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## 植物抗霾

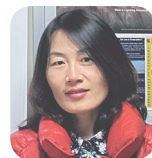
### Plant Use in Reduction of Atmospheric Haze

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**摘要 /** “霾”是指大气中细颗粒物浓度升高，而导致能见度下降的现象。本访谈介绍了治理霾的主要思路和措施，植物在消减PM2.5的机制，以及两个相关研究课题——“应对PM2.5空气污染的北京造林工程关键技术与示范”和“北京地区扬尘抑制技术研发及示范应用”——的最新研究进展。

**关键词 /** 气象灾害；PM2.5；霾；植物

**Abstract /** “Haze” reduces visibility when fine air particles build up in the atmosphere. This interview introduces the main concepts and methods of measurement for haze control and the PM2.5 reduction mechanisms of plants. It also gives an overview of recent research progresses made, such as “Technology Development and Demonstration of PM2.5 Control in Beijing Forestation Projects” and “Technology Development and Demonstration Applications on Dust Pollution Prevention and Control in Beijing”.

**Key words /** Meteorological Disasters; PM2.5; Haze; Plants

#### 在通过运用植物治理PM2.5方面，您和您的团队进行了哪些工作？

李延明：大气污染，尤其是霾，现在已经成为城市环境中最为严峻的一个问题，不少城市已经将“雾霾天气”作为灾害性天气现象进行预警。“霾”是指大气中细颗粒物（主要是PM2.5）浓度升高，而导致能见度下降的现象。这些颗粒物的直径范围在0.001~10μm，平均直径约为1~2μm。面对目前城市雾霾天气频频出现的情况，我们正在开展两个课题研究，第一个是“应对PM2.5空气污染的北京造林工程关键技术与示范”课题，主要探讨城区绿地和郊区造林对PM2.5的消减作用。第二个是国家科技计划支撑课题——“北京地区扬尘抑制技术研发及示范应用”，除了一直关注的总悬浮颗粒物（TSP）治理外，重点还是在围绕如何减少PM2.5开展研究。

#### 霾的防治目前主要包括哪些措施？

李延明：“减源增汇”是治理霾非常关键的思想。首先应该从源头治理，减少污染气体的排放。实施采用清洁燃料、减排、限排等措施都能有效地从根源上控制污染。另一个方向就是“增汇”，也就是增加汇集污染物的系统。

降雨、空气对流等都能有效降低空气中的PM2.5浓度，但就人为可以控制的层面来说，植被是最为有效的手段。虽然每一片叶子的吸附量很小，但植株的叶片总面积很大，一般来说是其垂直投影面积的2~5倍。其他手段，例如人工喷水，尽管也能起到缓解的作用，但能够影响的范围有限且时效较短、耗资高昂。

通过我们的研究，首先可以肯定的是，城市绿地对于降低PM2.5的浓度能够发挥明确的作用。

#### What did your team do in the control of PM2.5 by using plants?

**Yanming LI:** Air pollution, especially haze, has become one of the most serious problems in the Chinese urban environment. Many cities have weather forecasts that often include warnings of “fog and haze”. “Haze” refers to the concentration level of atmospheric fine particles (PM2.5) that 0.001 ~ 10 μm in diameter, and 1 ~ 2 μm on average, which leads to decreased atmospheric visibility. We have developed two studies that measure and evaluate frequent fog and haze in the city. The first one is “Technology Development and Demonstration of PM2.5 Control in Beijing Forestation Projects”, which focuses on the function of urban green spaces and suburban forestation in PM2.5 reduction. The second is “Technology Development and Demonstration Applications on Dust Pollution Prevention and Control in Beijing”, and is supported by the National Science and Technology Program. In addition to TSP (total suspended particles) it focuses on PM2.5 reduction.

#### What are the main methods for measuring reduction and prevention of haze?

**Yanming LI:** The main goal of haze control is “decreasing source and increasing sinks”. In regards to source control, reducing and restricting emissions of polluted gases and clean fuels can decrease the amount of haze. On the other hand, increasing sinks, which can absorb pollutants, is important for controlling existing haze emissions.

Rainfall and air convection can effectively reduce the concentration of PM2.5 in the air. However, vegetation is considered one of the most effective artificial methods. Other artificial methods include use of water, but this costs a lot, and affects a limited range and time.

Our study showed that green space could effectively reduce the concentration of PM2.5. Although each

plant leaf absorbs a small amount, the total area of the leaves is large, generally two to five times its vertical projection area if each piece of vegetation was arranged side by side.

The greenland ecosystem plays an important role in the “sink” effect of atmospheric pollutants. Individual plants or plant communities with adsorption functions can promote the deposition of atmospheric pollutants and reduce floating particles, which could purify the air. There is no definitive conclusion about what role plants play in the reduction of PM2.5 in the city, but from our studies the function of green space in mitigation of PM2.5 cannot be overstated. We are not going to achieve instant results, but PM2.5 governance needs to integrate a variety of approaches.

