

Detection of Plant Volatile Compounds

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INTRODUCTION

Plants are not just silent bystanders in the natural world. They are constantly communicating with the environment through complex interaction. One of the significant tools for their communication is volatile organic compounds (VOCs). Volatile organic compounds include a group of organic chemicals that can evaporate easily into the atmosphere at room temperature. They can originate from both natural processes and human activities.

Plants emit a diverse array of VOCs as a part of their biological process. Extensive research on this area revealed that there is a close relationship between emitted VOCs and the metabolic or pathological processes happening inside the plant system, which provides valuable insights into the physiological state of individual plants. It is also found that, in plants, there will be an increase in the release of VOCs during biotic and abiotic stresses such as environmental stress, mechanical damage, herbivore attack, and disease function. The emitted VOCs include C6 green leaf volatiles (e.g., (E)-2-hexenal and (Z)-3-hexenal), terpenoids (e.g., isoprene and α -pinene), and plant hormones (e.g., ethylene, methyl jasmonate, and methyl salicylate).

Signaling and Defense Mechanisms

To cope with environmental challenges including stress, herbivore attacks, etc., plants have developed various signaling and defense mechanisms. The release of volatile compounds is one such defense strategy that acts as chemical signals to communicate with their environment and

as a means of defense mechanism against both biotic and abiotic stresses. The plants release VOCs as warning signals to trigger defense mechanisms in the undamaged parts of the same plants and also in the neighboring plants against herbivorous attacks or stressed conditions. These preventive signaling mechanisms help the entire plant community against potential threats, fostering a collective defense response, and this phenomenon is known as plant-plant interaction or plant-plant communication.

Furthermore, Voc also has a direct deterrent effect on herbivores. It includes various biochemical mechanisms mediated by both direct and indirect defenses. Plants release these defensive compounds continuously or in response to the damage that affects herbivorous growth, feeding, and survival. Either way, it will defend itself by releasing compounds that are attractive to the natural enemies of the herbivores. These strategies either act independently or in connection with each other.

Understanding the role of volatile compounds in intricate signaling and defense mechanisms inside plants has significant importance. It emphasizes the interconnection between the plants and their ability to respond to various environmental challenges. This knowledge could have practical application in the field of agriculture, enabling the development of pest management strategies that make use of natural plant defenses.

Significance of Plant VOC detection

VOC detection in agriculture holds a significant role as these compounds can act as indicators of several issues affecting crop production including environmental factors, plant health, etc. Here are several reasons that highlight the importance of VOC detection in agriculture.

Early Pest and Disease Detection

Plants produce specific VOCs during diseases or even at the time of damage due to pests or pathogens. These VOCs serve as an indicator of disease conditions even before the symptoms appear on the crops. This will be helpful to the farmers to implement targeted and timely interventions to reduce the spread of crop disease and minimize the demand for pesticides.

Plant Stress Monitoring

Plants also release VOC in response to environmental stressors like extreme temperature, nutrient deficiencies, etc. The early detection of these changes allows the farmers to make changes in fertilization, irrigation, and other crop management practices to mitigate the stress and enhance crop health.

Crop Quality and Yield Improvement

VOC profiles will also help in understanding the quality of crops. Monitoring the VOC emissions during different stages of crop production facilitates the farmers to optimize the farm conditions for higher yields and in improving crop quality. This is significant in the production of high-value crops where the quality is a critical factor.

Applications of Sensors in Plant-Volatile Detection

Plant sensors are devices made to identify and examine the volatile organic compounds (VOCs) that plants create. These sensors are used in different fields, including research, environmental monitoring, and agriculture. These are a few fundamental features.

Evolution of plant health

Plants exhibit a superior way of communicating distress especially when they are confronted with stress agents like pests and diseases. This is done through the emission of volatile organic compounds which specialized sensors can easily detect. This offers valuable insights into the well-being of plants. With advancing technology, these sensors can identify specific chemicals associated with stress agents. By monitoring the quality and patterns of the volatile organic compounds that are identified by the sensors, any changes can be easily recognized which can be considered as an early warning system for issues concerning plant health. This early detection is important to prevent the growth of diseases or pests in the crop. It empowers farmers to take immediate action, such as targeted interventions such as the use of pesticides or other management strategies, to control risks and reduce impact. In this way, a proactive approach can significantly increase crop health and productivity.

The integration of greenhouse plants into precision farming practices exemplifies the convergence of technology and agriculture, providing farmers with a powerful tool to optimize crop health and yield. The real-time monitoring capabilities of these sensors enable farmers to make informed decisions, ensuring a consistent and efficient approach to plant disease management in particular, volatile plant sensors play an important role in rapid disease detection and control.

