AN OZONE EFFECTS MONITORING PROGRAM FOR THE LYE BROOK WILDERNESS AREA IN THE GREEN MOUNTAIN NATIONAL FOREST OF VERMONT

Progress Report
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- PROGRESS REPORT -

Project Title: A preliminary assessment of ozone effects on vegetation in the Lye Brook Wilderness.

Location: Arlington, VT; Estimated distance from the Lye Brook Wilderness = 3 miles;

Site Description: Large open field along the southwest face of Mt. Equinox on property owned by the Monastery of the Carthusian Order; Approximate elevation = 2000 ft.

Goals and Objectives

An ozone monitoring station and open-top chamber facility was established adjacent to the boundary of the Lye Brook Wilderness in the Green Mountain National Forest. The goal was to obtain an assessment of current air quality and the potential negative effects of ozone on sensitive vegetation. The findings are intended to provide essential support data for an ozone damage survey in the wilderness area. specific objectives of the 1989 field season were as follows:

1. To monitor ambient ozone concentrations during the growing season at a location representative of wilderness conditions.

2. To assess the biological significance of ambient ozone concentrations in the area through the use of biological indicators.

3. To compare foliar and growth characteristics of a representative sample of ozone sensitive plants grown in charcoal filtered, unfiltered, and ambient air plots.

Accomplishments - 1989

1. Establishment of an ozone monitoring site:

Ozone was monitored continuously from June 17th to September 30th using a UV photometric ozone monitor and chart recorder. A summary of the mean hourly ozone concentrations is provided in Table 1 showing peak concentrations and number of hours when ozone exceeded phytotoxic levels. A cumulative ozone dose for the study area is presented in Figure 1 with comparative data from similar monitoring sites in New Hampshire and Massachusetts.

2. Establishment of a tobacco biomonitoring site:

Tobacco plants, 6 each of Bel-B (ozone resistant) and Bel-W3 (ozone sensitive), were maintained at the monitoring site from June 30th to August 25th. New plants replaced the old so that an optimal and relatively constant level of ozone sensitivity was maintained. Tobacco foliage was evaluated for ozone damage on a weekly basis using a prescribed formula. Changes in plant height and leaf area were also recorded. Injury scores were compared to known ambient ozone concentrations and then plotted over time to obtain a relative measure of air quality.

3. Operation of the open-top field chambers:

Four open-top chambers, two carbon filtered and two non-filtered, plus an ambient air plot were set up in the same location as the ozone monitor and tobacco site. The chambers were operational from July 25th to September 30th. Potted seedlings of white ash, tulip poplar, black cherry, and red spruce were randomly allocated to each chamber. Ozone injury symptoms were fully described for each species in each chamber or ambient air plot, and measurements taken to calculate changes in stem height and diameter over the exposure period. At the end of the season, all plants were returned to UMass for winter storage and reuse in 1990.

4. Photodocumentation of ozone injury symptoms:

The cumulative effects of ozone on Bel-B and Bel-W3 tobacco plants were photographed as injury symptoms progressed from slight to moderate to severe over a two week exposure period. Photographs were also taken to record evidence of foliar injury on tree seedlings in the unfiltered chambers and ambient air plots, and the absence of symptoms on plants in the filtered chambers. Any evidence of ozone-like injury to native plants growing in the immediate vicinity of the study area was also documented. This documentation is presented in an appended document with descriptive detail on leaf age and location, color and pattern of the injured area.

Results to Date

Data analysis procedures are in progress. The emphasis at this time is to describe the amount and severity of ozone injury on the chamber-grown plants and the tobacco bioindicators, and to relate the injury data to the available air quality data.

1. Ozone monitoring:

The hourly ozone means exceeded 50 ppb for a total of 286 hours and 80 ppb for 16 hours (Table 1). We have found that an ozone concentration above 50 ppb will cause foliar injury to the most ozone sensitive plants (e.g. Bel-W3 tobacco). The 80 ppb value used to be the National Ambient Air Quality Standard for ozone and is still considered by many scientists to be an appropriate standard to protect plant health. The cumulative dose (Figure 1) is similar to that found in other forested areas where ozone damage surveys have generated reports of visible injury to native plants, both woody and herbaceous.

2. Biomonitoring with tobacco:

Ozone symptoms were first evaluated on July 7th, one week after the first set of 12 tobacco plants arrived on site. Injury intensity was rated less than 10% in early July, increasing steadily to more than 50% by the end of the month. Consistently high ozone levels during the period from July 18th to 27th account for the increase in foliar symptoms during the same time period. In August, ambient ozone levels were lower than in July and foliar injury scores dropped back to the 5% to 24% range. Changes in plant height and leaf area and their relationship to foliar injury data have not yet been analyzed.

