Clean Air Carolina

Your advocates for healthy air

Ozone Garden Toolkit

About this Toolkit

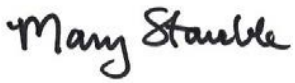
The Ozone Garden Toolkit is for individuals, schools, and community organizations interested in connecting people to the natural world by making the topic of air quality fun and educational. Ozone gardens use ozone-sensitive plants to make invisible air pollution visible.

Unfortunately, air pollution is part of modern daily life. Polluted air affects the health of plants, animals, and people. In Charlotte, North Carolina, where we are based, asthma is a major health problem. More than 10 percent of the students in our schools have been diagnosed with the disease. Nearly 10 percent more have asthma-like symptoms. In the American Lung Association's 2015 State of the Air Report, Mecklenburg County, home to Charlotte, was given an "F" for ground-level ozone.

Urban areas often suffer from chronic ozone levels caused by vehicle exhaust interacting with heat, sunlight and natural compounds. Many communities across the state face similar problems. In addition, our legislature has threatened to close a number of air quality monitors in North Carolina to reduce costs. These closures would leave residents unaware of the risks air pollution may pose to their health.

Knowing that clean air is essential for life, Clean Air Carolina wants to change this trend. Because most air pollution is invisible, projects like ozone gardens raise awareness of the risks associated with poor air quality. Clean Air Carolina works to educate people about these issues and advocates for stronger, more protective clean air policies. Clean air supports healthy children, a healthy environment, and a healthy economy. Working together, we can make this a reality.

For cleaner air,



Mary Stauble
Coordinator, *Clear the Air for Kids!* Program, Clean Air Carolina
NC Extension Master Gardener, Mecklenburg County, since 1998

Note: We've included materials from the *2011 Ozone Monitoring Guide* with permission from one of its authors, Susan Sachs in the Great Smoky Mountains National Park. The guide can be found at Hands on the Land: A National Network of Field Classrooms (www.handsontheland.org). Our Ozone Garden Toolkit presents these materials in a simplified format as we generally target a younger audience or those with a minimal science background. If you want to go deeper into the science of ozone gardens, be sure to refer to the list of resource materials at the end of the toolkit.

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Ozone Garden Project Overview

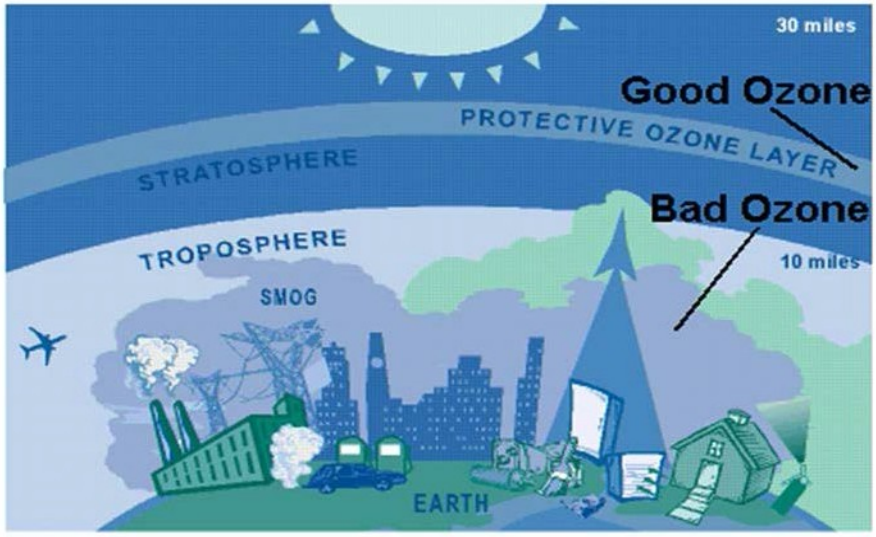
What is an Ozone Garden?

An ozone garden is a garden made up of plants that serve as bio-indicators of ozone injury. These bio-indicators are plants that exhibit a typical and verifiable response when exposed to a plant stress such as ground-level ozone. An ozone garden serves as an outdoor laboratory for citizens, educators and students to collect and analyze data on air pollution's effects on ozone sensitive plants. The plants used in ozone gardens can include cut-leaf coneflower (*Rudbeckia laciniata*), black-eyed Susan (*Rudbeckia hirta*), yellow crownbeard (*Verbesina occidentalis*), and common milkweed (*Asclepias syriaca*). These species exhibit stippling, or purple dotting, in response to ozone exposure. Students can monitor these responses to observe physical effects of ozone pollution.

What will the students learn from an Ozone Garden?

What is ozone?

Ozone, also known as O_3, is a colorless, highly reactive gas composed of three atoms of oxygen. Ozone occurs both in the Earth's upper atmosphere and at ground level. Ozone can be good or bad, depending on where it is found.



