



**ISSN:2229-6107**



**INTERNATIONAL JOURNAL OF  
PURE AND APPLIED SCIENCE & TECHNOLOGY**

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## **INSECTS AS BIO-INDICATORS OF CO<sub>2</sub> AND SO<sub>2</sub> CONCENTRATIONS**

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### **ABSTRACT**

The majority of known insect species are herbivorous, therefore factors that disturb plant physiology have effects on insect fauna relying on plants. A substantial amount of literature indicates that insect herbivore abundance often increases when the host plant is subjected to some abiotic stress. Insect outbreaks have been observed in the surroundings of polluted industrial areas and along highways. Species feeding plant phloem or species that mine or bore in living plant tissues have been more successful on pollutant-exposed plants than chewing insect herbivores. Phloem-feeding aphids are good indicators of pollutant stress on many plant species. Sulphur-dioxide (SO<sub>2</sub>), oxides of nitrogen, fluorides, or mixtures of pollutants have often promoted aphid performance. SO<sub>2</sub> exposures have shown that response curve of aphids is bell shaped, with a peak at an air concentration of 100 nL L<sup>-1</sup>. On the other hand, observations of aphid performance on ozone (O<sub>3</sub>) exposed plants have given very confusing results. Depending on the duration and concentration of O<sub>3</sub> exposure or the age of the exposed plants, aphid growth on the same plants can be decreased or increased compared with control plants grown in O<sub>3</sub>-free air. Increasing carbon dioxide (CO<sub>2</sub>) levels in the atmosphere increase the carbon–nitrogen ratio in plants, and this has resulted in reduced growth of the larvae of chewing insects despite the fact that the consumption of nitrogen-defiant plant foliage and subsequent plant injury is increased. The effects of CO<sub>2</sub> on aphids and their natural enemies are still poorly known.

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**Keywords:** Insect Fauna, indicator, pollution, injury.

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### **INTRODUCTION**

Insects are the most diverse group of organisms to maintain biodiversity on earth. There are 9,00,000 currently known insect species, forming about 80% of the

world's species. Floral scents provide insect and animal pollinators the necessary cues about location and identity of plant species.

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Other ecological functions of volatile organic compounds include protection of foliage against abiotic stresses such as high solar radiation loadings and elevated temperature (Sharkey *et al.*, 2001) or oxidative stress (Loreto *et al.*, 2001). The type of pollutant determines whether the effect of that pollutant is expected locally or on a wider scale. While concentrations of CO<sub>2</sub> and UV-B exposure are rising globally, local concentrations of oxides of nitrogen and sulfur are still rising in other industrialized areas of the world. One of the first observations of insect outbreaks on plants exposed to air pollution was an outbreak of the spruce-needle-mining moth, *Epinotia tedella*, in 1831 in a smoke damaged young spruce stand in Germany. Since then there have been numerous reports of insect damage in forests that have been exposed to SO<sub>2</sub>, oxides of nitrogen, fluorides, or heavy metals in the vicinity of industrial areas. El-shazly (2000) also used fractionation of ethanolic extract of *Nerium oleander* for screening of insecticidal activity. Neriifolin was also isolated from the evolution of scent plumes under the influences of varying levels of turbulence mixing and chemical reactions at small spatial scales, thereby providing detailed information of floral scent plume composition with high temporal and spatial resolution. Therefore, in the absence of detailed information from field observations, LES outputs are the most reliable source of information for studying transport and chemical degradation of scent plumes. A random walk model is developed and applied to compute foraging times based on insect detection threshold of floral scents and modified *scentscape* simplicity and convenience, for a given scenario, the ambient mixing ratios of OH and O<sub>3</sub>.