The cumulative injury curve for Bel-W3 tobacco (Figure 2) reflects the seasonal trend in ozone concentrations, showing a steep rise over the July observation period and than flattening out in August. The curve for Bel-B tobacco shows a similar trend even though the injury scores are much lower. Based on the known dose/response relationship for tobacco and the comparison of injury severity on Bel-B and Bel-W3, air quality in the study area may be categorized as fair (i.e. moderate ozone levels).

Tobacco plants were also used to monitor air quality in the open-top chambers. Plants in the filtered chambers were free of ozone injury symptoms. In the unfiltered chambers, the Bel-W3 cultivar showed light to moderate injury depending on the ambient conditions and the Bel-B cultivar, no injury.

3. Tree seedlings in the open-top field chambers:

The tree seedlings were evaluated for symptoms of ozone injury on July 25th prior to their distribution to the open-top chambers. Once in the chambers, they were checked weekly for obvious symptom development and then systematically re-evaluated on August 28th and 29th. Results are discussed separately for each species. Only the foliar injury data is available at this time. Growth response will be assessed after the second season of field treatment in order to maximize the opportunity for detecting significant effects.

Red spruce (n=95): On the July 25th observation date, prior to treatment initiation, the majority of spruce seedlings showed trace amounts of needle banding. None of the plants, however, showed any evidence of tip chlorosis, needle mottle or flecking, or general chlorosis. Mid-treatment, on August 10th there was no obvious change in symptom development. At the final evaluation date, plants in the unfiltered chambers showed a light amount of needle flecking and tip chlorosis and, just under half the plants, developed a bleached appearance on all but the youngest needles. A small number of plants in the filtered chambers also developed a bleached appearance but otherwise showed no change in symptom expression.

Yellow poplar (n=7): There were only a small number of this species on site but they were very responsive to ambient conditions, showing an unmistakable ozone response. All of the plants began the treatment period with trace amounts of classic ozone stipple on the older leaves. By August 10th, symptom intensity on plants in the unfiltered chambers and ambient air plot had progressed to a moderate to heavy stipple on as much as 35% of the leaf area per seedling. At the final observation date, on August 29th, the most heavily damaged leaves had dropped off leaving all but the youngest leaves showing light to moderate stipple. Injury symptoms also included a general chlorosis and light glazing on the older leaves. In contrast, the plants in the filtered chambers showed no increase in foliar injury over the treatment period.

Black cherry (n=95): Four plants out of the total showed trace amounts of upper-leaf surface stipple prior to the beginning of the treatment period. By August 29th, this number had increased to 19 and injury intensity had progressed significantly (light to moderate stipple). All of the symptomatic plants showing an increase in injury were in the unfiltered chambers or ambient air plot. The leaf color of all plants exposed to ambient ozone was a uniform faded green when compared to plants in the filtered chambers, even if there was no evidence of ozone stippling. Only the mid-aged and older leaves were affected, averaging about 30% of the leaf area per seedling.

White ash (n=10) and Green ash (n=50): The predominant symptom on both ash species was a uniform dark pigmentation on the upper leaf surface. It was present on seedlings in both filtered and unfiltered chambers and is believed to be unrelated to ozone stress. A characteristic ozone stipple developed on only 6 plants, the injury intensity not exceeding 25% in any case. A measurable increase in stippling from the July 25th start date to the August 29th end date was recorded only on those plants in the unfiltered chamber or ambient air plot.

Field symptoms: Foliar symptoms of ozone injury were observed on seedlings of trembling aspen and black cherry in the immediate vicinity of the monitoring site. Milkweed, aster, and blueberry also showed classic ozone symptoms, as did a sapling size white pine tree growing along the field edge. In the upcoming season, additional attention will be paid to verifying the ozone symptom on native plants and documenting changes in injury intensity over time.

Future Plans

The work plan for 1990 calls for a repeat of all procedures and evaluations at the monitoring site. The addition of a weather station is expected to add additional information on air flow patterns into the area and the influence of certain weather conditions on symptom expression.

FIGURE 1. Cumulative ozone dose at the Mt. Equinox monitoring site in Vermont, the Mt. Washington monitoring site in New Hampshire (lower curve), and the Mt. Greylock monitoring site in Massachusetts (upper curve). 1989.

