops (Moshynets *et al.*, 2019), as well as the induction of adventitious root formation in mung beans (Bai et al., 2012).

Stress tolerance

Quorum sensing is integral to the response of plant growth-promoting rhizobacteria (PGPR) to environmental stress and their ability to enhance plant tolerance to saline-alkaline conditions. According to a study by Zhuang *et. al.*, 2023, the quorum sensing molecule known as diffusible signal factor (DSF) facilitated the PGPR Stenotrophomonas rhizophila in overcoming stress during its active phase. DSF contributes significantly to enhancing the environmental adaptability and survival rate of S. rhizophila, consequently improving mustard seed germination under saline-alkaline stress conditions.

Biocontrol of plant pathogen

Plant bacterial pathogens pose significant threats to a wide array of crops globally, resulting in substantial economic losses in agriculture (Martins et al., 2018). Utilizing biocontrol agents represents a sustainable approach to promote plant growth and mitigate diseases in agricultural settings. Numerous plant growth-promoting bacteria (PGPB), such as various species of Pseudomonas, serve as biological control agents by producing compounds such as hormones, antibiotics, polysaccharides, and siderophores. These substances induce systemic resistance (ISR) in plants, enhancing their ability to defend against pathogens (Qessaoui *et al.*, 2019; Lyu et al., 2019).

According to a report by Rodriguez et al., 2020, Pseudomonas segetis strain P6 isolated from the rhizosphere of Salicornia europaea exhibits quorum quenching activity. This activity was found to reduce symptoms of soft rot caused by Dickeya solani, *Pectobacterium atrosepticum*, and *P. carotovorum* on potato and carrot crops.

Induction of systemic resistance

Induced systemic resistance (ISR) represents one of the various mechanism's plants employ to adapt to their environment, given their inability to evade unfavorable conditions. ISR is triggered by beneficial microbes associated with plants, a process influenced by the plants themselves (Zhalnina et al., 2018).

Wehner et al., 2019 observed that inoculating barley plants with *Ensifer meliloti* bacteria harboring a repaired expR gene, which produces oxo-C14-homoserine lactone (AHL), along with an *E. meliloti* strain carrying the attM lactonase gene from Agrobacterium tumefaciens—capable of degrading AHL—resulted in heightened resistance to leaf rust (*Puccinia hordei*). Leaf rust is a significant pathogen affecting barley crops.

Conclusion

Quorum sensing mechanisms, originally identified in bacteria for coordinating collective behaviors, have demonstrated significant implications for enhancing plant growth, stress tolerance, and defense mechanisms. By influencing gene expression, quorum sensing allows plants to respond dynamically to environmental cues, potentially leading to improved agricultural practices and sustainability.

References

Bai X., Todd C.D., Desikan R., Yang Y., Hu X. (2012). N-3-Oxo-Decanoyl-l-Homoserine-Lactone Activates Auxin-Induced Adventitious Root Formation via Hydrogen Peroxide- and Nitric Oxide-Dependent Cyclic GMP Signaling in Mung Bean. *Plant Physiol.* 158:725–736.

Goto, K., et al., (2000). Application of the partial 16S r DNA sequence as an index for rapid identification of species in the genus Bacillus. J. Gen. Appl. Microbiol. 46(1), 1-8.

Gracias, K. S., McKillip, J. L., (2011). Triplex PCR-based detection of enterotoxigenic Bacillus cereus ATCC 14579 in nonfat dry milk. J. Basic Microbiol. 51 (2), 147-152.

Graumann, P., (2012). Bacillus: Cellular and molecular biology, second ed. Caister academic press, Norfolk.

Martins, P. M. M., Merfa, M. V., Takita, M. A. & De Souza, A. A. (2018). Persistence in phytopathogenic bacteria: Do we know enough? *Front. Microbiol.* 9, 1099–1099,

Moshynets O.V., Babenko L.M., Rogalsky S.P., Iungin O.S., Foster J., Kosakivska I.V., Potters G., Spiers A.J. (2019). Priming Winter Wheat Seeds with the Bacterial Quorum Sensing Signal N-Hexanoyl-L-Homoserine Lactone (C6-HSL) Shows Potential to Improve Plant Growth and Seed Yield. *PLoS ONE*;14: e0209460.

Lyu, D., Backer, R., Robinson, W. G. & Smith, D. L. (2019). Plant growth-promoting rhizobacteria for cannabis production: yield, cannabinoid profile and disease resistance. *Front. Microbiol*. 10.

Qessaoui, R. *et al*. (2019). Effect of *Pseudomonas* as a preventive and curative control of tomato leaf miner *Tuta absoluta* (*Lepidoptera: Gelechiidae*). *J. Appl. Sci.* 19, 473–479.

Rodríguez, M., Torres, M., Blanco, L. *et al.* (2020). Plant growth-promoting activity and quorum quenching-mediated biocontrol of bacterial phytopathogens by *Pseudomonas segetis* strain P6. *Sci Rep* 10, 4121.

Rutherford, S.T., Bassler, B.L., (2012). Bacterial quorum sensing: its role in virulence and possibilities for its control. Cold Spring Harb. Perspect. Med. 2(11), 1-25.

Von Rad U., Klein I., Dobrev P.I., Kottova J., Zazimalova E., Fekete A., Hartmann A., Schmitt-Kopplin P., Durner J. (2008). Response of *Arabidopsis thaliana* to N-Hexanoyl-DL-Homoserine-Lactone, a Bacterial Quorum Sensing Molecule Produced in the Rhizosphere. *Planta*. 229:73–85.

Wahner, G et al., (2019). Priming is a suitable strategy to enhance resistance towards leaf rust in barley. Phytobiomes. 3(1): 46-51.

Zhalnina, K., Louie, K. B., Hao, Z., Mansoori, N., da Rocha, U. N., Shi, S., Cho, H., Karaoz, U., Loque, D., and Bowen, B. P. (2018). Dynamic root exudate chemistry and microbial substrate preferences drive patterns in rhizosphere microbial community assembly. Nat. Microbiol. 3:470-480.

Zhuang, X., Liu, Y., Fang, N., Bai, Z and Gao, J. (2023). Quorum sensing improves the plant growth-promoting ability of *Stenotrophomonas rhizophila* under saline-alkaline stress by enhancing its environmental adaptability. Front Microbiol. 14.

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