Evidences and implications of vegetation damage from ceramic industrial emission on a rural site in the Pearl River Delta of China

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Abstract: Community structure characteristics and vegetation damage degree were investigated and analyzed in a forest around village, which had been long term exposed to ambient atmospheric pollution stress, to study the influence of airborne pollutant emissions from the concentrated ceramic industries on vegetation. Field survey was carried out in a semi-natural secondary forest on hilly land, Nanhai District of Guangdong Province, for the tree layer in ten quadrates with the total area of 10×(10 m×10 m), and for shrub and herb layers in eight subquadrates with the total area of 4×(5 m×5 m). Results showed that exotic *Eucalyptus exserta* and *Eucalyptus urophylla* were dominated over the community, followed by native tree species, *Schefflera octophylla* and *Bambusa gibba*, with the importance value (I_V) of 26.75, 17.08, 16.27 and 11.50, respectively. Among all tree species, *Eucalyptus exserta* and *Pinus massoniana* were most severely damaged with nearly 100% damaged rate. *Bambusa gibba* and *Dalbergia balansae* were injured with damaged rate of 85.1%—68.3%, however, *Eucalyptus urophylla*, *Celtis sinensis*, *Helicia cochinchinensis*, *Cinnamomum burmanni* and *Vitex negundo* revealed moderate injuries (45%—57.5%). Most of other indigenous species including *Schefflera octophylla*, *Viburnum odoratissimum*, *Desmos chinensis*, etc. showed less injured symptoms under the pollution stress. Compared with species in tree layer, damages of undergrowths were largely less. These results suggested that attention and concern should be paid on those introduced *Eucalyptus* species which had ever been widely used for forest restoration in degraded hilly lands of south China since 1970–1980s, due to their fast growing aspect. The results also demonstrated the potentials and perspectives by developing native species as target plants for restoration of degraded area at similar polluted location, which may provide scientific base for scientists to study and understand the functional aspects of native species and process-based interactions with pollution stress.

Keywords: Airborne emission; Ceramic industry; Vegetation damage; Pearl River Delta

CLC number: X503.23 **Document Code:** A **Article ID:** 1007-662X(2006)01-0007-06

Introduction

Atmospheric pollution has been of a major problem in the Pearl River Delta of south China, particularly during the last two decades. Rapid industrialization and urbanization in the Delta area have largely enhanced people's living standard and socio-economic development. However, it has caused environmental pollution, which has already led to extensive damages on natural communities and environments, threatened wildness habitats and ecosystem services in a wide range of the Delta area (Yuan 2002). Ma (2002) reported that there were 94 ceramic factories and over 300 burning kilns within the scale of 78 km^2. Further expansion of large production centers and the rapid growing up of newly-built ceramic factories in the area had largely increased the emission of atmospheric SO_2, HF and heavy metals deposited with the dusts, which may accelerate local forest damage and ecosystem deterioration, and may hamper the sustainable development of economy and environmental resources. Therefore, evaluation of vegetation damage and alternatives for restoring the heavily damaged and degraded forest ecosystems are of the significance and urgency.

Leaves and crowns of forest are the active interface of energy, carbon and water exchanges between forest canopies and the atmosphere, which are more sensitive and react promptly to abiotic and biotic disturbance more than other stand structural components (Cutini 2002). Forest damage and its underlying mechanisms induced by atmospheric pollution have been extensively studied for decades at both local and global scales, particularly in American and European countries. Some investigators studied canopy properties and crown productivity to evaluate the quality of an ecosystem and its function status (Waring 1983; 1989; Aber *et al.* 1989; Romane 1995), while others analyzed the relationship between crown characteristics and atmospheric pollution to assess forest injuries (de Vries *et al.* 1999; UN/ECE and EC 1998; Solberg 1999). In the case of China, the serious environmental damage and economic costs of atmospheric pollution have prompted researches on assessing impacts of air pollution on plant vitality and forest ecosystem functions (e.g. Liu *et al.* 1989; Zhang *et al.* 1995; Yan *et al.* 1996; Luo *et al.* 2001). However, much of this work has mainly focused on the resistance or tolerance of species on the basis of their visible symptom injury caused by air pollution stress. Assessments on vegetation decline and natural forest ecosystem health are still limited, especially in some parts of the Pearl River Delta which have be affected by long-term atmospheric emission pollutants.