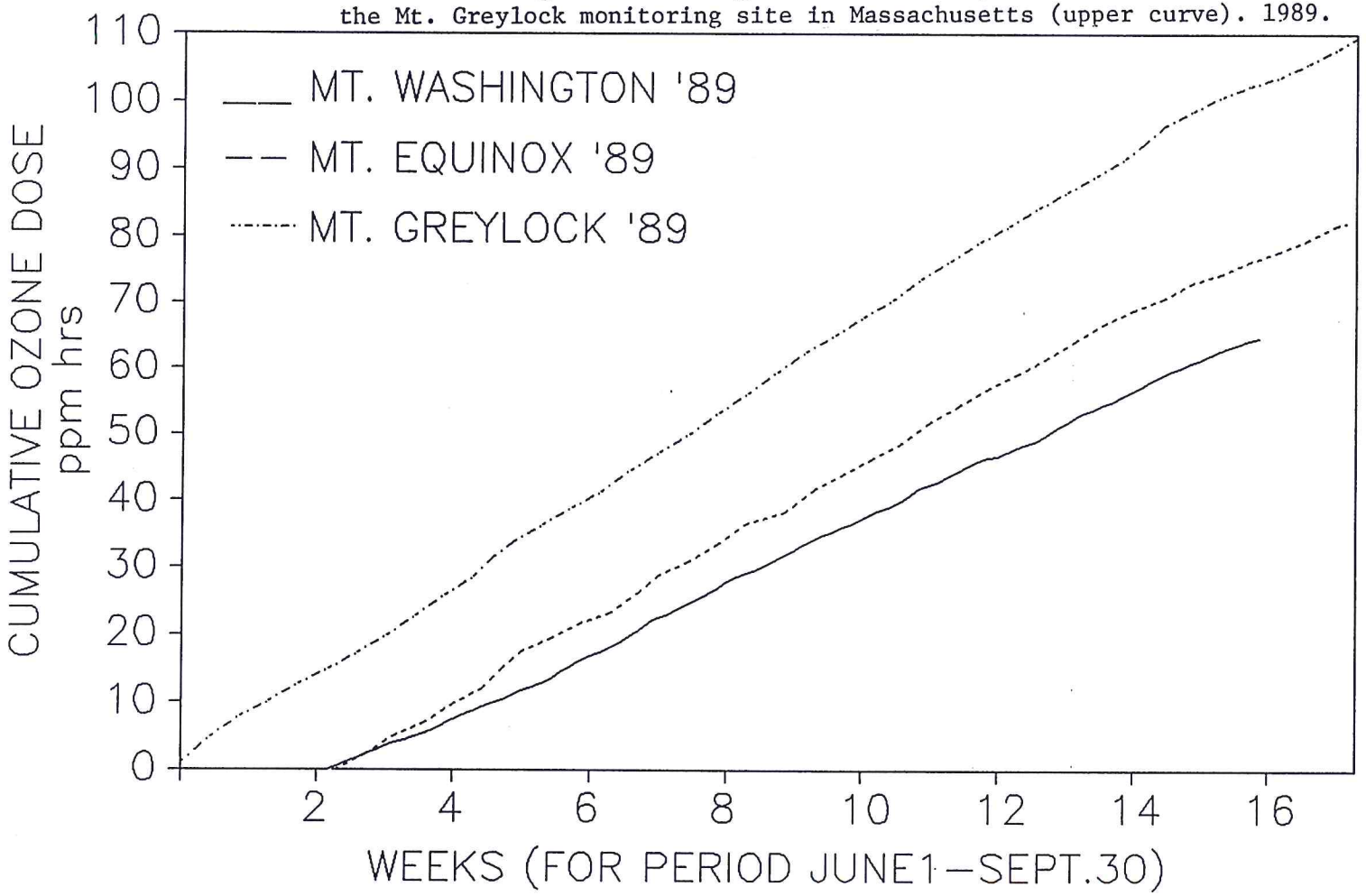


Figure 2. Cumulative foliar injury on Bel-B and Bel-W3 tobacco for the 1989 monitoring season in Vermont.