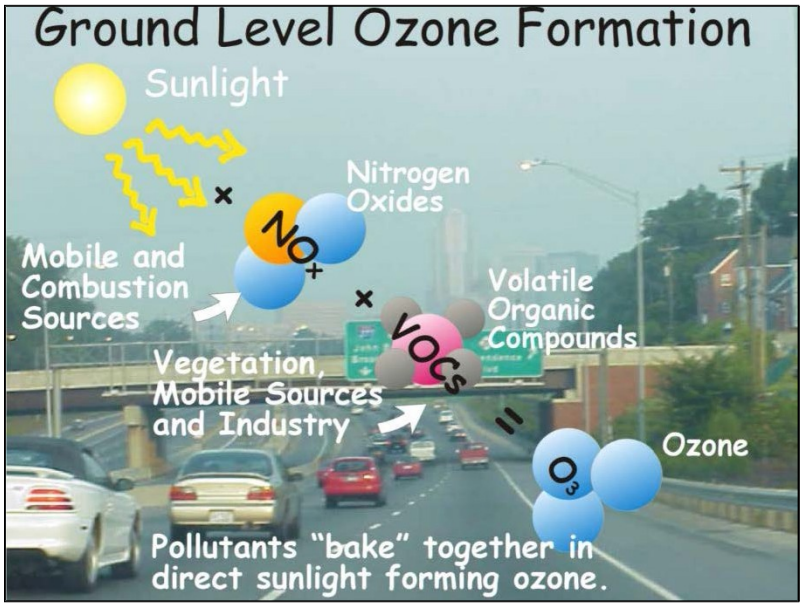
Capita.wustl.edu

Good Ozone (Upper atmosphere ozone)

Good ozone occurs naturally in the upper atmosphere, six to 30 miles above the Earth's surface, where it forms a protective layer that shields us from the sun's harmful ultraviolet rays. This beneficial ozone is gradually being destroyed by manmade chemicals. When the protective ozone "layer" has been significantly depleted; for example, over the North or South Pole; it is sometimes called a "hole in the ozone."

Bad Ozone (Ground-level ozone)

Tropospheric, or ground-level ozone, is formed when pollutants emitted by vehicles, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in the presence of sunlight. Ozone at ground level is a harmful air pollutant. Ozone is likely to reach unhealthy levels on hot sunny days in urban environments. Ozone can also be transported long distances by wind. For this reason, even rural areas can experience high ozone levels.



What are the ozone levels in my community?

Air quality forecasts are often given with weather forecasts on handheld devices, online, in the newspaper or on television. You can check ozone levels and other daily air quality information by visiting www.airnow.gov. In many areas you can receive daily air quality notifications via email through www.enviroflash.info.

Know the air quality code to better protect your health!

AIR QUALITY INDEX

Air Quality Index (AQI) Values	Levels of Health Concern
0 to 50	Good
51-100	Moderate
101-150	Unhealthy for Sensitive Groups
151-200	Unhealthy

Ozone's Effects on Health

Ozone in the air we breathe can harm our health. Even relatively low levels of ozone can cause health effects. Children, people with lung disease, older adults, and people who are active outdoors, including outdoor workers, may be particularly sensitive to ozone.

Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ground-level ozone also can reduce lung function and inflame the linings of the lungs. It has been compared to a sunburn in the lungs.

In ozone sensitive plants, ozone causes visual damage to the leaves. The effects of ozone pollution first show as a purple "stippling" on the topside of leaves. Eventually the leaves may yellow and begin to die. This process helps students see the harmful effects of invisible ozone gas on a living system.

The milkweed plant at the left has extreme ozone injury. Ozone injury usually appears as upper leaf surface purpling also called stippling, with the lower leaf surface clear of symptoms. Stipple is not present on the veins or veinlets.

Photo Credit: Handsontheland.org

Connection to NC Standard Course of Study

In keeping with the North Carolina Standard Course of Study, students are learning about the state of our local air quality, sources of air pollution, and health impacts on both plants and humans. They are also learning how our community is working to reduce air pollution and what they can do to improve our air quality.

How does air pollution affect children?

Children are particularly vulnerable to the effects of high ozone levels. They often spend more time outside involved in vigorous activities and they have a greater demand for intake of air. With their respiratory systems still developing, they are most susceptible to permanent lung damage. Low-income children in particular suffer disproportionately from breathing polluted air near their homes or schools. These children often live in areas with worse air quality. Studies have shown that children who grow up breathing polluted air have their lung capacity reduced by 15-20 percent.

Asthma has become a major children's health issue across the nation. It is aggravated by poor air quality. According to the Centers for Disease Control, one in 11 children have asthma. Children of color are particularly affected by poor air quality due to higher rates of asthma. Installing an ozone garden directly connects the issues of local air pollution and children's health.