This study aimed to (1) characterize the structure properties of plant community under long -term air pollution in the field; (2) assess vegetation damage of different species along the vertical

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Foundtion item: This work was supported by Natural Science Foundation of China (30370283), Natural Science Foundation of Guangdong Province (04002306), and the Special Fund for the Development of Science and Technology of Foshan (03020091).

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Received date: 2005-07-11; **Accepted data**: 2005-08-26

Responsible editor: Zhu Hong

stand profile; (3) analyze possible explanations on forest damages and reveal the potentials of some native species in phytorestoration of heavily degraded ecosystems. The expected results may provide baseline information for local resource management and restoration actions in degraded areas caused by air pollution throughout the Pear River Delta.

Methods

Site description

The study area is approximately at 40 km in west of Guangzhou, Guangdong Province of China, adjacent to a group of ceramic-kilns in Wuxing Town, Nanhai District of Guangdong Province (112°58'E, 22°55'N). Plots for assessment of vegetation damage were established in a village-nearby forest that was situated in the low hilly lands. The topography and geology of this area are relatively homogeneous. The underlying bedrock is sandstone; red soils are dominated throughout the area. The climate of this area is lower subtropical monsoon with warm and humid, southeast and southwest winds in summer. And rich rainfall appears in the summer and early autumn. According to Nanhai meteorological monitoring data in 2001, the annual average temperature is 23.1 °C with the maximum in July and minimum in January. The mean annual precipitation is 2202.2 mm, with 83% allocation in the flood and wet season (April to September). Winds at the ceramic plants are dominantly from the SE in the summer and NW in the winter. The study area was impacted by continuous emissions and deposition of gaseous and particulates from the concentrated ceramic industries, which resulted in large-scale vegetation damage in surrounding areas. The monitoring data during the growing season showed that the average sulfating rate, fluorine content and total suspended particles deposition at the polluted site were 14.4, 17.4 and 2.7 times respectively, remarkably higher than those at the clean site, greatly exceeded the recommended national standard level (Table 1).

Table 1. Sulfating rate, and the deposition of fluorine compound and dust at the polluted and the clean sites

Site	Sulfating rate ($mg \cdot dm^{-2} \cdot d^{-1}$)	Fluorine compound ($\mu g \cdot dm^{-2} \cdot d^{-1}$)	Dust deposition ($t \cdot km^{-2} \cdot mon^{-1}$)
Polluted site (Wuxing, Nanhai)	2.16 (0.52)	44.13 (16.46)	20.09 (9.34)
Clean site (Botanical Garden, Guangzhou)	0.14 (0.10)	2.53 (0.82)	7.27 (3.79)
National standard (recommended)	0.25	3.0	8.0

Notes. Values for sulfating rate and fluorine compound are calculated as the content of SO_3 and F, respectively, and expressed as the mean from June to October, 2002, with standard deviation in brackets. The monitoring and measurements were carried out according to methods presented by Ministry of Urban and Rural Construction and Environmental Protection, PRC (1986).

Plot survey

Plot survey was carried out in October 2002 on the basis of the standardized methods on "Survey, Observation and Analysis of Terrestrial Biocommunities of the Chinese Ecosystem Research Network" (Dong *et al.* 1996). Ten quadrates with total area of 10 ×(10m×10m) were established for survey and sampling of the tree layer. Then, eight quadrates were randomly selected from the above ten and each was further divided into four subquadrates with total area of 4×(5m×5m). One representative subquadrate was selected from each of the four subquadrates for the survey of shrubs which was more than 50 cm in height and less than 1.0 cm in diameter at breast height (DBH), and for that of the herb layer which is less than 50 cm in height. All tree species including seedlings greater than 1.0 cm in DBH was identified, and their DBH, height, and crown size at cross-section were measured and recorded in a given study plot. Undergrowths were directly measured in terms of abundance, coverage frequence, and height for shrubs, seedlings and herbs. Definitions and formulae used for community structure analyses were on the basis of Francisco (1992), Kong *et al.* (1997) and Song *et al.* (2001), listed as follows:

$$A_R = \frac{A}{\sum A} \times 100\ \% \tag{1}$$

$$D_R = \frac{D}{\sum D} \times 100\ \% \tag{2}$$

$$C_R = \frac{C}{\sum C} \times 100\ \% \tag{3}$$

$$F_R = \frac{F}{\sum F} \times 100\ \% \tag{4}$$

$$I_V = \frac{A_R + D_R + F_R}{3} \times 100\ \% \tag{5}$$

where, A, D, C and F represent individuals, sum of basal area, coverage and frequence of a single species, respectively; $\sum A$, $\sum D$, $\sum C$ and $\sum F$ are defined as total individuals, total basal area (Basal area=stem area at breast height (1.3 m)), sum of the coverage and sum of the frequence of total species, respectively; A_R, D_R, C_R, F_R, and I_V symbolize relative abundance, relative dominance, relative coverage, relative frequence and importance value, respectively. In formulae (5), C_R substitutes for D_R, when calculating the I_V of the shrubs and herbs.