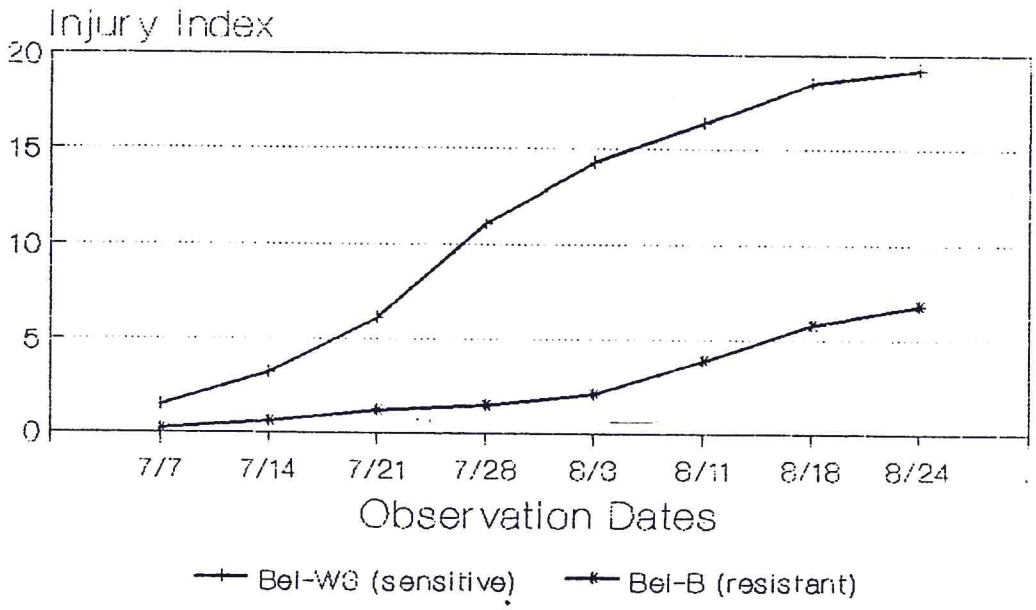


Table 1. Number of hours that the ozone concentration exceeded 80 and 50 ppb, the growing season average, and the second highest 1 hour average for the 1989 monitoring season.

	Monitoring Site*		Bennington/Airport Rd*	
Month	No. hrs. >80 ppb	No. hrs. >50 ppb	No. hrs. >80 ppb	No. hrs. >50 ppb
June*	5	38	11	53
July	9	143	12	143
August	0	83	0	62
September	2	22	1	68

Year	Growing Season Ave.**	Second Highest 1 Hour Ave.
M. Site	36.9 ppb	100 ppb
B./A. Rd	32.2 ppb	101 ppb

*The monitoring season extended from June 17th to September 30th for both sites. Data from the Bennington/Airport Road site is presented for comparative purposes only. The Bennington data was provided by Rich Poirot, State of Vermont, Air Pollution Control Division.

DOCUMENTATION OF FOLIAR INJURY SYMPTOMS

In addition to the prints displayed here, a catalogue of color slides is available providing additional detail on foliar injury symptoms and a record of all field activities.

Table 2. Comparison of 1988 and 1989 data from the ozone monitor at Bennington, Vermont

		APR	MAY	JUN	JUL	AUG	SEP	OCT	7 MONTH MEAN/TOTAL	MAY-AUG MEAN/TOTAL
7 hr ave (0900-1600) (ppb)	1988	42	55	59	61	51	39	32	48	56
	1989	50	55	45	47	43	37	37	45	48
Overall average (ppb)	1988	38	43	44	44	38	27	26	37	42
	1989	43	46	37	35	30	27	28	35	37
Average daily peaks (ppb)	1988	49	63	66	71	64	47	38	57	66
	1989	55	63	56	59	48	47	45	53	56
Number hours >50 ppb[1]	1988	55	218	161	207	197	61	43	942	783.
	1989	170	268	131	148	66	69	56	908	613
Percent hours >50 ppb	1988	9	37	31	32	29	9	6	21	32
	1989	25	39	19	21	10	10	8	19	23
Number hours ≥80 ppb[2]	1988	2	26	59	65	42	2	0	196	192
	1989	0	13	13	13	0	1	0	40	39
Percent hours ≥80 ppb	1988	3.4	4.4	10.8	9.4	6.1	0.3	0.0	4.4	7.7
	1989	0.0	1.9	1.9	1.9	0.0	0.2	0.0	0.9	1.4
Episodes[3]	1988	0	1	2	2	2	0	0	7	7
	1989	0	1	0	1	0	0	0	2	2

[1]50 ppb is the point where the most sensitive plants, such as Bel W 3 Tobacco (a variety commonly used as an indicator plant) show injury.

[2]Levels ≥80 ppb occurred on 35 days in 1988; 9 days in 1989. 80 ppb is the point where many sensitive plants show injury.

[3]An occurrence of ≥80 ppb for 2 hours on each of 2 consecutive days

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: Black Cherry - Filtered Chamber.

INJURY INTENSITY: None.

LEAF PIGMENTATION: Dark green.

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: Black Cherry - Unfiltered Chamber.

INJURY INTENSITY: Light to moderate.