How Ozone Gardens Teach Us about Air Quality

Ozone gardens help us to see the damage caused by unhealthy air due to ground-level ozone. Ozone damage on plant leaves is unique and easy to diagnose with a little practice.

Typical symptoms of ozone damage:

- Appear as purplish-black spots (called purpling or stippling) that **do not** cross leaf veins. If the spots do cross veins, it is likely caused by insects.
- Are seen only on the upper leaf surface, not on the back of the leaf. If it is on both sides of the leaf it is probably affected by insects, or another type of damage.
- Are found on most mature (older) leaves first.

NPS Photo

Note: Not all of the plants used in Clean Air Carolina ozone gardens are sensitive to ground-level ozone, but all contain at least one type of ozone sensitive plant. All the plants suggested for our gardens are native perennials that provide a long range of seasonal interest with a minimal amount of care. It is helpful to clearly label the plants so people know which ones are ozone sensitive.

Vocabulary Terms to Know

Bio-indicator: is a living organism (plant or animal) exhibiting a typical and verifiable response when exposed to an environmental stress such as ozone pollution.

Bio-monitoring: looking at a plant or animal that lives in a natural environment over time to check the quality of the ecosystem.

Chlorophyll: green pigment found in most plants that absorbs the light plants use to make food.

Chlorosis: yellowing of leaf caused by the loss of chlorophyll which is needed for photosynthesis.

Ecosystem: combined physical and biological components of an environment.

Ground-Level Ozone: an air pollutant resulting from a chemical reaction between nitrogen oxides and volatile organic compounds in the presence of sunlight. It occurs in the lower atmosphere (troposphere) where we live and breathe. Ground-level ozone is a component of smog.

Necrosis: localized death of a living tissue.

Nitrogen Oxides (NOx): produced from burning fuels, including gasoline, diesel and coal. Nitrogen oxides react with volatile organic compounds (VOCs) to form smog and ground-level ozone. Nitrogen oxides are also major components of acid rain.

Ozone (O_3): form of oxygen with three atoms of oxygen; a colorless, highly reactive gas that exists from the Earth's surface miles up into the atmosphere. Ozone occurs both in the Earth's upper atmosphere and at ground level. Ozone can be good or bad, depending on where it is found. "Good up high, bad nearby."

Photosynthesis: the process by which green plants containing chlorophyll use the energy of sunlight to produce carbohydrates (sugars).

Purpling (or stippling): most common symptom of ozone damage on specific species of broad leaf plants; discrete and very fine purple colored spots that are seen on the upper side of the leaf's surface. (Note: the actual color of the spots may vary depending on the plant species from tan to black.)

Stomata: tiny openings in a leaf surface through which gaseous interchange takes place.

Volatile Organic Compounds (VOCs): VOCs are released from burning fuel (gasoline, oil, wood, coal, natural gas, etc.) solvents, paints, glues, and other products used at work or at home. Vehicles are a major source of VOCs. VOCs combine with nitrogen oxides to form ozone. Trees naturally give off VOCs, 85% of the VOCs in North Carolina are from natural (or biogenic) sources.

Learn More About Air Quality and Ozone Gardens At School & At Home!

1. **KNOW THE CODE:** Go over the daily air quality code every morning. You can sign up to receive the daily forecast at www.enviroflash.info. When families know the air quality code they can see if it is a good day to be active outside.

AQI
AIR QUALITY INDEX

Air Quality Index (AQI) Values	Levels of Health Concern
0 to 50	Good
51-100	Moderate
101-150	Unhealthy for Sensitive Groups
151-200	Unhealthy
201-300	Very Unhealthy
301 to 500	Hazardous

2. **TURN OFF YOUR ENGINE:** Idling a car for just ten seconds uses more fuel than turning the engine off and restarting it. Turning off your engine while waiting saves you money and improves the air.

3. **CONSERVE**: Do your share to care for the air. Protect air quality by conserving energy. Drive less by using transit, biking, walking, or carpooling; turn off the lights if you leave the room, and close the doors and windows when the air conditioning or heating are on. Using less electricity reduces emissions from power plants that burn fossil fuels and release pollutants in the air.

4. **OZONE GARDENS:** Ozone gardens can help us learn about air quality. To learn more about ozone gardens go to the following link: bit.ly/1M2gZeN *(This link will take you to a site featured on www.handsontheland.org)*

5. **MONITORING:** To practice monitoring for ozone damage, go to the National Park Service ozone sensitive species training website: www.nature.nps.gov/air/edu/O3Training/index.cfm

6. **GET OUTSIDE:** Spend time outside! It is important to have an appreciation of nature, to understand our connection to the earth and to recognize our dependence on a healthy environment.

