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Research topics

- Removal of volatile organic compounds by plant leaves
- Biogenic VOC emission regarding air quality deterioration
- Wasabi cultivation methods against climate change

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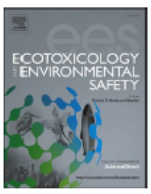

Leaf uptake of atmospheric monocyclic aromatic hydrocarbons depends on plant species and compounds

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ABSTRACT

Large amounts of monocyclic aromatic hydrocarbons (MAHs) are emitted into the atmosphere, but it is unclear which compounds among MAHs are effectively removed by the above-ground parts of plants. Although fumigation experiments of MAHs at unrealistically high concentrations (~ppmv) have been conducted, experiments with ambient concentrations have scarcely been conducted. In the present study, MAHs, including benzene, toluene, phenol, benzaldehyde, and benzyl alcohol, with concentrations ranging from several to several tens ppbv, were individually fumigated to four plant species, and the uptake was monitored using proton-transfer-reaction mass spectrometry and gas chromatography-mass spectrometry. No detectable uptake was observed for benzene and toluene, but phenol, benzaldehyde, and benzyl alcohol were significantly taken up by the plants. The uptake rate normalized to fumigated concentration varied from 3 to 50 mmol $m^{-2}s^{-1}$ during the light period, depending on light intensity and compounds. The difference in uptake capability may be attributed not only to different metabolic activities but also to different values of Henry's law constant, which regulates the partitioning of these compounds into the liquid phase in leaves. The uptake of phenol, benzaldehyde, and benzyl alcohol was affected by stomatal conductance, suggesting that stomatal opening is the main factor regulating the uptake of the three MAHs. This is the first observation that anisole is emitted when phenol is fumigated to *Spathiphyllum clevelandii*, suggesting that phenol is methylated to anisole within plant leaves. Anisole is more volatile than phenol, meaning that methylation enhances the emission of xenobiotics into the atmosphere by converting them to more volatile compounds. This conversion ratio decreased with an increase in phenol concentration (from 1.3 to 143 ppbv). Considering low reaction rate coefficient of anisole with OH radicals and low conversion ratio from phenol to anisole, it is concluded that plants act to effectively remove oxygenated MAHs from the atmosphere.

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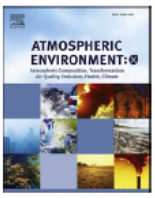

An absorption model of volatile organic compound by plant leaf: The most influential site in the absorption pathway

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Fick's first law of diffusion
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ABSTRACT

Plant leaves absorb some kinds of volatile organic compounds (VOCs) and can contribute to air purification, as revealed by recent exposure experiments conducted at environmentally realistic concentrations in ppb (v/v). However, the mechanisms underlying VOC absorption by plants remain unclear. In this study, we applied Fick's first law of diffusion to a VOC absorption model for plant leaves to account for the VOC diffusion process via stomata, air-liquid partitioning, partitioning into the plasma membrane, and metabolic conversion of the VOC in plant cells. The resistance and concentration of VOCs at individual sites were determined using previously reported absorption data for aliphatic aldehydes and ketones in three plant species and the leaf morphology parameters obtained from leaf cross-section micrographs. The highest resistance occurred at the metabolic site (r_{met}), suggesting that VOC metabolic capacity is the most influential factor in VOC absorption. The resistance of stomata (r_s) or plasma membrane (r_{pl}) was the second highest, depending on compound family. Using the absorption rate data of *Q. acutissima*, it is revealed that metabolic site resistance r_{met} for methyl vinyl ketone is affected by light intensity. Thus, our VOC absorption model can determine the most influential site in the absorption pathway both for different VOCs and plant species. Our model can contribute to the development of plant-based strategies for controlling air pollution.