#### What are the PM2.5 adsorption differences between plants?

**Xinyu LI:** We chose 60 green plants commonly used in Beijing and measured the PM2.5 adsorption quantity of each by dust collection. The dust collecting method

1. 北京某住宅区雾霾天气与晴朗天气空气能见度对比。© 田乐
1. Comparison of air visibility between haze and fine days, taken in a residential area in Beijing. © 田乐



也就是说绿地生态系统对大气污染物具有重要的“汇”的作用。通过植物个体或植物群落的吸附作用，能够减少漂浮在空气中的颗粒物，从而起到净化空气的作用。但整个城市绿地体系究竟能对降低PM2.5发挥多大的作用，目前还没有确切的定论。绿地对于治理PM2.5的作用不能被过分夸大，也并不能获得立竿见影的效果，PM2.5的治理需要整合多种途径。

#### 不同植物种类在吸附PM2.5的效果方面差异程度如何？

李新宇：我们选择了北京市常用的60种绿化植物，采用洗尘法对单株植物的单位面积上的PM2.5吸附情况进行了测定。洗尘法就是将叶片上的残留物收集起来，然后进行称重。

目前我们已经完成了29种植物（包括14种乔木、14种灌木和1种藤本）的测定。研究表明，不同植物种类吸附PM2.5的能力存在较大的差异。乔木中，银杏（*Ginkgo biloba*）单位叶面积上滞留PM2.5的质量是最高的，其吸附能力大约是柽柳（*Tamarix chinensis*）的十几倍。灌木中，小叶黄杨（*Buxus sinica* var. *parvifolia*）和大叶黄杨（*Buxus megistophylla*）的效果比较好，沙地柏（*Sabina vulgaris*）的效果略差。需要强调的是，这并不是表示在北京地区银杏是治理PM2.5效果最好的品种，只是针对我们研究的物种而言相对较好。

#### 空气中的悬浮颗粒物附着在植物表面后，会发生怎样的变化？

李新宇：目前我们主要通过电镜扫描来测定植物对PM2.5的吸附作用。除了绒毛结构和粘性分泌物，许多植物枝叶表面会有隆起、沟槽等特征。一些植物表面看起来比较光滑，也具有非常复杂的超微结构。电镜显示，细颗粒物可以稳定地附着在这些超微结构之上，PM2.5在空气中的再悬浮概率相对来说非常小。细小颗粒物被吸附之后，也会在叶表发生团聚，形成更大的颗粒物，通过降雨或刮风等自

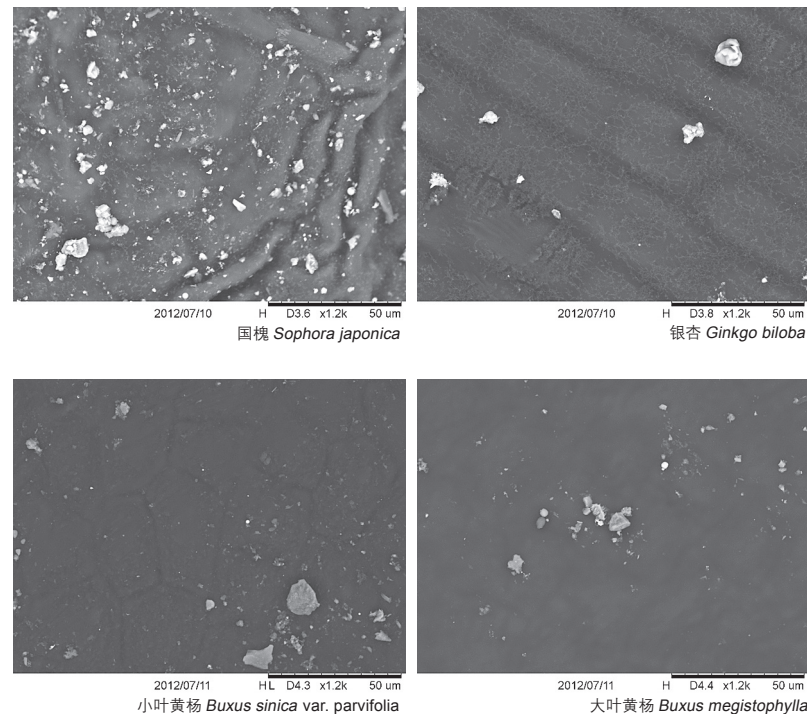
然现象，沉降到地面。

电镜照片显示，PM2.5的直径远小于植物气孔的直径，因此一部分PM2.5将会通过扩散运动进入气孔。PM2.5的成分非常复杂，包括元素碳、有机碳化合物、硫酸盐、硝酸盐等。进入气孔之后，不可溶性的成分不会发生太大的变化；可溶性成分，比如硝酸盐，将会参与到植物的代谢过程中，然后得到转换。不过现在对于这方面尚缺乏定量的研究。此外，由于二次污染是PM2.5形成一个重要来源，有研究团队发现植物能够有效吸收二氧化硫、氮氧化物和挥发性有机物这些会形成二次污染的物质。