## MATERIALS AND METHODS

### Pollution scenarios

Six scenarios (Table 1) are considered to determine changes in scents in response to varying levels of air pollutants as air parcels travel away from flowers. The first scenario (Sc0) considers no air pollutants to determine the spatial variation of floral volatiles away from sources in response to turbulent transport and to serve as the basis for comparison with the rest of scenarios. The second scenario (Sc1) includes 20 pp per billion(ppbv) of O<sub>3</sub>, 0.02 part per trillion on a volume basis (pptv) ( $5.0 \times 10^5$  radicals cm<sup>-3</sup>) of OH, and 0 pptv of NO<sub>3</sub>. This scenario may be viewed as the prevailing O<sub>3</sub> levels during pre-industrial times (Marenco *et al.*, 1994), with limited photochemical activity (and hence low OH levels) and no nitrogen oxides to generate NO<sub>3</sub>. The third scenario (Sc2) involves the levels radicals cm<sup>-3</sup>), 60 ppbv, and 1 pptv for HO, O<sub>3</sub>, and NO<sub>3</sub>, the fifth of 0.2 pptv ( $5.0 \times 10^6$  radicals cm<sup>-3</sup>), 40 ppbv, and 0 pptv of OH, O<sub>3</sub>, and NO<sub>3</sub>, respectively. The fourth scenario (Sc3) uses the levels of 0.3 pptv ( $1.0 \times 10^7$  radicals cm<sup>-3</sup>), 60 ppbv, and 1 pptv for HO, O<sub>3</sub>, and NO<sub>3</sub>, respectively. The fifth scenario (Sc4) involves the levels of 0.40 pptv ( $2.0 \times 10^7$  radicals cm<sup>-3</sup>), 80 ppbv, and 2 pptv for OH, O<sub>3</sub>, and NO<sub>3</sub>, respectively. The last scenario

(Sc5) involves the levels of 0.80 pptv ( $2.0 \times 10^7$  radicals  $\text{cm}^{-3}$ ), 120 ppbv, and 5 pptv for OH, O<sub>3</sub>, and NO<sub>3</sub>, respectively. We chose these last two scenarios to reflect the broad ranges in air pollutant deviations from pre-industrial times (Marenco *et al.*, 1994; Prinn *et al.*, 2005) to current summer conditions where maximum

O<sub>3</sub> levels can sometimes exceed 120 ppbv (Fiore *et al.*, 2002). Pollutants are assumed to logarithmically vary with altitude, and the values listed here are specified at a height  $z = 1.5\text{m}$  (the value at the top of the domain is twice the value at 1.5m). For NO<sub>3</sub> remain constant in time and space throughout the course of model simulations.

**Table 1:** Ambient mixing ratios of the ozone, hydroxyl radical, and nitrate radical

Scenario	O <sub>3</sub> (ppbv)	HO (pptv)	NO <sub>3</sub> (pptv)
Sc0	0	0.00	0
Sc1	20	0.02	0
Sc2	40	0.20	0
Sc3	60	0.30	0
Sc4	80	0.40	1
Sc5	120	0.80	2

included in the scenarios of the numerical simulations.included in the scenarios.

## RESULTS AND DISCUSSION

### Chemical degradation of floral volatiles

The chemical degradation of floral scents depends on the reactivity of volatiles and ambient levels of air pollutants. For the chosen air pollutant levels, floral species chemicals exhibit a broad range of lifetimes (for the reaction with O<sub>3</sub>, the individual floral scent ( $\chi_i$ ) lifetime is defined as  $T_{\chi_i, O_3} = (K_{\chi_i, O_3} [O_3])^{-1}$ ; similar expressions can be defined for  $T_{\chi_i, OH}$  and

$T_{\chi_i, NO_3}$ ). Concerning the O<sub>3</sub> reactivity,  $\beta$ -caryophyllene is the most reactive scent and its lifetime decreases from 12 to 2 minutes for O<sub>3</sub> levels between 5 and 120 ppbv. Linalool,  $\beta$ -ocimene, and  $\beta$ -myrcene have an intermediate reactivity with respect to O<sub>3</sub> and their lifetimes vary from 200 to 10 minutes when O<sub>3</sub> changes from 5 to 120 ppbv. In these simulations,  $\alpha$ -pinene is the

