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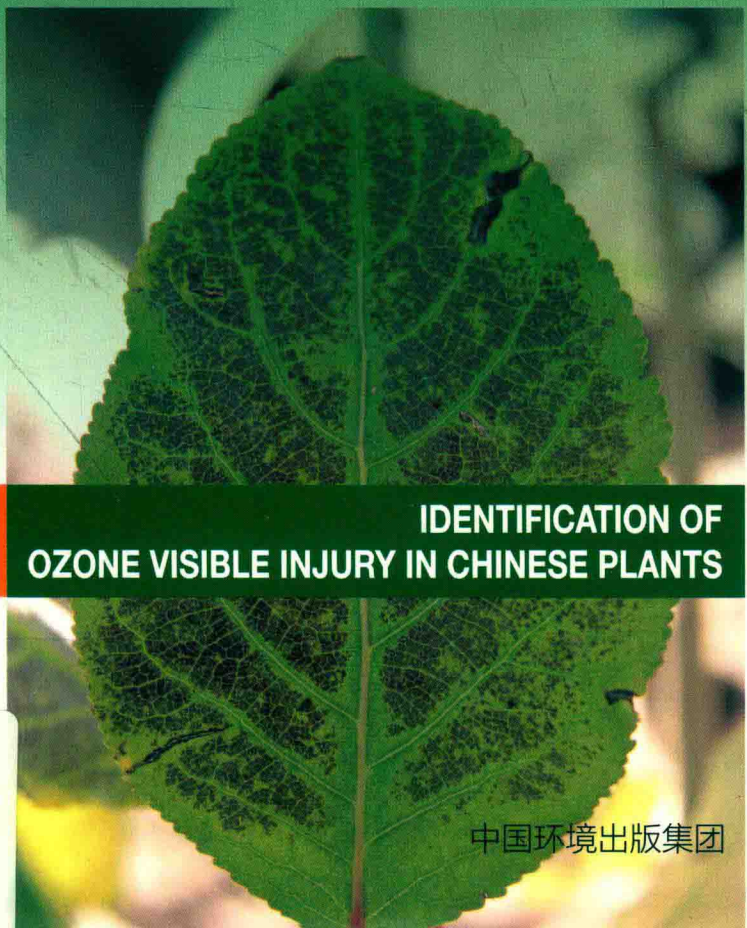

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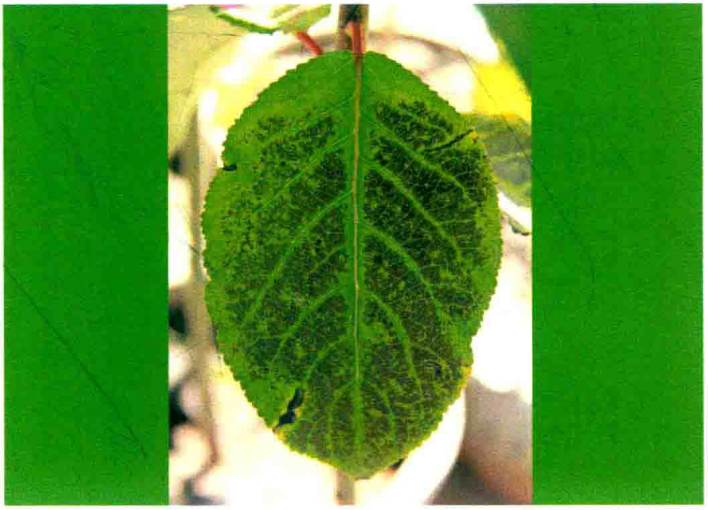