Strategies for Using Ozone Gardens in a School Setting

Ozone gardens are a tool for learning about air quality. The gardens help make invisible air pollution visible. At the most basic level, they get people thinking and talking about air quality, or "planting seeds for a new awareness". Actual ozone bio-monitoring is a more in-depth activity and teachers should not do it alone. They will need to enlist the help of student clubs, motivated students, and volunteers. They should also use creative classroom management strategies for garden observations to make it successful.

Prep with Classroom Lessons

It is beneficial to start with a lesson on air quality which will help students understand the air quality code and the role of ground-level ozone in impacting and degrading air quality. The students can become familiar with observing ozone damage on plants through online training such as *The Leaf Game in Online Lesson 1* on page 22 of this handbook. Practice completing an ozone data sheet is also helpful for students, and *Online Lesson 2* starting on page 23 accomplishes that. This preparation is important before going outside so students have a better understanding of what to do when collecting data in the ozone garden.

Work in Small Groups

Classrooms are busy places. Having 24-31 students makes garden observation difficult. It is best to divide the class into small groups of 6-12 people. They would then work in pairs to record data on three to six plants. When one group is finished taking observations, another group could follow. Having several groups collect data on the same plants allows the class to compare data collected and can help validate the accuracy of the observations. They will likely not be exactly the same, but a trend will be obvious and that's what is most important.

Develop a Regular Garden Maintenance Plan

Ozone gardens take some regular maintenance, so allow time for that. You should plan on weeding at least once a month and mulching in spring and fall to keep down weeds and keep in soil moisture. Once the plants are established, watering is only needed when the weather is extremely hot and dry. Although the plants in an ozone garden are perennials, they will die back after they have produced seeds and can be cut back to the ground in late fall. They will start actively growing again in early spring. Some plants can get very tall and can be staked or pruned back as needed to keep them from falling over.

Ozone Season

In North Carolina, ozone season starts in April and goes through October. This is when we have our warmest weather and the production of ground-level ozone is the highest. People can start monitoring their ozone plants in May or when the plants have at least

three sets of leaves. Plant identification (putting a metal ID label) and leaf tagging should take place at this time. This is best done by a school club or a volunteer. It takes some time and it is best to not be in a hurry. Most ozone damage is seen in July, August, and September and may vary depending on the plants used and the weather. It is important to have support for the project over the summer months to monitor the tagged plants and to water the garden if needed.

Bio-Monitoring Schedule

Ozone bio-monitoring gets easier with practice. It develops observation skills and the ability to accurately record what you see. Data is best recorded consistently: every week, every 2 weeks or every month as time allows. It is best to have a set time and day of the week (or month) to make ozone observations so it becomes a habit. But remember, this is your ozone garden. You can scale this up or down to suit your needs and the time and resources you have available. Enjoy your time in the garden. If you keep your eyes open there is always something interesting to see. Once a plant has produced mature seeds you can stop data collection as normal leaf death occurs at this time which mimics ozone damage.

Getting Started

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Ozone Garden Checklist

1. **Pick a Garden Location**
   Avoid places with fertilizer, pesticide, or insecticide usage. The garden should receive at least six hours of sunlight each day and have access to water. Once the location is finalized prepare the soil by removing weeds and adding compost.

2. **Build a Border for Your Garden**
   The shape of your garden will depend on how much space is available. Smaller is usually better, as smaller gardens are easier to maintain, but there needs to be room for the plants and an area to walk around the plants without stepping on them. A border is not essential, but is recommended so that people will know it is a garden space and should not be mowed or sprayed.

3. **Plant Your Ozone Sensitive Plants**
   Ozone sensitive plants can be purchased from a native plant nursery. If you know someone with an existing ozone garden, ask if you can collect rhizomes (underground stems with roots and shoots), or small plant divisions directly off their ozone sensitive plants. This is great to do in fall (October to November) so the plants have a chance to establish themselves before over-wintering.

4. **Maintain Your Garden While it Grows**
   Water, weed, and mulch the garden as needed to keep it healthy. It can take up to two years for some species to reach robust full growth. During this period you can make signage for the plants and mulch the garden. A two inch layer of mulch will help reduce maintenance by keeping down weeds and retaining soil moisture. It is good to refresh the mulch layer in November and again in May.

5. **Set Up Plant IDs**
   See pages 31-33 for a detailed description of this process.

6. **Collect Your Data**
   See pages 34-37 for a detailed description of the data collection process. Be sure to develop a monitoring plan for the summer months so the garden is maintained while students are on vacation. Note: Crownbeard flowers late in the season. For teachers who want to collect data in the fall rather than in the summer, it is a good ozone sensitive plant to use in the ozone garden.

7. **Maintain Your Garden**
   Remember to continue watering, weeding, and mulching the garden as needed. Check the garden at least every two weeks during the growing season from April to October. During cooler months, November to March, check the garden at least every 3-4 weeks. Timely weeding will keep your garden free of weed seeds and reduce maintenance.