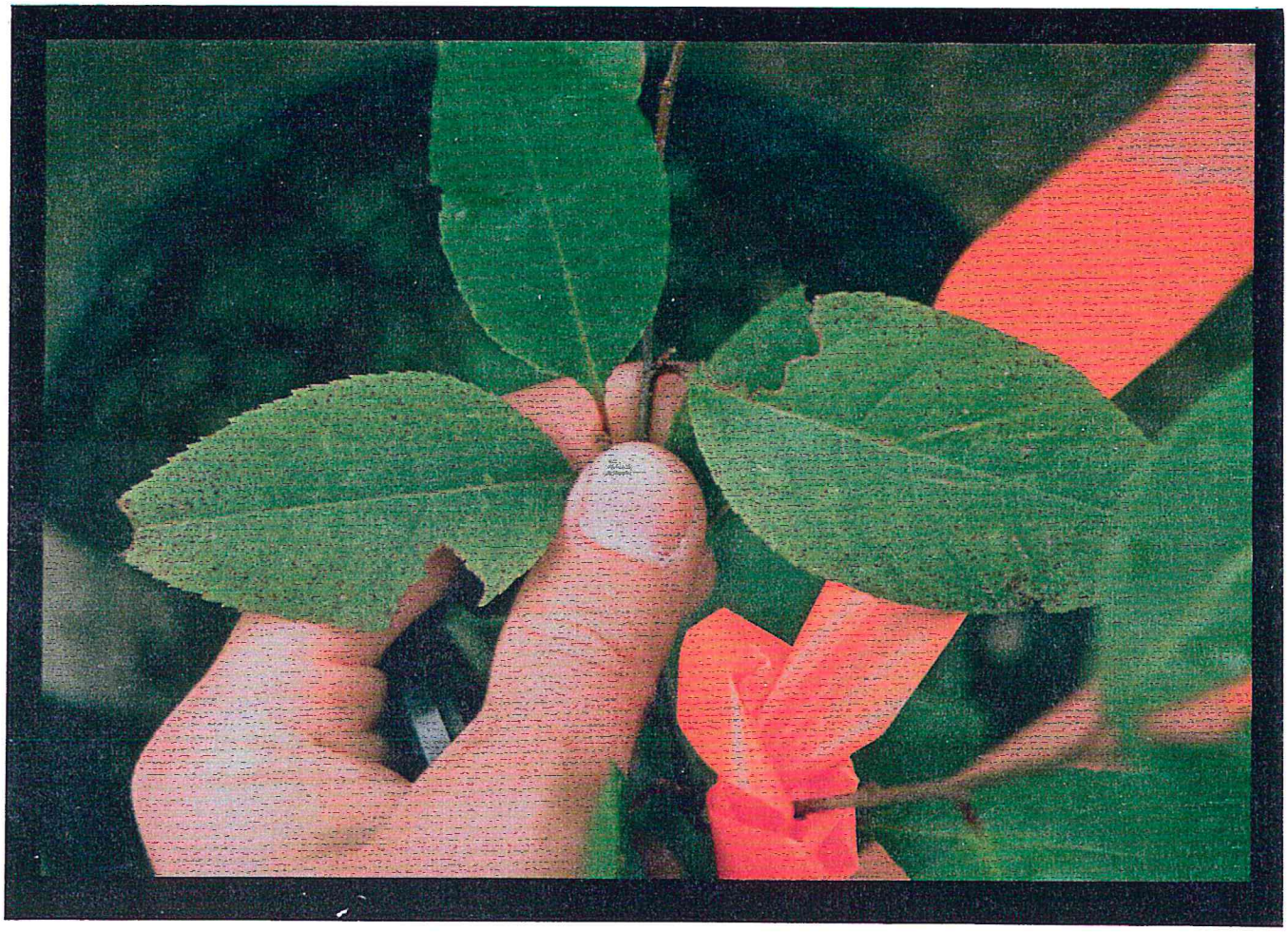
LOCATION: Older leaves, upper-leaf surface.

COLOR AND PATTERN: Purple-red stipple.

LEAF PIGMENTATION: Green to faded green.

PROBABLE CAUSE: Ozone.

Lye Brook Wilderness - 1989
Site: Arlington, VT



SPECIES: Black Cherry - Ambient air plot.

INJURY INTENSITY: Light to moderate.

LOCATION: Older leaves, upper-leaf surface.

COLOR AND PATTERN: Purple-red stipple.

LEAF PIGMENTATION: Faded green.

PROBABLE CAUSE: Ozone.

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: White Ash - Filtered Chamber.

INJURY INTENSITY: None.