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Uptake of Aldehydes and Ketones at Typical Indoor Concentrations by Houseplants

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The uptake rates of low-molecular weight aldehydes and ketones by peace lily (*Spathiphyllum clevelandii*) and golden pothos (*Epipremnum aureum*) leaves at typical indoor ambient concentrations (10^1—10^2 ppbv) were determined. The C3—C6 aldehydes and C4—C6 ketones were taken up by the plant leaves, but the C3 ketone acetone was not. The uptake rate normalized to the ambient concentration C_a ranged from 7 to 19 mmol m^{-2} s^{-1} and from 2 to 7 mmol m^{-2} s^{-1} for the aldehydes and ketones, respectively. Longer-term fumigation results revealed that the total uptake amounts were 30—100 times as much as the amounts dissolved in the leaf, suggesting that volatile organic carbons are metabolized in the leaf and/or translocated through the petiole. The ratio of the intercellular concentration to the external (ambient) concentration (C_i/C_a) was significantly lower for most aldehydes than for most ketones. In particular, a linear unsaturated aldehyde, crotonaldehyde, had a C_i/C_a ratio of ~0, probably because of its highest solubility in water.

(*4*) and ketones (*5*) from the atmosphere, and it has even been suggested that plants may be used to cleanse indoor air of pollutant VOCs (*6*), although the experimental evidence for this is rather tenuous. However, few quantitative and reliable measurements have been made of the uptake rates of low-molecular weight aldehydes and ketones by indoor house plants.

To measure VOC uptake rates by plants, two methods have been applied. The first is the static chamber method, in which VOC concentrations in the chamber are periodically measured and the uptake rate determined from the rate of change in VOC concentrations in the chamber (*7, 8*). Loss of soluble compounds to condensed water, soil, and other surfaces is likely to be major problem with this method. The second method uses a flow-through chamber (*4, 9, 10*) in which the VOC uptake rate is determined from the concentration difference between the inflowing and outflowing air (*4, 10*). Condensation is easier to avoid with this method.

Most previous plant uptake studies have been conducted at unrealistically high concentrations of VOCs (mixing ratios of 10^{-6}) because of the sensitivity limitations of, for example, gas chromatography. However, a highly sensitive and rapid analytical method, proton transfer reaction mass spectrometry (PTR-MS), allows the determination of VOC concentrations at mixing ratios of around 10^{-8} (10 ppbv) with a precision of 1—1.5% in humid air (*10, 11*). In order to investigate the uptake capacity of house plants for low-molecular weight ketones and aldehydes at typical indoor mixing ratios of 10^{-8} to 10^{-7} (10—100 ppbv), we used PTR-MS combined with a flow through chamber method.

Experimental Section

Plant Materials. Four plants (50—70 cm height) were obtained of each of the common houseplant species peace lily (*Spathiphyllum clevelandii*) and golden pothos (*Epipremnum aureum*). The plants were acclimated to indoor air for one month prior to the experiments.

Open Access

Review Paper

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Review: Exchanges of volatile organic compounds between terrestrial ecosystems and the atmosphere

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Abstract

Many VOCs are reactive in the atmosphere, may produce secondary organic aerosol (SOA), and keep photochemical ozone concentrations high by VOC-involved reactions. Accumulated studies have shown the importance of terrestrial ecosystems which can be sinks and sources of VOCs. The research progress in the exchange of volatile organic compounds (VOCs) between terrestrial ecosystems and the atmosphere was reviewed in this paper. Representative VOCs emitted from terrestrial ecosystems are low-molecular-weight oxygenated VOCs including methanol, acetone, formic and acetic acids, and terpenoids, including isoprene and monoterpenes. Terpenoid emissions have been intensively investigated from the leaf to the canopy level using advanced analytical systems, including proton-transfer-reaction mass spectrometry. Environmental factors, including temperature, light intensity, carbon dioxide and ozone concentrations, and water stress have been reported to affect terpenoid emissions from plants. The combined effects of these environments influence terpenoid emission additively or interactively, and are important in terms of VOC emission estimates against ongoing climate change. Isoprene is most abundantly released into the atmosphere among VOCs; the potential reasons why some plants release such large amounts of carbon as isoprene were summarized in this study. Among oxygenated VOCs, some compounds, including isoprene oxygenates methacrolein and methyl vinyl ketone, are bidirectionally exchanged, and both atmospheric chemical reactions and reactions under oxidative stress in leaves have been regarded as involved in bidirectional VOC exchanges. Bottom-up process-based models and top-down inverse models have been developed to estimate global and local terpenoid emissions. To validate the accuracy and precision of the models, the collection of additional in-situ ground truth data, such as long-term flux measurement data, at various sites is required. Otherwise, these models may still leave large uncertainties compared with CO_2 flux models that can be validated with a large number of ground truth flux data.