Ozone Sensitive Plants & Where to Find Them

Cut-leaf Coneflower
Rudbeckia laciniata

Black-eyed Susan
Rudbeckia hirta

Yellow Crownbeard
Verbesina occidentalis

Many studies and recently published reports in the United States have documented ozone induced foliar injury. A few samples of ozone sensitive native species are listed below. A more in-depth list can be found at: bit.ly/1NXs8wY.

If looking for native plants to use in an ozone garden, get the specific plant listed (use the Latin name). Do not choose cultivated plant varieties as they may, or may not, be ozone sensitive. The Clean Air Carolina ozone gardens use cut-leaf coneflower *(Rudbeckia laciniata)*, and yellow crownbeard (*Verbensina occidentalis*) for bio-monitoring.

1. Common Milkweed (*Asclepias syriaca*)
2. Eastern Redbud (*Cercis canadensis*)
3. Yellow Poplar or Tuliptree (*Liriodendron tulipfera*)
4. American Sycamore (*Platanus occidentalis*)
5. Black Cherry (*Prunus serotina*)
6. Cut-leaf Coneflower (*Rudbeckia laciniata*) **Recommended for ozone gardens in NC
7. Thornless Blackberry (*Rubus canadensis*)
8. American Elderberry (*Sambucus canadensis*)
9. Yellow Crownbeard (*Verbesina occidentalis*) **Recommended for ozone gardens in NC
10. Black-eyed Susan *(Rudbeckia hirta)*

Sources for Native Plants

UNC Chapel Hill Botanical Garden, http://ncbg.unc.edu/
UNC Charlotte Botanical Gardens, https://gardens.uncc.edu/
Carolina Heritage Nursery, CarolinaHeritageNursery@gmail.com

Cut-leaf Coneflower, *Rudbeckia laciniata*

Cut-leaf Coneflower is ozone sensitive and is recommended for ozone gardens in the Carolina Piedmont. It grows actively in the spring. The leaves are alternate and are highly dissected, giving a "cut-leaf" appearance. The yellow flowers bloom in the summer, with fruit and seed production continuing until fall. It spreads easily by seed. Leaves are not retained year to year. At maturity, the typical Cut-leaf Coneflower will reach 6-8 feet high. It is a perennial, but it dies back to the ground in the winter and grows up again each spring.

 Alternate leaves on stem, with a dissected or "cutleaf" appearance	 Flowers

Yellow Crownbeard, *Verbesina occidentalis*

Yellow Crownbeard is ozone sensitive and is recommended for ozone gardens in the Carolina Piedmont. The opposite leaves have winged petioles that extend down the stem. It is a tall plant, growing from 3 feet to 10 feet during the growing season. Crownbeard has yellow flowers later in the season than cut-leaf coneflower. For teachers who want to collect ozone data in the fall rather than in the summer, it is a good plant to use in the ozone garden. It is a perennial, but dies back to the ground in the winter and grows up again each spring.

 Opposite leaves on stem	 Flowers

Black-Eyed Susan

There are many plants known as black-eyed Susans. This descriptive common name is frequently used for different plants which can be confusing. The Latin name is more specific and is what botanists use to identify plants. Note that the ozone sensitive black-eyed Susan, *Rudbeckia hirta,* is an annual so we do not use it as a bio-indicator in our ozone gardens since it would need to be replanted every year. Instead we use the black-eyed Susan *Rudbeckia fulgida* which is a perennial and will last for many years. It is not listed as ozone sensitive, but provides a long season of flowering, which helps to make the garden more attractive. There are many cultivated varieties of black-eyed Susans which are fun to see. Birds love to eat the seeds from the mature flower heads. The plants below are all in the genus *Rudbeckia,* but comprise several different species and cultivars.

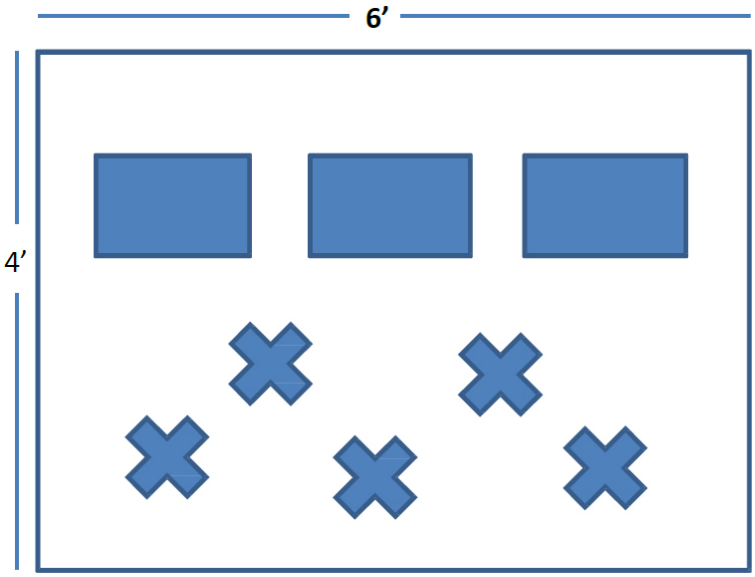
Common Milkweed, *Asclepias syriaca*

Common milkweed, though ozone sensitive, is not recommended in ozone gardens as it can become very aggressive and will crowd out other plants. It is a good food source for monarch larva and the flowers offer high quality nectar to many pollinators like bees, butterflies and hummingbirds. It is a great addition for less manicured areas that have the space for it.

