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Ozone and ozone injury on plants in and around Beijing, China

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ABSTRACT

Ozone (O_3) levels were assessed for the first time with passive samplers at 10 sites in and around Beijing in summer 2012. Average O_3 concentrations were higher at locations around Beijing than in the city center. Levels varied with site locations and ranged from 22.5 to 48.1 ppb and were highest at three locations. Hourly O_3 concentrations exceeded 40 ppb for 128 h and 80 ppb for 17 h from 2 to 9 in August at one site, where it had a real-time O_3 analyzer. Extensive foliar O_3 injury was found on 19 species of native and cultivated trees, shrubs, and herbs at 6 of the 10 study sites and the other 2 sites without passive sampler. This is the first report of O_3 foliar injury in and around Beijing. Our results warrant an extensive program of O_3 monitoring and foliar O_3 injury assessment in and around Beijing.

1. Introduction

Episodes of high concentrations of particulate and gaseous pollutants, referred to as smog, occur frequently in Beijing, raising concerns about effects on human health. Ozone (O_3) is a major part of this complex urban pollution mixture. Ozone levels increased at a rate of 1.1 ± 0.5 ppb/year from 2001 to 2006 (Tang et al., 2009). Ozone levels have been increasing significantly from 2002 to 2010 in China (Wang et al., 2011; Wang et al., 2012a,b,c; Xu and Zhang, 2006). The new air quality standards for O_3 for China established in 2012 says that an 8 h average of 80 ppb and an hourly average of 50 ppb are allowed for the First Grade Standard for nature reserves and scenic areas, and 100 ppb and 80 ppb for the Second Grade Standard for most areas, separately (GB 3095-2012). The higher value is permitted in the new standard than in the old one (GB 3095-1996). It reflected the incidence of high levels of ambient O_3 in China.

The effects of O_3 on crop plants and some tree seedlings have been reported from controlled field experiments with Open-Top Chambers and Free-Air Exposure Systems in China (Wang et al., 2007; Tang et al., 2011). Little is known about the effects of ambient levels of O_3 on plants in and around Beijing or anywhere else in China.

Older leaves of ozone-sensitive plants exhibit characteristic injury symptoms when O_3 levels are high enough and exposure is long enough and environmental conditions are appropriate for gas exchange. Symptoms of ambient O_3 injury on a wide variety of native plants have been observed in the field and then verified as being caused by O_3 (Skelly et al., 1999; Innes et al., 2001; Porter, 2003; Manning and Godzik, 2004; Kohut, 2005; Davis, 2007; ICP Forests, 2010; Paoletti et al., 2009; Sanz and Catalayud, 2011). Using these references and pictorial data bases as a guide, symptom expression is a widely accepted and reliable method of assessing plant response to O_3 in the field and providing biological significance for O_3 monitoring data (Manning, 2003).

Coulson et al. (2003) rated tree species in mid-Atlantic States using O_3 injury symptoms. The Carpathian Mountain Range was surveyed for O_3 injury on plants over a 10-year period (Manning and Godzik, 2004). Davis (2007) and Davis and Orendovici (2006) used foliar O_3 injury symptoms on plants as evidence of O_3 injury to plants in Maine and Pennsylvania. Native bioindicator plants for O_3 were extensively used in forest health monitoring programs over a16-year period in the Eastern USA (Smith et al., 2003, 2008; Smith, 2012). Ozone injury on ornamental plants has also been investigated in the field. Ozone symptom expression on *Hibiscus*