Stress recognition

Volatile sensors for the detection of plant stress offer a variety of applications in agriculture, horticulture, and environmental monitoring. In agriculture, these sensors enable farmers to report stress agents such as drought, pests, and nutrient deficiencies, hence enabling targeted interventions to address the specific needs of plants. This approach helps improve crop resilience and overall productivity. Plant volatile sensors used in farming help optimize growing

conditions for ornamental plants, fruits, and vegetables. Early identification of stress agents allows farmers to adjust variables such as environmental conditions, irrigation, or nutrient supply to promote healthy, robust plants. Environmental management benefits from the use of plant volatile sensors to provide insight into the overall health of ecosystems. Stress observed in plants is indicative of changes in environmental conditions, levels of pollutants, or the presence of harmful substances. This information is important for conservation initiatives and biodiversity conservation.

Harvest timing optimization

The manipulation of plant volatiles to optimize harvest depends on the relationship between temperature fluctuations, growth processes, and metabolite excretion. If variables are monitored, this properly allows farmers to make informed decisions about the best time to harvest, bringing production efficiencies and shelf life extensions. Metabolites, chemicals produced in plant metabolism, are indicative of maturity. Plant volatile sensors are specifically designed to detect and analyze these potential compounds, providing a non-invasive and real-time method for measuring crop ripeness. By understanding the process, farmers can optimize the harvesting season to improve the quality and market value of the seeds.

Furthermore, plant metabolites play an important role in maintaining postharvest quality during storage and transportation. During these stages, crops continue to release volatile chemicals. Monitoring these emissions allows the detection of issues such as decay, contamination, or early decomposition. Sensors act as a warning system and facilitate early corrective action to prevent further damage and ensure product quality is preserved. The ability to manage and optimize harvest time through plant volatile sensors has significant implications for the agricultural industry. Farmers can reduce post-harvest losses, reduce waste, and provide consumers with fresher, higher-quality products. This not only increases the economic profitability of agricultural

processes but also helps to achieve sustainability goals by encouraging more efficient use of resources.

Evaluation of environment

Plant volatile sensors for air quality monitoring introduce a new approach to environmental research. These sensors are designed to detect and measure volatile organic compounds (VOCs) released by plants, providing valuable insight into the dynamics between plant emissions and air pollution. Plant volatile sensors play an important role in the chemical handling of plant-emitted VOCs in air quality studies. Because plants release VOCs as part of their natural products or as environmental stress agents, these compounds can interact with air pollutants. Monitoring these networks helps monitor the overall state of the ecosystem and provides real-time information on air quality.

Plant volatile sensors are environmental indicators where air pollution is a concern. Specific pollutants in the air can affect the types and amounts of VOCs released by plants. Analysis of these differences enables scientists and environmentalists to determine the presence and quantity of contamination, facilitating timely intervention and taking preventive measures.

Precision agriculture

The implementation of precision agriculture with plant volatile organic compound (VOC) sensing transforms the precision of fertilization and irrigation methods. By controlling temperature fluctuations associated with plant VOC emissions, farmers can fine-tune irrigation water and fertilizer use, resulting in more efficient agricultural practices, and in turn, it will reduce the environmental footprint. The incorporation of plant VOC sensing into precision agriculture not only improves resource use but also enhances environmentally friendly agricultural practices. The

ability to accurately assess plant needs using VOC monitoring allows farmers to improve their practices, and develop more sustainable and efficient agricultural practices.

Pest management

In response to pest infestation, plants release specific volatile organic compounds (VOCs) as part of their defense mechanisms. VOC sensors are designed to detect these emissions, providing a non-invasive and immediate method of detecting the presence of pests.

Timely identification of pests is essential for implementing targeted pest control measures. By analyzing VOC data, farmers can identify specific organisms affecting plants and locate infections. This information facilitates the development of more accurate and effective pest control strategies, reducing their reliance on a wide range of pesticides.

CONCLUSION

The Plant volatiles act as a dynamic language through which the plant communicates with its surroundings. This communication not only includes signaling and defense mechanisms but also plays a significant role in agriculture, specifically in stress monitoring, disease management, and overall crop quality improvement.

The application of sensors in plant VOC detection has become a vital tool for farmers and researchers. It provides remarkable contributions in the field of agriculture, including optimization of crop management, plant stress monitoring, and pest and disease detection. The early insight gained from VOC profiles enables the farmers to take necessary steps to enhance crop health and overall crop yield and quality.

Furthermore, the application of Plant VOC sensors also extends beyond agriculture to environmental monitoring, precision agriculture, and ecological assessment. The information

provided by VOCs provides deeper insights into the health of ecosystems, plant physiology, and the potential of selective breeding systems. The extended research on Plant – plant communication, and the availability of advanced sensors is prominent in sustainable and efficient agricultural practices.