least reactive with  $O_3$  and its lifetime changes from 30 to 1 hours for  $O_3$  levels between 5 and 120 ppbv. With regard to the OH reactivity,  $\beta$ -ocimene,  $\beta$ -myrcene, and  $\beta$ -caryophyllene are the most short lived scents and their lifetimes range from 50 hours to 5 minutes when OH changes from 0.001 to 0.8 pptv. Concerning the  $NO_3$  reactivity,  $\beta$ -ocimene and  $\beta$ -caryophyllene are the most reactive species and their lifetimes range from 18 hours to 5 minutes as  $NO_3$  varies from 0.01 to 5 pptv. In polluted air masses (i.e.,  $[OH] > 0.3$  pptv), all floral scents have lifetimes of few ( $< 30$ ) minutes. Source strength of floral volatiles, levels of air turbulence, and rates of chemical reactions dictate the three-dimensional characteristics of the scents downwind from sources. For example, iso-surfaces of time averaged scent mixing ratios in the three-dimensional space (i.e., a surface formed by all the points with a chosen constant gas mixing ratio value) downwind from the chosen floral patches. Blue iso-surfaces represent mixing ratios of 0.6 pptv for myrcene and  $\beta$ -caryophyllene (under the influences of scenarios Sc0, Sc3, and Sc5), indicating that all the points inside the blue surface have scent

levels above 0.6 pptv and all the points outside the surface have scent mixing ratios below 0.6 pptv.

Air pollutant levels and reactivity of floral scents exert control on the spatial extent of floral volatile transported away from sources. Horizontal cross sections provide the spatial distribution of floral scents downwind from sources under the influences of different levels of air pollutants. To some extent, they represent the *scentscape* that insects can detect while foraging for food resources. The unpolluted case (Sc0) serves as a basis for comparison and shows similar spatial distributions of  $\beta$ -myrcene and  $\beta$ -caryophyllene, confirming that the difference in source strength between the two compounds is not the dominant factor in determining their spatial distributions. Under moderate levels of air pollutant (Sc3), significant levels of  $\beta$ -myrcene ( $\sim 1$  pptv) can reach about 800 m downwind from floral sources whereas similar levels of  $\beta$ -caryophyllene reach at most 100 m downwind from sources. The most dramatic effect occurs in polluted air masses (Sc6) when plumes of  $\beta$ -myrcene remain within 400 m of scent sources; in contrast, plumes of

$\beta$ -caryophyllene can only be found directly above the floral patches.

For those insects that have evolved to rely upon the unique signature of a specific flower, a change in the composition of these scents could be troubling, depending upon how sensitive their antennae are to detecting particular compounds (Skiri *et al.* (2005) and their tolerance for shifts in relative concentration among plume components. Many insect species hone in on specific scents because it increases their likelihood of being consistently rewarded. If particular flowers are proven to be reliable sources of nectar for foraging insects then they can train themselves to that specific scent, what is known as flower constancy (Gegear and Laverly, 2005). In polluted conditions, however, the plume of floral volatiles may no longer be recognized as such because its composition no longer corresponds to the scent that insects associate with a particular flower. Moreover, because plant odors mediate both mutualistic and antagonistic relationships between plants and insects, a disruption in the communication system could either help or hurt plants depending on which insects are most affected. In cases where antagonists and mutualists respond to different volatiles from the

same plant (e.g.) Andrews *et al.* (2007), the outcome will depend partly on the reactivity of the different compounds. More generally, however, mutualistic relationships may be more sensitive to disruption because they typically rely on repeated tracking of scent to source (e.g., pollinators and natural enemies searching for new resources) whereas antagonists such as herbivores may find sufficient resources at a single resource once discovered and rely less on long-distance plant signals from that point forward.

