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A COMPARISON OF *CHIONASPIS SALICIS* INFESTATION INTENSITY UNDER ARTIFICIALLY ELEVATED CO_2 AND O_3

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ABSTRACT. Elevated greenhouse gases have significant impacts on forest communities at multiple trophic levels. To understand the effect of greenhouse gases on the phytophagous *Chionaspis salicis* bi-weekly observations were made at the Aspen Free-air Carbon Enrichment site in northern Wisconsin. These observations show that although the presence versus absence of scale was not related to greenhouse gas treatment, the intensity of scale infestation is related to greenhouse gas treatment.

Keywords: *Chionaspis salicis*, greenhouse gases

INTRODUCTION

Atmospheric carbon dioxide (CO_2) levels are increasing with the current average concentration of CO_2 being approximately 360 parts per million (ppm) and the concentration is expected to increase to 550 ppm by 2050 (IPCC 2007). Troposopheric ozone (O_3) levels have also increased by 40% (IPCC 2007). Given these increases it is important to understand how changes in greenhouse gases affect forest ecosystems and at what trophic level these gases are most influential. Plants grown under elevated CO_2 have lower concentrations of foliar nitrogen compared to plants grown under ambient concentrations of CO_2 (Mattson 1980; Lincoln et al. 1986; Fajer et al. 1989). Decreases in foliar nitrogen concentration alter feeding behavior of herbivorous insects and result in the consumption of more plant material (Lincoln et al. 1986; Fajer 1989). Other consequences of feeding on plants grown under enriched CO_2 include increased mortality, decreased mass, and longer periods of time in larval stages (Price et al. 1980; Osbrink et al. 1987; Akey & Kimball 1989; Fajer et al. 1989, 1991).

Chionaspis salicis (Walsh 1868, Hemiptera: Diaspididae) is a forest insect pest (Miller & Davidson 1990; Miller et al. 2005) distributed throughout the United States, Ontario, and Mexico (Nakahara, 1982; Kosztarab 1996). *Chionaspis salicis* has been collected from bark and leaves of several ornamental trees including Canadian serviceberry (*Amelanchier canadensis* L.), red osier dogwood (*Cornus sericea*), eastern roughleaf dogwood (*C. florida*), white ash (*Fraxinus americana* L.), balsam poplar (*Populus balsamifera*), eastern cottonwood (*P. deltoides*), quaking aspen (*P. grandidentata*), sandbar willow (*Salix exigua*), and black willow (*S. nigra*; Kosztarab 1963; Dekle 1976). Infestation by *C. salicis* can completely cover twigs and branches of trees. Sap extraction by *C. salicis* can result in decreased tree vigor, dieback, stunting, and eventual death (Ulgenturk & Canakeloglu 2004). Scale insects are rare in forest habitats. But when present damaging infestations have been observed in managed ecosystems with low levels of plant diversity and structural complexity (Langford 1926; Johnson & Lyon 1988). In northern Wisconsin (where this study was conducted) *C. salicis* becomes active in late May. Two generations of *C. salicis* emerge each year (pers. obsv.).

Elevated greenhouse gasses have been shown to act on multiple trophic levels, however the majority of this research has utilized leaf chewing insects (Fajer et al. 1989, 1991). Insect damage can also occur when the insect feeds on plant sap, rather than leaves, and therefore may be less affected by elevated greenhouse gases. The goal of this research is to examine the effect of greenhouses gases (CO_2 and O_3) on the frequency and intensity of scale infestation of quaking aspen (*P. tremuloides*).

METHODS

The Aspen FACE site.—The Aspen Free-air Carbon Enrichment (FACE) site in Harshaw,

Table 1.—The intensity of infestation of *Chionaspis salicis* on aspen tree clone 216 grown under one of four conditions. The data analysis was conducted on trees showing infestation only.

	No infestation	Low infestation	Moderate infestation	Heavy infestation
Control	390	6	0	0
Elevated CO2	382	2	4	8
Elevated O3	379	1	7	9
Elevated CO2 + O3	385	8	3	0
Total	1536	17	14	17

WI, located in north-central Wisconsin, U.S.A. (89.7° W, 45.7° N). A complete description of experimental design, set-up, and operation of the FACE site is described in Dickson et al. (2001). In brief, the FACE site (32 ha) is comprised of 12 rings (30-m diameter), each of which is divided into three sections: the eastern half is made up of mixed aspen genotypes of five clones. The southwestern quarter is alternately planted with aspen clone 216 and paper birch (*Betula papyrifera*). Finally, the northwestern quarter is alternately planted with aspen clone 216 and sugar maple (*Acer saccharum*). The trees are exposed to one of four treatments: (1) control, (2) elevated CO_2, (3) elevated O_3, or (4) elevated CO_2 and O_3. Elevated CO_2 concentrations are based on levels predicted for 2060. Elevated O_3 levels are approximately 1.5 times that of background concentrations which replicates levels of moderately polluted locations in the western Great Lakes region (Pinkerton & Lefohn 1987). Ambient air is blown into the rings for the control treatment. The gasses were blown into the rings during daylight hours of the growing season. At the time of this study the trees were 6-years old.

