MATURE BLACK CHERRY USED AS A BIOINDICATOR OF OZONE INJURY

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Abstract. Incidence and severity of foliar symptoms due to ambient ozone exposures were documented on mature black cherry (Prunus serotina) in two National Parks (Great Smoky Mountains National Park (GRSM) and Shenandoah National Park (SHEN)) in the Appalachian Mountains of the eastern USA during the summer of 1991-1993. Three plots in each park containing 30 trees each (Big Meadows in SHEN had 60 trees) with 90 and 120 trees total trees were evaluated in GRSM and SHEN, respectively. Pits were established at different elevations adjacent to ozone monitoring stations. Samples of foliage were collected and three exposed branches from the upper- crown and three branches from the mid-to-lower crown were examined for symptoms of foliar ozone injury. Incidence was greatest in 1991 at both locations; 60% and 45% for GRSM and SHEN, respectively. In 1992 and 1993, incidence was very similar in both parks, with approximately 33% of the trees affected. Black cherry at the highest elevations exhibited the greatest amount of symptoms in both parks all three years of the study. These sites also exhibited the highest ozone concentrations. In addition, the percent of trees injured by ozone was positively correlated with SUM05 and W126. These results along with forest surveys and open-top chamber studies indicate that black cherry may be a reliable bioindicator of foliar injury due to ambient ozone.

Keywords: black cherry, ozone exposure-plant response, national parks, bioindicator.

1. Introduction

A bioindicator is a vascular or non-vascular plant that exhibits a typical and verifiable response when exposed to an air pollutant (Manning, 1993). These plants can be used to detect the presence of a specific air pollutant in a specific location or region. Whether introduced (sentinels) or native (detectors), these plants can provide unique information regarding the ambient air quality in a particular area (Manning, 1993). Bioindicator plants are especially useful in areas where electrical power is not available to operate ozone monitors.

Ozone is considered as the most important phytotoxic air pollutant in the eastern United States and can be transported long distances from urban sources to rural, forested areas (US EPA, 1996). The major effects of ozone on terrestrial vegetation include visible injury, reductions in growth and productivity, changes in crop quality and increased susceptibility to other abiotic or biotic stresses (US EPA, 1996; Chappelka and Samuelson, 1998).

Visible symptoms of ozone injury have been observed on sensitive plant species in many areas of the eastern USA (Duchelle and Skelly, 1981; Neufeld et al., 1992; Simini et al., 1992; Chappelka et al., 1997). Black cherry (Prunus serotina Ehrh.), has been identified as a sensitive native bioindicator of ambient ozone in the USA (Davis and Skelly, 1992; Simini et al., 1992; Chappelka et al., 1997), Mexico (Skelly et al., 1997) and Europe (Innes et al., 1996).

The purpose of this paper is to report three-year results (1991-1993) relating ambient ozone concentrations to visible foliar injury on mature black cherry in Great Smoky Mountains National Park (GRSM) and Shenandoah National Park (SHEN) in the eastern USA. The findings reported here were made during two independent investigations using the same protocols in GRSM (Chappelka et al., 1994) and SHEN (Hildebrand et al., 1996), and illustrate the usefulness of this species as a native bioindicator of ambient ozone over the mid-Atlantic region of the USA.

2. Materials and methods

During August-September 1991-1993 three mature canopy black cherry plots were established and subsequently measured in GRSM and in SHEN; each plot in each park containing 30 trees each (Big Meadows in SHEN had 60 trees). The presence of an ozone monitor at each site (3 per park) permitted correlations of ozone exposure statistics with observed biological effects. Selection criteria have been detailed in Hildebrand et al. (1996) and Chappelka et al. (1994).

In GRSM the monitors were located at Cove Mountain, Look Rock and Twin Creeks. All monitors were located on the north-west periphery of the park (Tennessee). The air quality monitoring stations in SHEN were located at Dickey Ridge, Big Meadows and Sawmill Run. These stations were located at the northern (mile post 5), central (mile post 50) and southern (mile post 95) regions of the park, respectively. Ozone exposure statistics are shown in Table I; SUM0 = total cumulative ozone concentration (ppm-h), SUM06 = cumulative ozone concentration ≥ 0.06 ppm, and W126 = cumulative ozone concentrations weighted by a sigmoidal function (Lefohn et al., 1988).

Three exposed branches from the upper-crown and three branches from the mid- to lower-crown of each tree were collected and evaluated for visible ozone injury expressed as an adaxial leaf surface stipple; foliage was examined for incidence and severity of injury. If injury was observed, the percentage of injured leaves per branch was estimated. The Horstall-Barratt rating scale was used to quantify the relative severity of symptoms on the injured leaves (Horstall and Barratt, 1945). Before going to the field, crews were trained in ozone symptom recognition using a computer-based “expert system” (Nash et al., 1992). Although crews from both parks were not “cross-checked” during the study, before evaluations were started crew members from both parks met and discussed the evaluation system and symptom recognition, and co-evaluated several plants in the field for ozone injury. During the study, several meetings were held among the crews from both parks, where methodologies were discussed and revised if necessary.

The results for the individual parks have been presented elsewhere (Hildebrand et al., 1996; Chappelka et al., 1994, 1999). To compare results among the two parks Spearman’s Rank Correlation Analysis was used (SAS, 1985). This is a non-parametric procedure. The variables used in this comparison were % injured trees, the total leaf area injured (% leaves injured x % leaf area affected), elevation, SUM0, SUM06 and W126.