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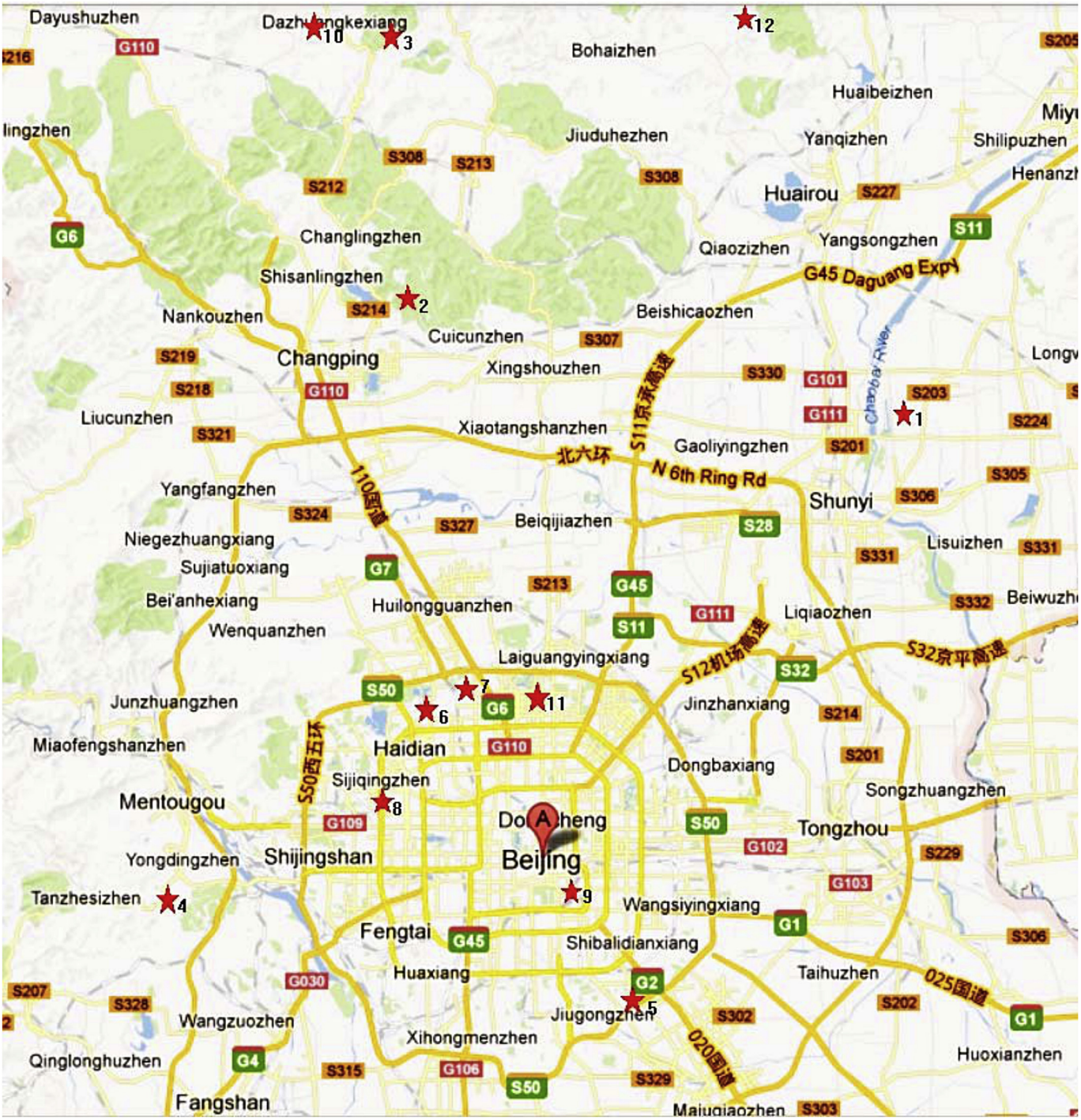

Fig. 1. The distribution of 12 sites where the survey taken place from 11 to 15 August, 2012, Beijing. Sites: (1) The Olympic Aquatic Center, Shunyi District; (2) Mangshang Tianchi, Changping District; (3) Mountaintop in Dazhuangke village, Yanqing County; (4) Jietai Temple, Mentougou District; (5) Liangshui River in Yizhuang, Daxing District; (6) Haidian Bridge near the South Gate of Peking University; (7) RCEES (Research Center for Eco-Environmental Science); (8) Sijiqing Bridge, the West 4th Ring Road; (9) Beijing Teaching Botanical Garden. (10) Dongjiagou, Yanqing County; (11) The Olympic Forest Park, Chaoyang District; (12) Mutianyu Section of the Great Wall, Huairou District. O_3 passive samplers were set at sites 1–10.

syriacus was detected in the field and verified by treatment of plants to EDU (ethylenediurea) and exposure of plants to O_3 in open-top chambers (Paoletti et al., 2009).

Surveys for O_3 injury on native plants have been combined with and located near passive O_3 samplers or active real-time O_3 analyzers (Manning et al., 1996; Yuska et al., 2003; Bytnerowicz et al., 2004; Manning & Godzik, 2004; Sager et al., 2005). This makes it possible to relate O_3 injury symptoms on native plants to O_3 exposure.

Here we report the results from our survey of native and cultivated plants at 10 study sites with O_3 passive samplers and two additional sites without passive samplers in and around Beijing.