Original Research Article

Discussion on the potential influence of sampling pipeline diameter on measurement results during canopy photosynthetic gas exchange measurement

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Abstract: This report focuses on discussing the key factor of sampling pipeline diameter in canopy photosynthetic gas exchange measurement. We discussed the influence mechanism of different pipeline diameters on gas collection, transmission, and measurement accuracy was summarized, aiming to provide a basic ideas for optimizing canopy photosynthetic gas exchange measurement methods, improving the reliability and scientificity of relevant research data, and assisting the development of ecosystem photosynthesis research.

Keywords: Canopy photosynthetic gas exchange; Sampling pipeline diameter; Measurement effect; Gas transmission

The process of canopy photosynthetic gas exchange plays a central role in the material cycle and energy flow of terrestrial ecosystems. Plants absorb carbon dioxide and release oxygen through photosynthesis, while also undergoing transpiration. These physiological processes not only affect the growth and development of plants themselves, but also have profound impacts on global climate change, atmospheric composition balance, and ecosystem functional stability. Accurately measuring canopy photosynthetic gas exchange parameters is crucial for a deeper understanding of plant physiological and ecological characteristics, assessing ecosystem productivity, and predicting the impact of global climate change on ecosystems. In the measurement technology of canopy photosynthetic gas exchange, the sampling pipeline serves as a key bridge connecting the measuring instrument and the canopy environment, and its diameter directly affects the collection efficiency and quality of gas samples.

1. The influence of sampling pipeline diameter on gas collection

The diameter of the sampling pipeline is directly related to the gas collection effect. In the case of a relatively small pipeline diameter, the flow process of gas in the sampling pipeline is restricted .On the one hand, if the diameter of the sampling tube is too large, it will cause the gas flow rate to be too fast during the sampling process, making it difficult to uniformly collect gas from different positions of the canopy in a short period of time. There are subtle differences in gas distribution within the canopy, and excessively fast flow rates make the sampling tube more inclined to collect gas from local areas along the flow path, while ignoring other parts, resulting in a lack of representativeness in the collected gas samples and an inability to fully reflect the true composition of canopy gas. In this way, subsequent measurements of various parameters of canopy gas exchange based on the sample, such as carbon dioxide absorption rate, oxygen release, etc., may have errors due to sample bias, greatly affecting the accuracy and reliability of measurement results, which is not conducive to accurate analysis and research of the canopy gas exchange process.On the other hand, when collecting gas with small-diameter pipes, the chance of gas molecules colliding with the pipe wall is relatively increased, resulting in changes in the trajectory of gas molecules and the occurrence of turbulence. Turbulence interferes with the normal collection of gas, causing uneven distribution in the pipeline, which may result in excessive collection in some areas and insufficient collection in others,ultimately leading to deviations in the collected gas samples, which cannot truly reflect the actual concentration and composition ratio of canopy gas, causing significant errors in subsequent measurement and analysis.

2. The influence of sampling pipeline diameter on gas transmission

During gas transmission, the diameter of the sampling pipeline plays a major role. For small-diameter sampling pipes, the internal space is relatively narrow, resulting in high resistance during gas transmission. Just as water flows through narrow pipes and encounters significant frictional forces, the friction between gas molecules and between gas and the pipe wall causes the gas flow velocity to become unstable.The instability of gas flow rate can lead to pressure fluctuations during gas transportation, which can cause gas leakage or backflow, greatly affecting the efficiency and stability of gas transportation.

In the case of unstable gas flow rate and pressure fluctuations, the gas flow rate and pressure delivered to the measuring instrument will fluctuate accordingly, which poses difficulties for the measuring instrument to accurately measure various parameters of the gas. Taking photosynthetic gas exchange measurement as an example, currently commonly used gas analyzers require stable gas flow rate and pressure to accurately test changes in carbon dioxide, oxygen, and other gas concentrations. If the gas transmission is unstable, the gas signal received by the analyzer will deviate, resulting in inaccurate and unreliable measurement results that cannot reflect the true situation of canopy photosynthetic gas exchange.Compared to others, large-diameter sampling tubes can effectively reduce the resistance during gas transmission, allowing gas to be transported at a smoother speed and pressure in the pipeline. The reason is that the internal space of large-diameter pipes is relatively spacious, allowing gas molecules to move more freely, reducing the impact and friction between gas molecules and the pipe wall to ensure stable gas transmission. Stable gas transmission can ensure that the measuring instrument receives stable gas flow and pressure signals, which is conducive to improving the accuracy and repeatability of measurement data, thus providing a reliable guarantee for the accurate evaluation of canopy photosynthetic gas exchange. However, large-diameter pipes also require strong pumping power to maintain stable gas transportation. If the pumping equipment performance is not perfect, it can also cause gas transportation problems and affect measurement results.