Assessment of vegetation damage

An assessment of vegetation damage was carried out at the level of individuals on the basis of the presence of leaf chlorosis and necrosis, the proportion of foliage defoliation and the dieback of woody tissues at the crown profile. The vegetation damage was visually estimated and recorded in 10% classification according to the proportion of the injured leaf area to the total leaf area in the plant crown (UN/ECE and EC 2000). The causes leading to the injured symptoms were also recorded. As air pollution may cause direct and/or indirect effects on herbivores, the symptom and degree of plants injury induced by insects were also recorded. Other possible causes that aid cause-effect explanations, such as twisting and shading, were also recorded.

Classification of vegetation damage

The average damage degree of each species was calculated by the total amount of the injured species and the related damage classification in the same plot. The assessment standards of forest damage were obtained according to the Europe Five Classification (Yang *et al.* 2000), (Table 2).

Results and discussion

Species composition

In the tree layer, *Eucalyptus urophylla*, *Bambusa gibba* and *Schefflera octophylla* had the highest relative abundance, followed by the species of *Eucalyptus exserta*, *Mallotus apelta*, *Celtis sinensis*, *Vitex negundo* and *Syplocis lancifolia* (Table 3).

Analysis of the relative dominance showed that *Eucalyptus urophylla*, *Eucalyptus exserta* and *Schefflera octophylla* accounted for more than 90% of the total, suggesting that these species were dominated the community. *Eucalyptus urophylla*, *Schefflera octophylla*, *Mallotus apelta*, *Syplocis lancifolia* and *Eucalyptus exserta* were higher in relative frequency, with the range of 8.22%–13.7%, showing these species were more spatially homogeneous than other species. The relative frequency for each of *Bambusa gibba*, *Celtis sinensis*, *Vitex negundo*, *Aporosa dioica*, *Carallia brachiata*, *Broussonetia papyrifera* and *Trema tomentosa* was around 5%, followed by other companion species, whose value was less than 3%. *Bambusa gibba* had greate number of individuals compared with other species, but its relative frequency was not high, since bamboos clustered in the community. *Eucalyptus urophylla* had the highest importance value (I_V) (26.75), followed by *Eucalyptus exserta* (17.08) *Schefflera octophylla* (16.27), and *Bambusa gibba* (11.50), and each of other species had the I_V less than 5. Although *Eucalyptus exserta* had individuals less than *Schefflera octophylla* and *Bambusa gibba*, it had larger basal area than the later two, leading to the high I_V in the community.

Table 2. Classification and evaluation on vegetation damage

Class	Damage category	Evaluation	Symptoms
0	<10%	Healthy	No visible injury with natural and normal leaf color
1	10%–25%	Lower damage	Visible injury or discoloration at leaf edge for leaves, accompanied with minor loss of leaves
2	25%–60%	Moderate damage	Visible injury or discoloration extending from edge to inner part in most leaves, accompanied with moderate loss of leaves
3	60%–100%	Severe damage	Visible and significant injury and discoloration, accompanied with heavy loss of leaves
4	100%	Dead	All branches dieback and no leaves attached

Table 3. The number of individuals, relative abundance (A_R), relative frequency (F_R), relative dominance (D_R), importance value (I_V) and average plant damage degree in the tree layer under long-term air pollution stress