LEAF PIGMENTATION: Dark green.

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: White ash - Unfiltered chamber.

INJURY INTENSITY: Light to moderate.

LOCATION: Mid-aged and older leaves, upper-leaf surface.

COLOR AND PATTERN: Purple-red stipple.

LEAF PIGMENTATION: Faded green.

PROBABLE CAUSE: Ozone.

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: Yellow Poplar - Filtered Chamber.

INJURY INTENSITY: None.

LEAF PIGMENTATION: Faded green to green.

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: Yellow Poplar - Unfiltered Chamber.

INJURY INTENSITY: Heavy

LOCATION: Mid-aged and older leaves, upper-leaf surface.

COLOR AND PATTERN: Purple-red to brown stipple.

LEAF PIGMENTATION: Faded green to yellow.

PROBABLE CAUSE: Ozone

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: Red Spruce - Unfiltered Chamber.

INJURY INTENSITY: Moderate

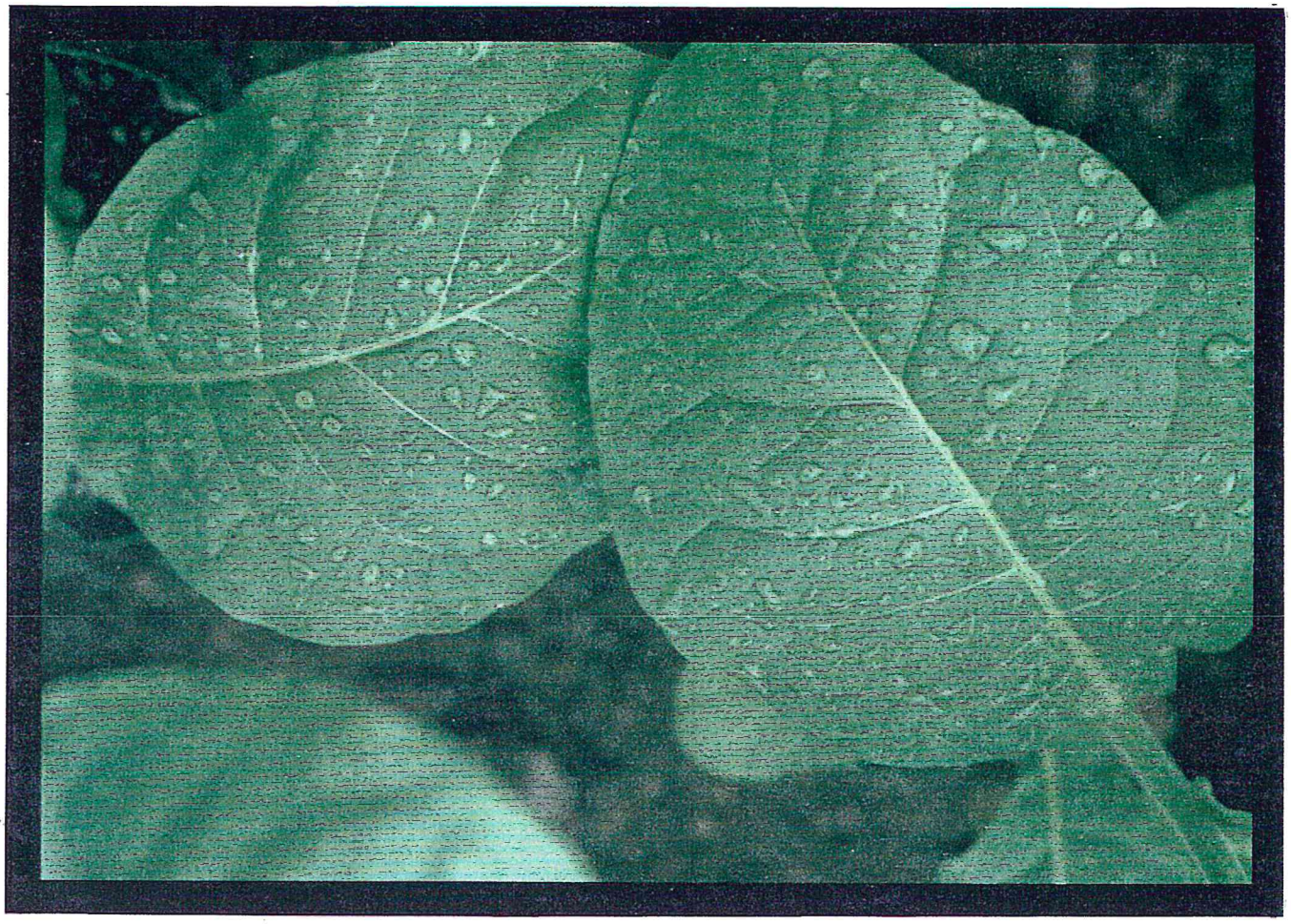
LOCATION: Mid-aged and older leaves.