 Opposite leaves on stem	 Flowers	 Lots of seeds that blow in the wind

Ozone Garden Design- Small School Ozone Garden

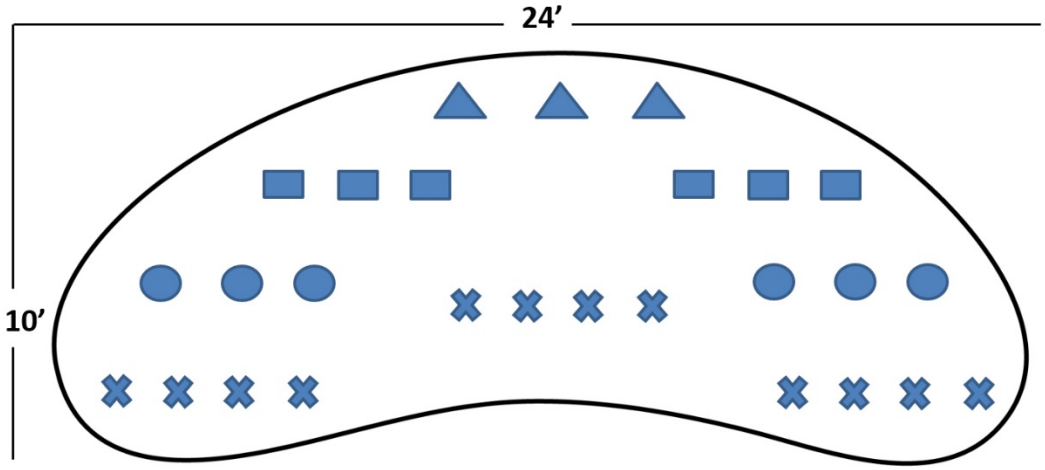
All plants included in this garden are native perennials to the southeast. They will last for many years and provide food for pollinators.



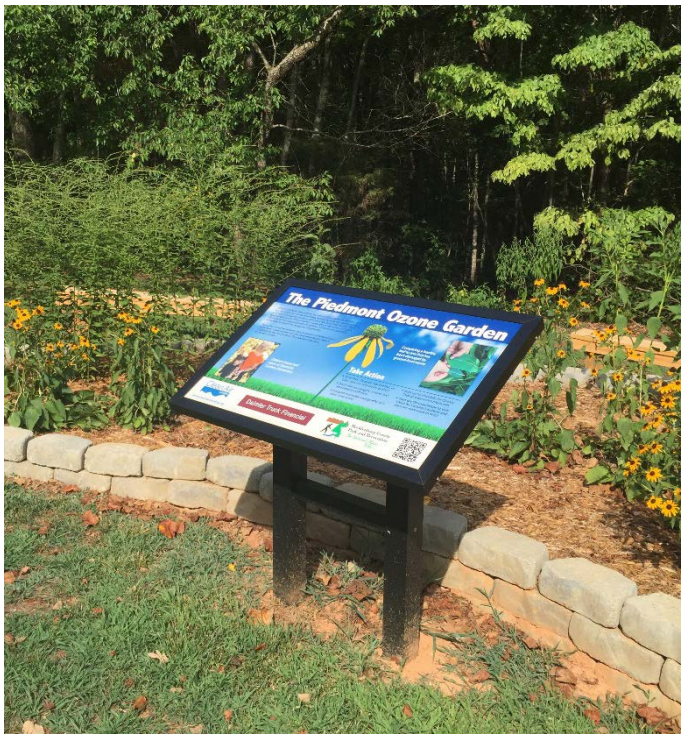
Key		Common Plant Name	Latin Name	
3		Cut-leaf Coneflower	*Rudbeckia laciniata*	Ozone Sensitive
5		Black-Eyed Susan	*Rudbeckia fulgida*	