#### 请问在研究的过程中是如何与大气专业进行衔接的？有哪些跨学科研究方面的思考？

李延明：我们的研究目前尚处于前期阶段，重点是植物对PM2.5的吸附机理和研究方法的探讨。相

2. 不同植物叶片滞留颗粒物的形态。
2. Particles adsorption by different plant species.



required us to collect and weigh residue on the leaf blade using an electron microscope and converting stable masses.

At present we have determined 29 plant species, including 14 trees, 14 shrubs, and one vine that absorb PM2.5. Research indicates that there are big differences in the PM2.5 adsorption capability of plants. In trees, the PM2.5 per unit leaf area of *Ginkgo biloba* appears to be the highest, retaining about twelve times the PM2.5 of *Tamarix chinensis*. In shrubs, *Buxus sinica* var. *parvifolia* and *Buxus megistophylla* are better than *Sabina vulgaris*. However, it does not necessarily illustrate that the PM2.5 absorption rate of *Ginkgo biloba* is the best. *Ginkgo biloba*'s effect is relatively good compared to the other plants we measured.

#### What changes once the particles adhere to the plants' leaves?

Xinyu LI: We mainly surveyed and evaluated the PM2.5 adsorption of plants by electron microscopy scanning. In addition to villus structures and sticky secretions, there are also upheavals and grooves on the surface of leaves that help trap the PM2.5. Electron micrographs of PM2.5 shows that fine particles can adhere to the ultra-microscopic structures stably. After the fine particles are bonded onto the sticky plant surfaces, they bind into larger particles on the leaf surface and settle to the ground through wind or rain.

Electron micrographs show that the diameter of PM2.5 is much less than stoma's diameter, and a portion of PM2.5 from the air will enter through the stoma by diffusive motion. The composition of PM2.5 is complicated, and includes carbon, organic compounds, sulphate, and nitrate. Organic carbon or some other insoluble substances will not change after they enter through the stoma, but some soluble ingredients, such as nitrate, will be completely absorbed into the plant's metabolism. However, there are few quantitative research about this. Moreover, researchers found that plants can

effectively adsorb SO<sub>2</sub> nitrogen oxides and volatile organic compounds that form secondary pollution, an important source of PM2.5.

#### How are these studies connected with atmospheric research? What are your reflections on interdisciplinary research?

Yanming LI: Our study is still in its initial period, and it mainly focuses on research methods and adsorption mechanisms of PM2.5. We are now carrying out related experiments, but have only gotten preliminary results so far. On one hand, the dynamic atmospheric presence of PM2.5 brings our study enormous difficulties. On the other hand, the study in PM2.5 is also resulting in cutting-edge atmospheric research. There is not any clear final conclusion for our reference.

Xinyu LI: In respect to atmospheric versus environmental governance, PM2.5 adsorption by plants is always being neglected a viable option for reduction. Our previous studies mainly focused on the research of TSP governance, which resulted in a research gap. Working with atmospheric experts, we have explored how to extract the particles from plants' leaves and how to weigh the particles' mass. Our work is exploring the way forward in cooperation with these experts.

#### What is the main application of the intended research results? What will be the instructive suggestions for urban planners and landscape architects?

Xinyu LI: Our research results will provide guidance about species selection and green space configuration. We carried out a comparative study of planting designs in several typical green spaces in parks, roads, and urban spaces. Looking at the green spaces on roadways, for example, we chose four typical locations that experienced similar conditions of pollution and traffic, and compared PM2.5 adsorption through a long-term

关的实验正在进行，目前只形成了一些阶段性的成果。一方面在于PM2.5始终处于动态的变化过程中，为我们的研究带来了非常大的困难。另一方面在于对于PM2.5的研究在大气专业中也是一个非常前沿的领域，尚未形成特别明确的定论以供我们参考。

李新宇：在大气治理或环境治理方面，一直以来都忽视了植物对于PM2.5的消减作用。而我们以往的研究也都集中在TSP治理的研究中，所以这一交叉领域可以说是空白的。我们与大气专家合作，对如何才能获取植物叶片上的颗粒物，以及如何称量等问题进行了探讨。我们的工作是在与大气专家的合作中摸索前进。