***Chionaspis salicis* Assessment.**—The current generation of *C. salicis* (as evidenced by intact and pure white cover of the test) were examined on quaking aspen (*P. tremuloides*) clone 216 under field conditions. There are 132 clone 216 in each of the 12 rings. The intensity of scale infestation from the current generation was recorded between 20 May and 25 September, 2003 twice a week. To relate the presence of the white test (a waxy secretion that covers the body) to the number of scale on a tree, trees were recorded as having none, low, moderate, or heavy scale infestations (Van Driesche et al. 1998; Matadha et al. 2003). No infestation occurred when, upon close inspection of trees, there was no current generation as evidenced by the presence of the white test. Low infestation occurred when the trees examined from 1 m away appear uninfested, but upon close inspection revealed the presence of scattered scale. Moderate infestation occurred when the tree was visibly infested, but scale did not encrust stems and dieback of branches was not apparent. Heavy infestation occurred when the infestation was immediately visible from a distance, scales encrusted stems and dieback of branches was apparent.

Statistical Analysis.—The number of trees infested shown to have some scale present was low (Table 1) as was observed in other research (Langford 1926; Johnson & Lyon 1988). To understand the effect of elevated greenhouse gases on scale infestation the data analyzed includes only those trees that are infested. A chi-squared statistical test was used to assess the distribution of scale infestation in the four treatments.

RESULTS

Biweekly surveys showed that scale infestations were present early in the growing season (mid-May) and scale were present throughout the growing season. Scale infestation in this experimental forest was low (48 trees out of 1584). The presence of scale was not related to greenhouse gas treatment ($X^2 = 5.793$; df = 3; p = 0.1221; Table 1). However, the intensity of scale infestation was related to the greenhouse gas treatment ($X^2 = 22.067$; df = 6; p = 0.0012). All trees (n=6) with scale infestation in control rings had an infestation categorized as low. Trees grown under elevated CO_2 or O_3 had more severe infestations (Table 1).

DISCUSSION

Increases in greenhouse gases have been shown to influence tree growth, physiology, and phytochemistry (Poorter et al. 1997; Penuelas & Estiarte 1998; Isebrands et al.

2001; Percy et al. 2002; Veteli et al. 2002). Elevated CO_2 can decrease herbivore growth (Zvereva & Kozlov 2006) and elevated O_3 has been shown to increase insect growth (Valkama et al. 2007). Generally, in natural ecosystems, sap-sucking insects are found at low infestations as was observed in this study. Although there were scale present on trees under all three elevated gas treatments the severity of infestation was greatest under elevated CO_2 or O_3 and least under the CO2 + O3 rings and control rings. There could be several possible explanations for this pattern. First, the infestation could have been related to tree health rather than the greenhouse gas treatment. The severity of infestation was the greatest in the CO2 and O3 rings and if the infestation is related to tree health or vigor the growth and survivorship of trees in these treatments should be similar. This is not the case. Trees growth and survivorship in the CO2 rings was higher compared to the other treatments (Kubiske et al. 2007). Conversely, tree growth and survivorship in the O3 rings was lower compared to the other treatments (Kubiske et al. 2007).

Second, greenhouse gases could affect population dynamics of predators and prey. An increase in the number of aphids found under elevated O_3 and this is coincident with a decrease in the number of natural enemies (Percy et al. 2002). Thus, the increase in O_3 has affected predator prey dynamics of aphids. Therefore, it is possible greenhouse gases affect population dynamics of natural predators of scale insects similar to that seen in aphids.

Third, plants produce secondary metabolites important in defense against plant herbivory. It has been shown that changes in these secondary metabolites in response to atmospheric changes are more likely to occur in juvenile trees. However, phloem is generally lacking in these secondary metabolites (Douglas 2013). It is unclear how elevated atmospheric gases affect the presence or absence of secondary metabolites in phloem.

In summary, the presence of *C. salicis* on quaking aspen is independent of the greenhouse gas condition. However, the intensity of infestation is greater under elevated CO2 or O_3. Understanding these effects is important to better manage these habitats as greenhouse gases continue to increase.

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