3. The common influence of sampling pipeline diameter size on measurement accuracy

The diameter of the sampling pipeline affects the measurement accuracy, which is the result of the combined action of gas collection and transmission. From the perspective of gas collection, if the selection of pipeline diameter is inappropriate, even the most accurate subsequent gas transmission and measurement process is impossible, and the final measurement results cannot truthfully reflect the real situation in the canopy photosynthetic gas exchange process. For example, if the gas sample collected by a small aperture sampling tube cannot accurately represent the composition of the canopy gas, then gas concentration analysis and photosynthetic rate calculation based on these inaccurate samples will produce deviations, resulting in measurement results deviating from the true values.

In terms of gas transmission, the instability of the transmission process can cause fluctuations in the gas signal received by the measuring instrument, thereby introducing measurement errors. Even if the collected gas samples have high accuracy, there are some problems during the transportation process, such as unstable flow rate and pressure fluctuations in small-diameter pipes, which prevent the measuring instrument from accurately measuring gas parameters and also affect the measurement accuracy. Although large-diameter sampling tubes have advantages in gas transmission stability, if they cannot effectively solve the problems of external impurities entering and matching the pumping force, they will also have adverse effects on the accuracy of measurement. Therefore, in order to ensure the measurement accuracy of canopy photosynthetic gas exchange, it is necessary to consider the influence of pipeline diameter on measurement results during gas collection and transportation, select appropriate pipeline diameter, and take corresponding measures to optimize gas collection and transportation conditions. Based on the characteristics of the canopy, environmental conditions, and measurement equipment performance, the selection of pipeline diameters that ensure both gas collection representativeness and stable gas transmission is necessary. At the same time, corresponding filtering measures are taken to prevent impurities from entering the sampling tube, and appropriate exhaust equipment is configured to ensure the required power for gas transmission, minimizing measurement errors, improving the reliability and scientificity of measurement results, and laying a solid data foundation for further research on canopy photosynthetic physiological and ecological processes.

4. Study on the adaptability of pipeline diameter under different environmental conditions

The natural environment's light intensity, temperature, humidity, and wind speed are all in a continuous process of change, which can significantly affect the measurement of canopy photosynthetic gas exchange, thereby making the adaptability of sampling pipeline aperture a key issue.

From the perspective of light intensity, photosynthesis in the canopy is strong under strong light. In practical work, the absorption rate of CO2 needs to be measured within 1-3 minutes to ensure that the dynamic changes in gas exchange can be accurately reflected. Due to the promoting effect of strong light on plant photosynthesis and respiration, the rate of gas release and assimilation significantly increases. If the sampling tube diameter is too small, it may not be able to capture complete information about gas exchange, resulting in under estimation of the key parameters of photosynthesis rate and respiration rate, making the measurement results unable to accurately reflect the physiological state of the canopy[2].

Temperature is still an important environmental factor. Under high temperature conditions, the movement of gas molecules is enhanced and air viscosity decreases, which may cause instability of gas flow velocity in small-diameter sampling tubes and increase measurement errors. In addition, excessive temperature can also lead to an increase in gas diffusion coefficient, thereby affecting the accuracy of gas collection. Therefore, appropriately increasing the diameter of the sampling pipeline and supplementing it with good sealing measures under high temperature conditions can reduce gas leakage and unstable flow rate, and increase measurement reliability. However, a large diameter may make it easier for water vapor to enter the sampling tube in high-temperature and high humidity environments, resulting in an increase in humidity of the gas sample and affecting the measurement accuracy of some gas analysis instruments. Therefore, it is necessary to choose the correct response measures based on the actual situation.

Humidity can also affect the selection of pipeline diameter. In high humidity environments, water vapor is prone to condense on the wall of the sampling tube, especially when the diameter of the pipeline is relatively small. Water vapor condensation may block the pipeline, hinder the normal transportation of gas, and cause measurement data loss or abnormality. At this point, if a larger diameter sampling tube is used in conjunction with appropriate heating or dehumidification devices, it can effectively reduce the problem of water vapor condensation and ensure smooth gas transmission. However, it should be noted that the dehumidification device should not dry the gas sample too much to avoid changing its original properties and affecting its measurement accuracy[3].

5. Conclusion

This study comprehensively explored the influence of changes in sampling pipeline diameter on measurement results in canopy photosynthetic gas exchange measurement, and described the mechanism and performance of pipeline diameter changes on gas collection, transportation, and final measurement accuracy. Through in-depth analysis, it is crucial to clarify the reasonable selection of sampling pipeline diameter for obtaining accurate and reliable canopy photosynthetic gas exchange data. Future research can further optimize pipeline pathways under different environmental conditions and plant species, while combining advanced measurement techniques and equipment to continuously improve the measurement methods of canopy photosynthetic gas exchange, in order to provide more accurate data support for ecosystem research.

References

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