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前　言

臭氧引起的植物叶片可见损伤已被纳入一些森林健康监测项目的指标中，如北美的 Forest Health Monitoring 及欧洲的 ICP Forests 和 ICP Vegetation。观察臭氧对植物叶片的可见损伤已成为一种重要的研究方法，据此可确认臭氧对植物可能有损伤的污染区域，可评估不同物种对臭氧污染的敏感性，可筛选指示植物，以及可在不同地区和城市开展臭氧风险评估研究。目前，中国大部分地区的臭氧小时浓度已超过 40 nmol/mol（植物损伤阈值），给臭氧敏感植物带来巨大风险。然而，我国很少有在野外通过原位观察叶片可见损伤来评估臭氧对植物的影响。因此，我国各级生态与环保部门的管理人员和研究人员迫切需要一本指南性书籍，用于正确地鉴定臭氧引起的植物叶片可见损伤症状。本书介绍了臭氧浓度变化趋势、臭氧与气候变化的交互反应，以及我国当前近地面的臭氧污染现状。本书主体部分则给出了用于鉴定阔叶植物和针叶植物臭氧可见损伤的方法，并罗列了 49 种典型植物叶片臭氧可见损伤的症状图片。本书

臭氧症状图片来源于野外实地调查和臭氧暴露实验。臭氧暴露实验的图片对野外识别植物叶片臭氧症状起到一定参考作用。本书旨在推动我国臭氧污染生态效应方面的研究，提高我国臭氧风险评价研究水平，并希望在臭氧引起的植物可见损伤症状鉴定中起到抛砖引玉的作用。鉴于编者水平和时间有限，书中难免存在不足之处，敬请阅者批评指正。

PREFACE

Ozone-induced leaf visible injury has been included in some forest health monitoring programmes such as the Forest Health Monitoring in North America, and the ICP Forests and ICP Vegetation in Europe. Observation of visible injury has been used as a tool to identify areas in which ozone may be harmful to plants, to estimate the sensitivity of the different species to this pollutant and to select indicator plants, and also for ozone risk assessment studies in different regions and cities. At present, ozone concentrations in most parts of China exceed the hourly threshold value of 40 nmol/mol thus representing a risk for ozone-sensitive plants. However, very few field studies have been conducted in order to assess the impacts of this pollutant through the observation of visible injury. Therefore, both practitioners and researchers from the Ministry of Ecology and Environment of the People's Republic of China, working at the central and local governments, urgently need a guide book

to properly identify ozone visible injury in the field. The first section of this book is mainly devoted to the ozone concentration trends, interaction with climate change, and current ground-level ozone pollution in China. In the main body of this book, the method for identifying the visible injury symptoms in broadleaf and conifer species is introduced, and typical ozone symptoms of 49 plants are documented with pictures. The book combines field photos and symptoms induced by exposing plants to elevated ozone concentrations under experimental conditions. The latter are a reference for symptom recognition in the field. We do hope that this book, which covers an important gap in our knowledge of the ozone effects in China, becomes interesting to the readers and contributes to improve ozone risk assessment in China.

摘　要

臭氧是一种二次污染物，通过其前体物质（VOC，CO、NO_x 和 CH_4）在大气中经阳光照射发生光化学反应而产生。近 30 年来，由于我国工业化和城市化的快速发展，导致我国地表臭氧浓度显著上升。因此，臭氧超标现象较为普遍，臭氧污染日趋严重。近地面臭氧污染对植物影响的具体表现为降低植物光合固碳能力及损伤植物叶片。长期低浓度的臭氧暴露会影响植物的光合作用、生长发育、产量 / 生物量以及果实和籽粒的品质。暴露在臭氧污染下的敏感性植物（如田间作物和绿化树木）通常叶片会出现可见损伤症状。典型的症状通常表现为叶片上表面叶脉之间均匀散布着黄色或棕色的细密点，其他症状还包括坏死、斑点、黄化、叶片衰老加速等，当然不同植物表现的症状有所差异。因为臭氧症状通常是户外识别臭氧对植物损伤的唯一的直接证据，因此臭氧可见症状的识别与量化是臭氧风险评估的重要工具。欧洲和北美一些国家已将臭氧可见症状纳入臭氧风险评估研究中。本书收集了分布在中国且出现臭氧可见