Species	Number of individuals	A_R (%)	F_R (%)	D_R (%)	I_V	Average damage (%)
Eucalyptus urophylla	226	30.62	13.70	35.94	26.75	57.5
Eucalyptus exserta	40	5.42	8.22	37.61	17.08	99.5
Schefflera octophylla	154	20.87	10.96	16.99	16.27	23.1
Bambusa gibba	195	26.42	5.48	2.61	11.50	85.1
Mallotus apelta	27	3.66	9.59	0.24	4.50	36.5
Syplocos lancifolia	13	1.76	9.59	1.77	4.37	12.3
Celtis sinensis	22	2.98	5.48	1.17	3.21	54.5
Vitex negundo	14	1.90	4.11	0.35	2.12	45.0
Pinus massoniana	4	0.54	2.74	1.83	1.70	100.0
Aporosa dioica	6	0.81	4.11	0.13	1.68	38.2
Carallia brachiata	6	0.81	4.11	0.04	1.65	26.7
Broussonetia papyrifera	4	0.54	4.11	0.17	1.61	35.0
Trema tomentosa	3	0.41	4.11	0.10	1.54	43.3
Ficus hirta	3	0.41	2.74	0.01	1.05	6.7
Dalbergia balansae	6	0.81	1.37	0.25	0.81	68.3
Helicia cochinchinensis	4	0.54	1.37	0.51	0.81	55.0
Viburnum odoratissimum	4	0.54	1.37	0.15	0.69	5.0
Desmos chinensis	2	0.27	1.37	0.01	0.55	20.0
Brucea javanica	2	0.27	1.37	0.01	0.55	5.0
Cinnamomum burmanni	1	0.14	1.37	0.06	0.52	50.0
Litsea glutinosa	1	0.14	1.37	0.02	0.51	25.0
Bambusa stenostachya	1	0.14	1.37	0.01	0.50	5.0
Total of all species	738	100	100	100	100	

Notes: The total area of all quadrates for field survey of the tree layer is 10×(10m×10m)

The biodiversity and dynamic change of plants in the low layer in a forest were closely relative to the direction of community succession, particularly under the cases of long-term air pollution on the health of community. The number of individuals, relative cover and the I_V of *Jasminum amplexicaule* were much greater than those of *Carallia brachiata*, *Aporosa dioica*, *Schefflera octophylla* and *Urena lobata*, which were the co-dominant species in the shrub layer (Table 4). The I_V of *Vitex negundo*, *Ficus hirta*, *Clerodendron fortunatum*, *Mallotus apelta*, *Celtis sinensis*, *Bambusa stenostachya* and *Broussonetia papyrifera* was summed up to 28.1, and that of the rest species was up t 17.9. In the herb layer, *Logodium japonicum* and *Commelin diffusa* had more individuals, higher relative abundance, relativ cover and relative frequency than other species with the I_V o 20.21 and 14.92, respectively, and then followed by *Ischaemum indicum*, *Lantana camara*, *Elephantopus scaber*, *Alocasi macrorrhiza*, *Stephania longa* and *Mallotus apelta* with their sum I_V of 36.7. The rest 17 species occurred occasionally and scattered in the community with their total I_V (less than 28.2), (Tabl 5).

Table 4. The number of individuals, relative abundance (A_R), relative coverage (C_R), relative frequency (F_R), importance value (I_V), and average plant damage degree in the shrub layer under long-term air pollution stress

Species	Number of individuals	A_R (%)	C_R (%)	F_R (%)	I_V	Average damage (%)
Jasminum amplexicaule	52	18.37	48.84	9.30	25.51	5.0
Carallia brachiata	27	9.54	3.66	9.30	7.50	44.4
Aporosa dioica	27	9.54	4.64	8.14	7.44	36.4
Schefflera octophylla	23	8.13	5.37	6.98	6.83	5.0
Urena lobata	26	9.19	4.15	6.98	6.77	23.3
Vitex negundo	15	5.30	4.88	4.65	4.95	5.0
Ficus hirta	15	5.30	1.95	6.98	4.74	8.3
Clerodendron fortunatum	18	6.36	1.95	5.81	4.71	5.0
Mallotus apelta	15	5.30	2.44	4.65	4.13	21.1
Celtis sinensis	8	2.83	2.93	4.65	3.47	22.5
Bambusa stenostachya	9	3.18	4.88	2.33	3.46	7.5
Broussonetia papyrifera	11	3.89	1.71	2.33	2.64	5.0
Eucalyptus urophylla	4	1.41	1.22	3.49	2.04	13.3
Brucea javanica	3	1.06	3.66	1.16	1.96	50.0
Bridelia monoica	3	1.06	1.22	3.49	1.92	28.3
Desmos chinensis	4	1.41	0.73	2.33	1.49	5.0
Paederia scandens	2	0.71	0.98	2.33	1.34	7.5
Lantana camara	4	1.41	1.22	1.16	1.27	20.0
Litsea glutinosa	2	0.71	0.49	2.33	1.17	5.0
Artocarpus nitidus ssp. lingnanensis	2	0.71	0.37	2.33	1.13	9.0
Wikstroemia indica	4	1.41	0.49	1.16	1.02	40.0
Melastoma candidum	3	1.06	0.24	1.16	0.82	5.0
Other 6 species	6	2.10	1.94	6.96	3.70	5—25
Total of all species	283	100	100	100	100	

Notes: The total area of all subquadrates for field survey of the shrub layer is 4x(5mx5m).