Ozone Garden Design- Large Public Ozone Garden

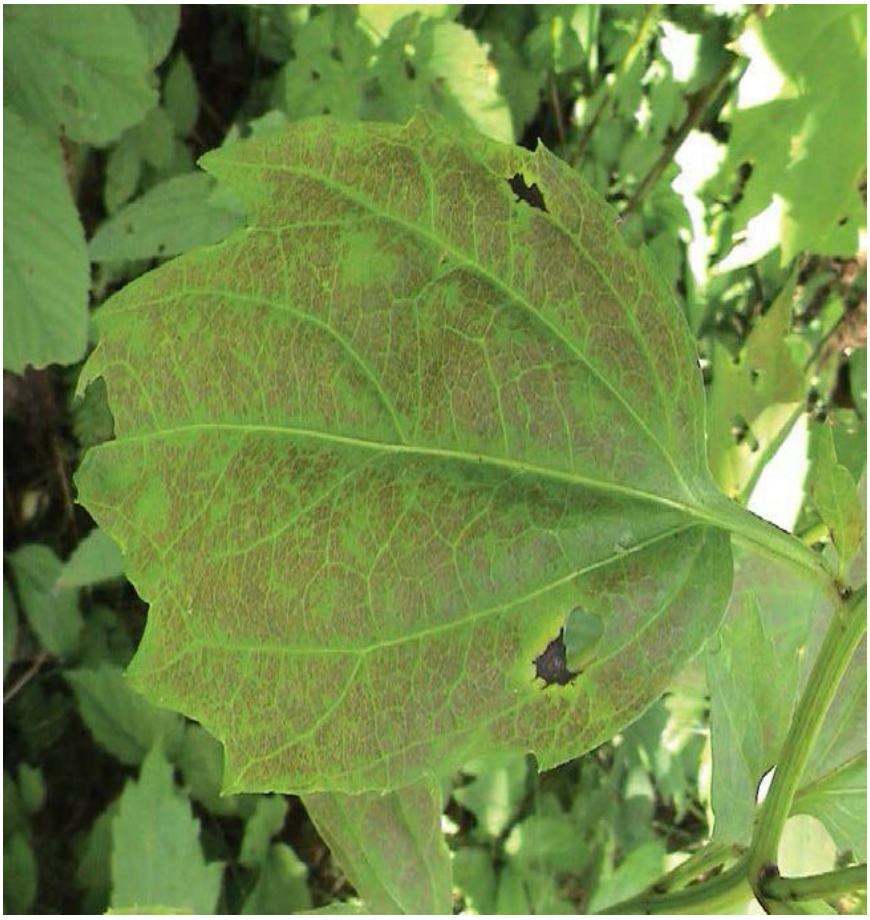
All plants included in this garden are native perennials to the southeast. They will last for many years and provide food for pollinators.



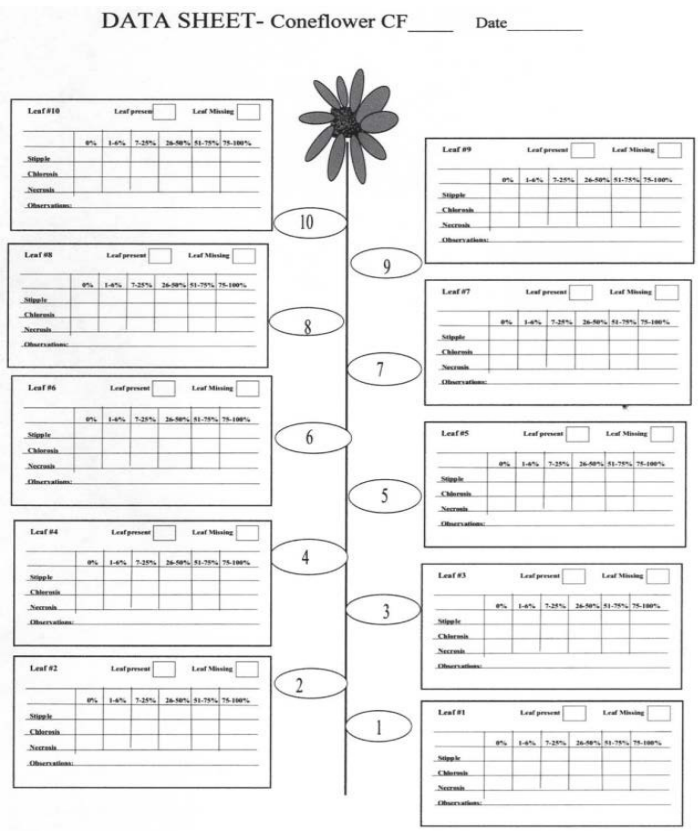
Key		Common Plant Name	Latin Name	
3	▲	Yellow Crownbeard	*Verbesina occidentalis*	Ozone Sensitive
6	■	Cut-leaf Coneflower	*Rudbeckia laciniata*	Ozone Sensitive
12	✖	Black-Eyed Susan	*Rudbeckia fulgida*	
6	●	Goldenrod	*Solidago rugosa*	



Online Lessons



To recognize ozone damage



DATA SHEET- Coneflower CF____ Date_____

Leaf #10 Leaf present ☐ Leaf Missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	75-100%
Stipple						
Chlorosis						
Necrosis						