COLOR AND PATTERN: White to tan, uniform, bifacial.

LEAF PIGMENTATION: Faded green.

PROBABLE CAUSE: Ozone

Lye Brook Wilderness - 1989
Site: Arlington, VT

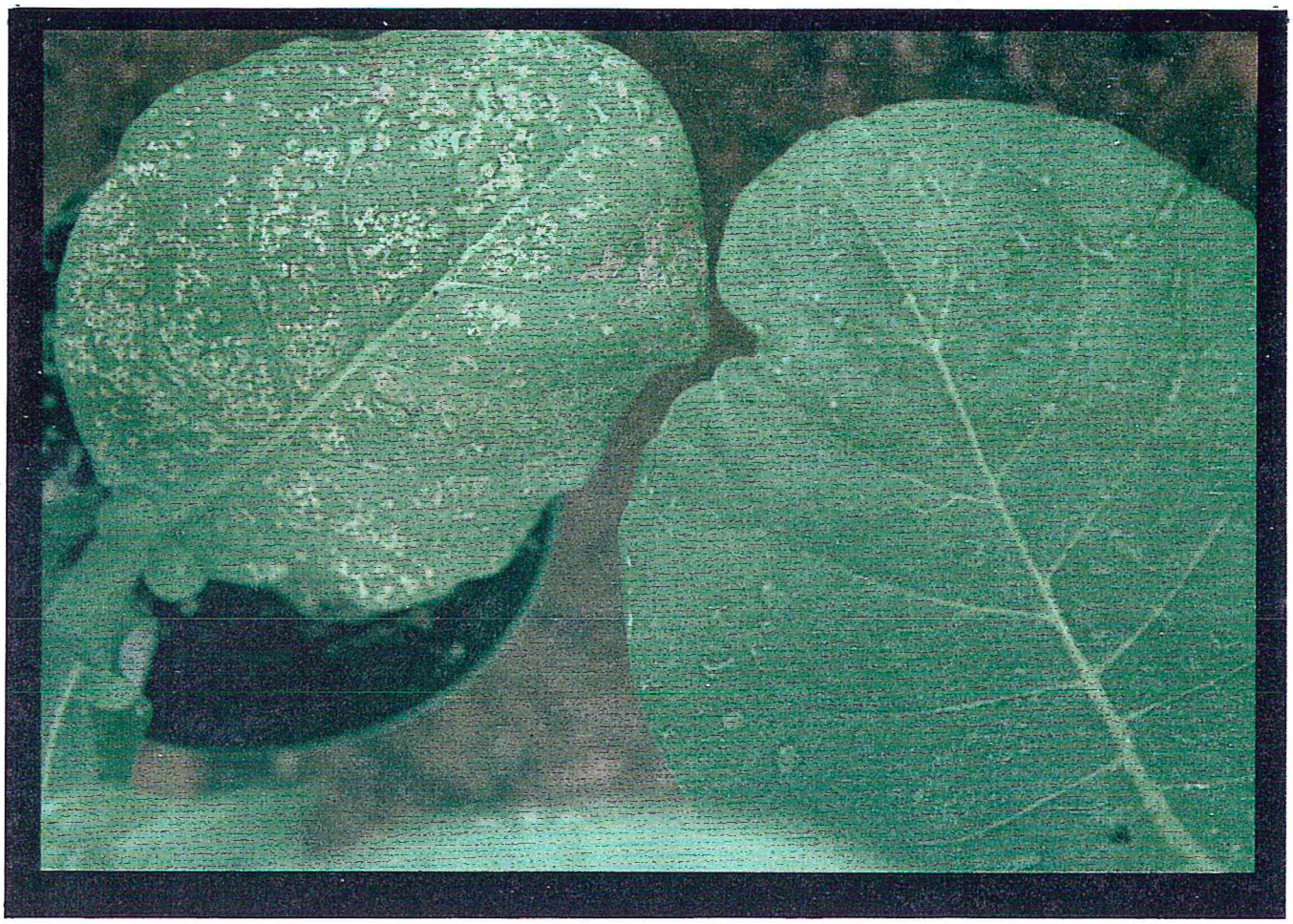


SPECIES: Bel-W3 (left) and Bel-B (right) Tobacco.
Filtered Chamber.

INJURY INTENSITY: None.