Table 5. The number of individuals, relative abundance (A_R), relative coverage (C_R), relative frequency (F_R), importance value (I_V), and average plant damage degree in the herb layer under long-term air pollution stress

Species	Number of individuals	A_R (%)	C_R (%)	F_R (%)	I_V	Average damage (%)
Logodium japonicum	33	16.92	27.69	16.00	20.21	60.6
Commelina diffusa	35	17.95	18.80	8.00	14.92	11.3
Ischaemum indicum	25	12.82	11.97	4.00	9.60	7.5
Lantana camara	11	5.64	14.70	8.00	9.45	5.0
Elephantopus scaber	12	6.15	5.81	4.00	5.32	7.5
Alocasia macrorrhiza	9	4.62	2.39	8.00	5.00	7.5
Stephania longa	8	4.10	2.74	6.00	4.28	5
Mallotus apelta	6	3.08	2.05	4.00	3.04	10
Brucea javanica	5	2.56	3.42	2.00	2.66	50
Ficus pyriformis	8	4.10	1.03	2.00	2.38	5
Wikstroemia indica	4	2.05	0.51	4.00	2.19	10
Phyllanthus urinaria	4	2.05	0.51	4.00	2.19	7.5
Paederia scandens	2	1.03	1.37	4.00	2.13	5
Centella asiatica	5	2.56	1.71	2.00	2.09	5
Clerodendron fortunatum	3	1.54	0.51	4.00	2.02	12.5
Ficus hispida	4	2.05	1.71	2.00	1.92	10
Urena lobata	6	3.08	0.34	2.00	1.81	50
Melastoma candidum	4	2.05	0.34	2.00	1.46	5
Phytolacca acinosa	3	1.54	0.68	2.00	1.41	95
Hedyotis hedyotidea	2	1.03	0.34	2.00	1.12	5
Diplazium donianum	2	1.03	0.34	2.00	1.12	5
Other 4 species	4	2.04	1.02	8.00	3.68	5—10
Total of all species	195	100	100	100	100	

Notes: The total area of all subquadrates for field survey of the herb layer is 4x(5mx5m).

Damage assessments on plants

The tree crown, particularly the amount of leaf biomass and leaf quality such as color and nutrient status are most frequently used as the index of tree survival, self-resistance, tolerant ability under stresses and self-recovery when the stresses were removed. The deteriorated leaf productivity may lead to the decrease of net

C yield and the growth of the whole tree (UN/ECE and EC 2000). Waring (1985) hypothesized that reductions in canopy leaf area should accompany the chronic stress induced by air pollution. Christiansen *et al.* (1987), thereafter, suggested that any environmental factors limiting the crown size and the photosynthesis efficiency might decrease the resistant ability of plants. In the tree layer, *Eucalyptus exserta* and *Pinus massoniana* were most seriously damaged with full foliage defoliation and whole crown dieback. *Bambusa gibba* and *Dalbergia balansae* revealed secondly severe damage with the injured degree of 85.1% and 68.3%, respectively. Moderate damaged plants included *Eucalyptus urophylla, Celtis sinensis, Vitex negundo, Aporosa dioica, Mallotus apelta, Helicia cochinchinensis, Cinnamomum burmanni, Broussonetia papyrifera, Carallia brachiata* and *Litsea glutinosa*, with the injured degree of 25%–60%. Other species experienced relative lower damage with the injured degree (less than 25%), (Table 3).