#### 该研究成果将主要应用在哪些方面？对城市规划师、景观设计师的工作有怎样的切实指导意义？

李新宇：我们的研究成果将主要为设计师提供两个方面的指导。一方面在于提供有关物种选择的参考，另一方面在于提供有关绿地配植模式的建议。我们针对几种典型的绿地类型——公园绿地、道路绿地、附属绿地——中不同的植物配植群落进行了对比研究。例如，针对道路绿地，我们在北京四环路上选取了4处典型的地段——污染状况、交通流量等情况类似——通过长期的户外监测，对不同的配植模式下的PM2.5消减情况进行了对比。虽然该课题尚处研究阶段，但我们希望能够尽快根据研究成果编制出一套植物配植的基本导则。这套导则将同时兼顾绿地的环境改善、观赏和休闲娱乐功能，而非一味地强调其改善环境的作用。

#### 在以落叶树和落叶灌木为主的北方地区，冬季时植被对PM2.5的吸附作用是否会变得很微弱？

李新宇：植物的降温、滞尘、减碳、减少噪音等功能都与其叶片有关，所以我们通常用“绿量”——植物功能性叶片的总量来衡量植物的生态效应。的确，冬季时，北方地区植物的绿量很低，生态效应会减弱很多。冬季的空气污染物以粉尘为主，粉尘

属于一次污染物。测试结果表明，北方地区还有多种常绿针叶树，例如雪松（*Cedrus deodara*）、圆柏（*Sabina chinensis*）等植物均具有较强的滞尘能力。此外，一些能在北方地区越冬的常绿灌木，例如大叶黄杨和小叶黄杨，也能发挥较好的效果。但是这些灌木在冬季时常常用无纺布包裹，这样的做法也会影响植物的滞尘效果。

李延明：这其中存在一个很大的误区。将绿篱包裹起来的做法本来是由于冬季降雪后需要在行车道路上喷洒融雪剂，其成分主要为氯盐类，会对植物造成伤害，因此需要对绿篱进行防护。但其他很多区域（包括公园、居住区、广场）不加了解就盲目效仿，也在绿篱表面覆盖防护物。实则完全没有必要，大叶黄杨和小叶黄杨完全可以在北京地区露地越冬。近年来，北京地区正在逐步用胶东卫矛（*Euonymus kiautschovicus*）替代大叶黄杨。这两者在形态上非常相似，但胶东卫矛的抗寒性更强。常绿植物在北京无法越冬不完全由于低温所致，更关键在于在冬春之交，气温已经回升，但土壤还未完全解冻，造成植物生理性干旱而死亡。我们不能只看到现象，更关键的是要去探寻现象背后的原因，才能采取正确的解决措施。LAF

outdoor monitoring. With these studies, we hoped that we could develop a general guidance for plant configuration that not only emphasized the function of improving environment, but also considered quality of space.

#### In northern China, which is mostly deciduous trees and shrubs, will PM2.5 absorption by plants be weaker in the winter?

**Xinyu LI:** Cooling, detaining dust, reducing carbon emissions, and noise abatement are functions related to the plant's leaves. The "Green Quantity" — the total amount of leaves — can usually measure the ecological effect of plants. In winter, the green quantity of plants in the north of China is low and the ecological effects significantly decrease. Ironically, dust is the primary air pollutant in winter. There are many kinds of evergreen conifers in northern China, and tests have indicated that evergreen conifers such as *Cedrus deodara* and *Sabina chinensis* have a good capability for detaining dust. In addition, evergreen shrubs such as *Buxus megistophylla* and *Buxus sinica* var. *parvifolia* have also proven to be quite effective. However, *Buxus microphylla* and *Buxus sinica* var. *parvifolia* are usually wrapped in non-woven fabric in winter, which greatly affects particles adsorption.

**Yanming LI:** This is a big misunderstanding. Originally, the wrapping began because snowmelt chemicals, essentially Chlorides, will be harmful to plants when it is used on roads after a snowfall. Thus we needed to begin wrapping the plants. However, without fully understanding the initial reason, hedges in parks, residential areas, and plazas also began to be covered. There is actually no need to do this. *Buxus megistophylla* and *Buxus sinica* var. *parvifolia* can survive in the winter in Beijing. In recent years, *Euonymus kiautschovicus* has become an alternative for *Buxus megistophylla* in Beijing. Both are similar

in shape, but the cold resistance of *Euonymus kiautschovicus* is much stronger. Some evergreen plants cannot survive winter in Beijing. This is not entirely due to the low temperature, but a slow increased temperature that only partially thaws the soil when winter turns into spring. Because of physiological drought, the plants die. We should continue to explore the reasons behind this phenomenon. LAF

3, 4. 对不同植物配植模式下的PM2.5消减情况所进行的户外监测。  
3, 4. Outdoor monitoring of PM2.5 adsorption in different planting design environments.