症状的 49 种植物物种，这些物种的症状是在户外原位观测或者通过臭氧暴露实验发现的。本书将对户外植物臭氧可见症状鉴定提供参考，同时也为评估臭氧对中国植物的影响提供科学依据。

SUMMARY

Ozone is a secondary pollutant formed in the atmosphere by sunlight driven chemical reactions between the ozone precursor gases: VOC, CO, NO_x, and CH_4. Due to fast industrialization and urbanization in China in last three decades, the ozone concentration has been rising significantly. High ambient ozone concentrations are now common in different parts of China, posing a serious problem both for human health and vegetation. In plants, photosynthetic carbon fixation capacity and plant foliage are usually damaged by ozone. Long-term low ozone concentration exposure can affect photosynthesis, growth, yield, biomass and quality of fruits and seeds. Ozone also induces characteristic visible foliar symptoms in sensitive plants, including crops and natural vegetation. Typical ozone symptoms frequently consist of yellow or reddish brown stipples affecting the interveinal parts of the upper surface of the leaves, but depending on the plant. Necrosis, flecking, yellowing or accelerated leaf

senescence are also induced by this pollutant. As ozone injury is often the only clear evidence of ozone damage to the plants in the field, the identification and quantification of ozone-induced visible injury are an appropriate tool for risk assessment. For this reason, it has been included in monitoring programmes in Europe and North America. In the present book, ozone symptoms of 49 plants relevant for China are shown. They have been either observed in the field or induced by ozone fumigation under controlled conditions. This information may be used as a reference for ozone injury recognition in the field and for supporting ozone risk assessment to vegetation in China.

目 录

CONTENTS

1 大气污染

污染物的定义是“任何直接或间接由人类引入环境空气中，且对人类健康和整个环境产生有害影响的物质”。根据其形成过程，大气污染物被分为一次污染物和二次污染物。一次污染物是由其来源直接排放而成，通常由燃烧过程产生。典型的一次污染物有二氧化硫（SO_2）、一氧化氮（NO）、一氧化碳（CO）和碳氢化合物。二次污染物是由一次污染物（也称作前体物质）在其他大气介质和太阳辐射（光化学污染物）参与下，经过化学反应而形成。其中臭氧（O_3）或硝酸过氧化乙酰（PAN）等二次光化学污染物应被高度重视。

AIR POLLUTION

A pollutant is defined as "any substance introduced directly or indirectly by man into the ambient air and that may have harmful effects on human health and the environment as a whole". The pollutants, according to their formation process, are divided into primary and secondary. Primary pollutants are emitted directly by their sources and usually derive from combustion processes. The typical primary pollutants are: sulfur dioxide (SO_2), nitrogen monoxide (NO), carbon monoxide (CO) and hydrocarbons. The secondary pollutants are formed by chemical transformations from the primary pollutants (precursors), with the intervention of other atmospheric agents and solar radiation (photochemical pollutants). Among the secondary photochemical pollutants, ozone (O_3) or peroxyacetyl nitrate (PAN) should be highlighted.

2 臭氧污染物

臭氧是一种由三个氧原子组成的无色气体，非常不稳定，特别容易发生反应。根据臭氧在大气中的位置不同，它可以是有益的（平流层臭氧，即所谓的臭氧层，能过滤有害的紫外线辐射），也可以是有害的（在位置较低的对流层，臭氧作为大气污染物与生物直接接触）。这种臭氧污染物是由氮氧化合物（主要由汽车和工业排放）与来自工业（汽油、溶剂等）和天然植物产生的挥发性有机化合物（VOCs，如异戊二烯、萜烯等）经复杂反应而产生的（Seinfeld & Pandis，1998），导致臭氧污染物形成的前体物质还有甲烷（CH_4）和一氧化碳（CO）。在这些反应中，太阳辐射起着决定性的作用。臭氧是光化学反应的产物，且光化学反应最终会导致氮氧化合物形成亚硝酸盐、硝酸盐和硝酸。