Diversity of hydrogen sulfide concentration in plant: a little spark to start a prairie fire
Zhuping Jin, Zhiqing Wang, Guangdong Yang, Yanxi Pei
School of Life Science, Shanxi University, Taiyuan 030006, China
Department of Chemistry and Biochemistry, Laurentian University, Sudbury, ON P3E 2C6, Canada

The ubiquitous and versatile signal-transduction role of hydrogen sulfide (H2S) has been revealed in mammals and plants in recent years [1–5]. It is very important to grasp the physiological concentrations of H2S in vivo because of its toxic characteristics at high concentrations. However, the reported data fail to reach an agreement owing to the use of different methods and technique limitations. In fact, this is a common problem for gasotransmitters. What is the exact boundary between the physiological and toxicological concentration? What is the accurate endogenous content? These problems have been plaguing us even though there are a great number of research papers that explore H2S signals. Different H2S concentrations were reported due to different methods and materials used by different research groups, as follows: ~8 nmol min−1 g fresh weight (FW)−1 that was light dependent [6] and 0.02 to 0.2 ng g−1 dry weight s−1 after fumigation with SO2 in cucumber (Cucumis sativus L.) [7]; ~80 nmol/g FW [8] and 1–5 μmol/L [9] in Vicia faba L.; and 1–5 μmol/L in Arabidopsis thaliana [10]. Additionally, 100 μmol/L NaHS was applied in the range of the physiological concentration and became toxic at concentrations >500 μmol/L [9,11].

To systematically determine the physiological concentration of H2S in plants, we selected 17 typical species as experimental materials in this study (Fig. 1a and b). Simultaneously, two widely adopted methods, methylene blue and electrode, were compared. The former is the most classic and commonly used [11–13], and the latter (TBR4100) is real-time and more sensitive [14,15].

Determining the H2S contents of different species is important. It is expected that H2S exists in all plant materials, but there is no significant difference among the species as assessed by the methylene blue method. The whole H2S content ranges from 0.010 to 0.199 μmol g−1 FW (Fig. 1a). Using the electrode method, the H2S content showed a wider range, from 0.177 to 0.708 μmol g−1 FW, in which Platyclus sp. had the highest level and tobacco had the lowest level (Fig. 1b). However, there was still no obvious pattern change between lower plants and higher plants, among materials from different growth environments, species or developmental stages. This suggested that the H2S content in plants in vivo was maintained at a stable level, probably in the range from 0.010 to 0.708 μmol g−1 FW, which corroborates the results of previous reports [6–11].

Different stages from 2-week (w) to 10-w rosette leaves of Arabidopsis were used to determine the development-specific H2S content. Using the methylene blue method, the H2S content in rosette leaves was concentrated at 0.045–0.117 μmol g−1 FW. It was the highest in 2-w-old seedlings, decreased gradually and then remained stable in 4–10-w-old plants. There was a significant difference in that the H2S content of the 2-w-old plants was 2.6 times that of the 6-w-old plants (Fig. 1c). The electrode method’s data showed the same trends, with the H2S content decreasing gradually with development, and the content was concentrated in the range of 0.67–1.978 μmol g−1 FW. The H2S content of 2-w-old plants was 3.3 times that of 6-w-old plants (Fig. 1d). In our previous study, the expression levels of H2S-producing genes increased during plant development [11,16]. This indicated that the transcription of H2S-producing genes and the H2S emissions in vivo are not synchronized.

Different organs of 8-w-old Arabidopsis were used to determine tissue-specific H2S contents. With a range of 0.0089–0.035 μmol g−1 FW, the highest content in flowers was 3.94 times the lowest in rosette leaves as assessed by the methylene blue method (Fig. 1e). A similar trend was found in the results of the electrode method (Fig. 1f). The highest content of H2S in flower, 0.515 μmol g−1FW, was 11 times that of the lowest in cauline leaves, 0.046 μmol g−1 FW. Thus, the H2S content showed tissue-specificity, being higher in the flowers, seeds and roots than in other parts. This trend did not match the expression pattern of H2S-producing genes [11]. The H2S content in reproductive organs was higher than in vegetative organs, which implied that H2S might play an important role during development. This also explained why the H2S content in rosette leaves gradually decreased with development (Fig. 1c and d).

The data of chemical method are indirect results obtained through a series of step pattern “reaction–absorption–reaction–color–detection” according to its measurement principle. Meanwhile, the electrode method requires only one electron exchange step which generates a current showing the real-time change of H2S concentration. It seems that electrode method is more sensitive and the data is more accurate. Anyway, the emission pattern of H2S was similar whether using the chemical or electrode method...
method. H$_2$S was widely presented in all plants and showed a spatial–temporal pattern. The physiological concentration range of H$_2$S remained 0.0089–1.978 µmol g$^{-1}$ FW independent of species, organs and developmental stages. As a result, the H$_2$S content in vivo is on a microscale, which explains the difficulty in developing fluorescent probes. Here, a sharp contrast was found between trace H$_2$S concentrations and its versatile physiological functions.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (31672140 to Jin ZP and 31671605 to Pei YX).

References


Yanxi Pei is a full professor in the School of Life Science, Shanxi University, China. He is working on the function, transduction and application of gasotransmitters, especially focusing on the roles and mechanism of hydrogen sulfide in plants defense against heavy metals stress or drought stress.

Guangdong Yang is an associate professor in the Department of Chemistry and Biochemistry, Laurentian University, Canada. Dr. Yang’s research focuses on the gasotransmitter’s role of H$_2$S in post-translationally modification of proteins as well as the regulation and functions of H$_2$S in cell differentiation and organ development in both health and diseases.

Zhuping Jin is an associate professor in the School of Life Science, Shanxi University, China. Now she works as a post-doctoral fellow supervised by Prof. Rui Wang in Cardiovascular and Metabolic Research Unit (CMRU), Laurentian University, Canada. Her current research interests focus on the mechanism of gasotransmitters in plants under abiotic stress, particularly on the regulation of hydrogen sulfide on stomatal movement.