Key words: Bidirectional exchange, Canopy flux, Isoprene, Monoterpene, Process-based models, Volatile organic compounds

Eco-Engineering, 34(1), 1-9, 2022

原著論文

ワサビ稚苗の生育に及ぼす気温の影響

Effect of air temperature on the growth of wasabi seedlings

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ABSTRACT

To clarify optimum temperature range for the growth of Wasabi (*Eutrema japonicum* (Miq.) Koidz.) seedlings, the seedlings of a cultivar Izuma and a selected strain Shizuoka A were grown in various temperature conditions. In experiment 1, daytime /nighttime temperatures were kept 15℃/15℃, 20℃/15℃, 25℃/20℃, 30℃/25℃ and 30℃/20℃. Fresh and dry weights of Izuma were highest at 20℃/15℃ and significantly lower at higher temperature treatments (25℃/20℃, 30℃/25℃ and 30℃/20℃). Chlorophyll content of the identical leaves at 25℃/20℃, 30℃/25℃ and 30℃/20℃ decreased with days after the start of the experiment. Fresh and dry weights of Shizuoka A were highest at 15℃/15℃ and significantly lower at higher temperature treatments (25℃/20℃, 30℃/25℃ and 30℃/20℃). Chlorophyll content of the identical leaves at 30℃/25℃ decreased with days. In experiment 2, nighttime temperature was kept 15℃ and daytime temperature was set 15℃, 20℃, 25℃ and 30℃. No significant differences in fresh and dry weights of Izuma were observed between 15/15, 20/15 and 25/15, and they were significantly higher than those at 30/15. This is also the case of Shizuoka A. Chlorophyll content of the identical leaves was kept almost constant during the experiment, suggesting that low nighttime temperature can inhibit chlorophyll degradation. By combining the two experimental results, the optimum temperature range for Izuma was determined to be 15℃ nighttime temperature coupled with 15–30℃ daytime temperature. The optimum temperature range for Shizuoka A was determined to include 25℃ daytime and 20℃ nighttime temperature, in addition to the above temperature range. The difference in the optimum temperature range between the two strains may be due to the difference of high temperature tolerance.

Eco-Engineering, 36(1), 1-8, 2024

原著論文

二酸化炭素濃度、光強度および培養液濃度が、制御環境下でのワサビ苗の生育に及ぼす影響

Effects of carbon dioxide concentration, light intensity, and nutrient solution strength on growth of wasabi seedlings cultivated under controlled environment

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ABSTRACT

To investigate effects of CO_2 concentration, light intensity, and nutrient solution strength on the growth of wasabi (*Eutrema japonicum* (Miq.) Koidz.) seedlings, they were grown in environmentally controlled chambers. In the first experiment, single effect of CO_2 concentration on growth of wasabi cultivar 'Izuma' was investigated. The dry weight of the whole seedling was increased more under enriched CO_2 concentrations (1000 and 2000 ppm (v/v)) than under ambient CO_2 concentration (400 ppm). However, the CO_2 effect to raise photosynthesis was weakened in the latter half of the experiment. To sustain the effect of the enriched CO_2 throughout the whole seedling cultivation period and maximize the wasabi seedling growth, the wasabi seedlings were grown under different light intensities and different nutrient solution strengths in the second experiment. Two wasabi cultivars 'Izuma' and 'Fujimidori' were used. 'Fujimidori' is a newly developed cultivar that is more tolerant to high temperatures. The results revealed that 'Fujimidori' had the highest whole dry weight under enriched CO_2 concentration (1000 ppm), higher light intensity (200 μmol m^{-2} s^{-1}), and higher concentration of the nutrient solution. Contrary, the whole dry weight of 'Izuma' under such environmental conditions was almost the same as that of 'Izuma' grown under a lower concentration of nutrient solution but enriched CO_2 concentration and higher light intensity, and under lower light intensity but enriched CO_2 concentration and higher concentration of nutrient solution. This suggests that a combination of a higher concentration of the nutrient solution and higher light intensity cannot amplify the CO_2 effect on 'Izuma' growth. The difference in the environmental response between the two cultivars seemed to be partially caused by the different temperature tolerances.

Key words : CO_2 concentration, Light intensity, Nutrient solution strength, Net photosynthetic rate, Cultivar