Average damage extent of the plants in the shrub layer were less than 60% (Table 4), which was generally less than those of most plants in the tree layer. In the shrub layer, *Brucea javanica, Carallia brachiata, Wikstroemia indica, Aporosa dioica, Bridelia monoica* and *Breynia fruticosa* were classified as moderately injured species, with the damage degree ranging from 25% to 60%. The rest co-occuring species including *Jasminum amplexicaule, Schefflera octophylla, Vitex negundo, Ficus hirta, Clerodendron fortunatum, Bambusa stenostachya, Desmos chinensis, Melastoma candidum* showed lower injured symptoms, with the average injured degree of less than 10%. In the herb layer, *Phytolacca acinosa* was the heavily injured species, with injuried degree of more than 95%, followed by *Logodium japonicum, Brucea javanica, Urena lobata* with the injuried degree of 50%–60%, and most of other species revealed highly resistant to air pollution with injured degree around or less than 10% (Table 5). In general, it can be seen that plants growing under the tree canopy were lightly damaged than those in the tree layer. This might be explained as: (1) the *Eucalyptus exserta, Pinus massoniana* and *Eucalyptus urophylla* were fast growing species, whose canopies had been long-term and directly exposed to the pollutants, and also experienced the interactions of pollutants with other stresses, such as high solar radiation and extreme temperature; (2) the pollutants deposited and captured by the protruding tree canopies may greatly decrease the risk of injury to the plants under forest canopy.

Determination of the cause and effect of air pollution on vegetation is difficult in the field inventories, since other factors may cause injuries on foliage and canopy profile, which lead to uncertainties in identifying the real damage extent caused by pollutants. Further, air pollutants can indirectly alter the composition and the structure of a forest system to boost or restrain certain disease and herbivore damages to the forest. In the study, we found that some of plants had hardly visible injury, while different extent of damage symptom caused by insects was observed. For instance, five of the six *Aporosa dioica* individuals and two of six *Carallia brachiata* individuals surveyed in the tree layer showed both evident insect damage and severe pollution injuries. Although *Schefflera octophylla* showed less visible pollution-injured symptoms, 15% of the total individuals were twisted and wrapped by the climbers, which greatly reduced the crown thickness and productivity, even led to crown breaking off. Previous studies demonstrated that reduced growth efficiency may increase susceptibility to insect attacks (Waring *et al.* 1985), and acid pollution may aggravate the threat caused by other stresses such as insect pest attacks (Yang *et al.* 1991). On the other hand, there are no generally and universally accepted conclusions about the interaction of air pollution, insects and pathogens on plants and forest health. Not always posing positive effects on, sometimes, air pollution played a restrictive role in the spreading of pathogens or insect pests, which was highly associated with the environmental conditions, the kind of and the emission level of pollutants, and plant populations (Wang *et al.* 1996; Jia 2000; Zhang *et al.* 2002).

Conclusions and implications

The atmospheric measurements and vegetation health assessment here provided an insight into possible threats to a plant community in a specific region and by specific pollution sources. During the 1970s–1980s, Masson pine and introduced Eucalyptus species were used as pioneer species in afforestation, and planted extensively on hills and in lowlands of subtropical region in China, particularly in Guangdong Province, owing to their fast growing aspects. Heavy dieback of these species in this study implied that plantations dominated by the same species in other areas could be also affected by atmospheric changes, and therefore, should be given increasing concern. Compared with the natural forests growing far away from urban center or pollution sources, forest ecosystems under pollution stresses were affected by both the common environmental variables such as light, soil-water regimes, nutrient status and their interactions, and the long-tem environmental pollution, which may further increase their instability and frangibility. Investigations on the dynamics of community structure and function and risk assessment of these ecosystems should be emphasized, for providing valuable management strategies and biodiversity protection of forests.

Pollution-resistance or -tolerance of plants and their adaptations to regional soils are the fundamental issue and pre-requirement precondition in species consideration for the restoration of heavily polluted and degraded ecosystems. In this study, some of indigenous evergreen broad-leaved species, for instance *Schefflera octophylla, Desmos chinensis, Syplocos lancifolia, Litsea glutinosa, Ficus hirta, Broussonetia papyrifera, Carallia brachiata, Aporosa dioica, Bridelia monoica* and *Melastoma candidum* showed higher resistance than the conifer Masson pine and the introduced Eucalyptus plants, revealing their potentials in ecosystem rehabilitation. However, acclimation mechanisms and defense strategies of these native species to air pollution are still unclear, particularly in field condition loaded with natural emission of multiple pollutants. In addition, other environmental factors such as soil pH, moisture, and status of nutrients (e.g. N richness and availability) may affect the response of plants to pollution. Therefore, we suggest that concern should be made on exploring the interactions between plant responses and pollution stress as well as other environmental factors in order to provide scientific base for species selection and restoration scheme in these polluted and degraded areas.

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