This study concludes that even moderate air pollutant levels (e.g.,  $[O_3] > 60$  ppbv) substantially degrade the chemical constituents of released floral scents. The chemical degradation of floral volatiles contributes to substantial reductions in the concentrations of scents as they are transported away from sources. Decreases in scent abundances away from sources show steeper decreases with increasing levels of air pollutants. In the most polluted air masses ( $[O_3] = 120$  ppbv), compounds such as  $\beta$ -ocimene decrease to 25 % of the original abundance within a downwind distance of 100 m from sources whereas  $\beta$ -caryophyllene retains only 10 % of the original amount within 50

m of sources. In all scenarios examined, concentrations of the studied floral volatiles substantially decrease in response to increasing levels of air pollutants and rates of scent destruction depend on gas reactivity with respect to O<sub>3</sub>, OH, and NO<sub>3</sub>.

Our simulations indicate that air pollution will have the greatest impact on patch discovery time when highly reactive volatiles elicit foraging responses at low scent concentrations. Increased discovery time of flower patches may have pernicious effects on insects. Thus, pollution may reduce insect fitness through changes in food detectability. Similarly, insects needing to locate a scent plume only once to complete a life stage, such as ovipositing in a flower just prior to death, might be less affected than those that must repeatedly locate flowers, given that the inherent advantage of insects finding a bigger plume target would be compounded by repetition. Additionally, insects that wander throughout the landscape searching for odor plumes each time a resource is needed may be more affected than central-place foragers that locate resource patches and return to them repeatedly using spatial memory.

Overall, we predict that existing air pollution levels in urban and industrial corridors can have deleterious impacts on insect efficiency and on plant-insect interactions. Levels of ambient pollutants, types of volatiles comprising the scent plume, sensitivity of insect antennae to plume constituents, the abundance of host plants in the environment and the air conditions (windy versus calm) of the location may all differentially impact the extent of the negative ecological impacts.

## REFERENCES

- Andrews, E. S., Theis, N., Adler, L. S., 2007. Pollinator and herbivore attraction to cucurbit floral volatiles. *Journal of chemical ecology* 33 (9), 1682–1691.
- Byers, K. J., Bradshaw, H., Riffell, J. A., 2014. Three floral volatiles contribute to differential pollinator attraction in monkey flowers (*mimulus*). *The Journal of experimental biology* 217 (4), 614–623
- Chen, C., Song, Q., Proffit, M., Bessi`ere, J.-M., Li, Z., Hossaert-McKey, M., 2009. Private channel: a single unusual compound assures

- specific pollinator attraction in *Ficus semicordata*. *Functional Ecology* 23 (5), 941–950
- Cunningham, J. P., Moore, C. J., Zalucki, M. P., West, S. A., 2004. Learning, odour preference and flower foraging in moths. *Journal of Experimental Biology* 207 (1), 87–94.
- Dunn, D. W., Jand'ér, K. C., Lamas, A. G., Pereira, R. A., 2014. Mortal combat and competition for oviposition sites in female pollinating fig wasps. *Behavioral Ecology*, 35(3), 5–10.
- Farré-Armengol, G., Peñuelas, J., Li, T., Yli-Piril, P., Filella, I., Llusia, J., Blande, J. D., 2016. Ozone degrades floral scent and reduces pollinator attraction to flowers. *New Phytologist* 209 (1), 152–160.
- Fiore, A. M., Jacob, D. J., Bey, I., Yantosca, R. M., Field, B. D., Fusco, A. C., Wilkinson, J. G., 2002. Background ozone over the United States in summer: Origin, trend, and contribution to pollution episodes. *Journal of Geophysical Research: Atmospheres* 135(3), 7-11.
- Fuentes, J. D., Roulston, T. H., Zenker, J., 2013. Ozone impedes the ability of a herbivore to find its host. *Environmental Research Letters* 8 (1), 4048.
- Loreto, F., Mannozi, M., Maris, C., Nascetti, P., Ferranti, F., Pasqualini, S., 2001. Ozone quenching properties of isoprene and its antioxidant role in leaves. *Plant Physiology* 126 (3), 993–1000.
- Maia, A. C. D., de Lima, C. T., Navarro, D. M. d. A. F., Chartier, M., Giulietti, A. M., Machado, I. C., 2014. The floral scents of *Nymphaea hydrocallis* (nymphaeaceae), the new world night-blooming water lilies, and their relation with putative pollinators. *Phytochemistry* 103, 67–75.