LEAF PIGMENTATION: Dark green.

Lye Brook Wilderness - 1989
Site: Arlington, VT



SPECIES: Bel-W3 (left) and Bel-B (right) Tobacco.
Unfiltered Chamber.

INJURY INTENSITY: Moderate (Bel-W3) - None (Bel-B).

LOCATION: Older leaves, upper-leaf surface.

COLOR AND PATTERN: White/tan flecks, small contiguous areas.

LEAF PIGMENTATION: Faded green.

PROBABLE CAUSE: Ozone.

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: Bel-W3 Tobacco.
Arrival date at site (left photo).
After 1 week exposure to ambient air (right photo).

INJURY INTENSITY: Moderate to severe.

LOCATION: Older leaves, upper-leaf surface.

COLOR AND PATTERN: White/tan flecks, small contiguous areas.

LEAF PIGMENTATION: Faded green.

PROBABLE CAUSE: Ozone.

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: Milkweed - Ambient air, roadside.

INJURY INTENSITY: Moderate to severe.

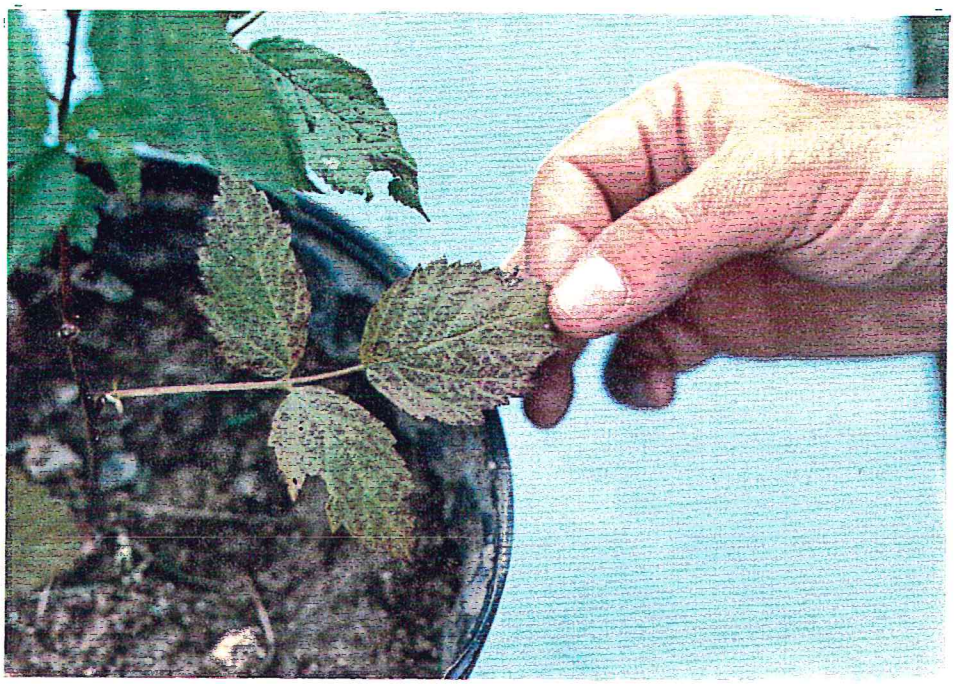
LOCATION: Mid-aged and older leaves, upper-leaf surface.

COLOR AND PATTERN: Purple-red stipple.

LEAF PIGMENTATION: Faded green.

PROBABLE CAUSE: Ozone.

Lye Brook Wilderness - 1989
Site: Arlington, VT



SPECIES: Blackberry - Ambient air plot.

INJURY INTENSITY: Moderate to severe.

LOCATION: Older leaves, upper-leaf surface.

COLOR AND PATTERN: Purple-red stipple.

LEAF PIGMENTATION: Faded green.

PROBABLE CAUSE: Ozone.

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: White pine - Ambient air, roadside.

INJURY INTENSITY: Moderate to severe.

LOCATION: Current and 1-year old needles, exposed crown area.

COLOR AND PATTERN: Brown to yellow tip-burn and banding.

LEAF PIGMENTATION: Faded green.

PROBABLE CAUSE: Ozone followed by secondary needle-cast fungi.

Lye Brook Wilderness - 1989
Site: Arlington, VT

SPECIES: Common Buckthorn - Ambient air.

INJURY INTENSITY: Moderate to severe.

LOCATION: Mid-aged and older leaves, upper-leaf surface.

COLOR AND PATTERN: Purple-red stipple.

LEAF PIGMENTATION: Faded green.

PROBABLE CAUSE: Ozone (sensitivity unknown)