Observations:

Leaf #9 Leaf present ☐ Leaf Missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	75-100%
Stipple						
Chlorosis						
Necrosis						

Observations:

Leaf #8 Leaf present ☐ Leaf Missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	75-100%
Stipple						
Chlorosis						
Necrosis						

Observations:

Leaf #7 Leaf present ☐ Leaf Missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	75-100%
Stipple						
Chlorosis						
Necrosis						

Observations:

Leaf #6 Leaf present ☐ Leaf Missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	75-100%
Stipple						
Chlorosis						
Necrosis						

Observations:

Leaf #5 Leaf present ☐ Leaf Missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	75-100%
Stipple						
Chlorosis						
Necrosis						

Observations:

Leaf #4 Leaf present ☐ Leaf Missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	75-100%
Stipple						
Chlorosis						
Necrosis						

Observations:

Leaf #3 Leaf present ☐ Leaf Missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	75-100%
Stipple						
Chlorosis						
Necrosis						

Observations:

Leaf #2 Leaf present ☐ Leaf Missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	75-100%
Stipple						
Chlorosis						
Necrosis						

Observations:

Leaf #1 Leaf present ☐ Leaf Missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	75-100%
Stipple						
Chlorosis						
Necrosis						

Observations:

To use a data sheet

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Online Lessons for Understanding your Ozone Garden

Grades 5 and above

The following lessons will help you get familiar with recognizing ozone damage on leaves.

Lesson I

Practice Estimating Ozone Injury: The Leaf Game

The National Park Service has created an online training for Ozone Sensitive Species: www.nature.nps.gov/air/edu/O3Training/index.cfm

The online training helps students recognize ozone damage and estimate the percentage of leaf injury. This activity is vital for students to practice to ensure their field activities are meaningful to them and the data they collect is accurate. Students should work in pairs at computers or view from a large screen as a class. The teacher should first walk the students through an example reading the instructions on the "Leaf Game" activity sheet. Students record their answers on the activity sheet found on the next page.

Lesson II

Practice Collecting Ozone Garden Data

During this lesson, students get practice using a data sheet to record information about a virtual ozone garden. Students look at pictures of cut-leaf coneflower leaves and estimate the percentage of ozone damage for the first eight leaves. They record the data for each leaf on their data sheet. The teacher can project images of each leaf or make color copies of the *Lesson II: Ozone Damage Data Sheet* at the end of this section for each student.

Lesson I: The Leaf Game

Navigate to the Foliar Injury Assessment Module website:
http://www.nature.nps.gov/air/edu/O3Training/index.cfm

- Change the number of leaf images for training to 10
- Click "select"
- Start training on Common Milkweed

Record your results here

Trial 1 = 10 leaves
1. Which species did you use?

2. Errors are to be expected, but it is important to record and track the categories in which you have wrong answers. Please write the total wrong answers in each category in the spaces below.

__ 0% __ 1%-4% __5%- 12% __ 13%-25% __ 26% - 50% __ 51% - 75% ___ 76% - 100%

Trial 2 = 10 leaves
1. Which species did you use?

2. Errors are to be expected, but it is important to record and track the categories in which you have wrong answers. Please write the total wrong answers in each category in the spaces below.

__ 0% __ 1%-4% __5%- 12% __ 13%-25% __ 26% - 50% ___ 51% - 75% ___ 76% - 100%

Trial 3 = 10 leaves
1. Which species did you use?

2. Errors are to be expected, but it is important to record and track the categories in which you have wrong answers. Please write the total wrong answers in each category in the spaces below.

__ 0% __ 1%-4% __5%- 12% __ 13%-25% __ 26% - 50% __ 51% - 75% ___ 76% - 100%

Trial 4 = 10 leaves
1. Which species did you use?

2. Errors are to be expected, but it is important to record and track the categories in which you have wrong answers. Please write the total wrong answers in each category in the spaces below.

__ 0% __ 1%-4% __5%- 12% __ 13%-25% __ 26% - 50% __ 51% - 75% ___ 76% - 100%

Did you get any better with each trial? In order to collect data in the ozone garden, you must get at least 80% correct on one of the 4 trials and be no more than one category off on incorrect answers.

Lesson II: Ozone Damage Data Collection

Monitoring Life in Great Smoky Mountains National Park

Grade Level:
5th grade and up

Subject Areas:
Earth Science

Activity time: 30 minutes

Setting: Indoors

Skills: Gathering information through observing; Analyzing information; Drawing conclusions.

Vocabulary:
- Biomonitoring: Over time, looking at a plant or animal that lives in a natural environment to check the quality of the ecosystem.
- Chlorophyll: Green pigment found in most plants that absorbs light plants use to make food.
- Chlorosis: a condition where plants produce insufficient chlorophyll and become discolored. Leaves often become pale yellow.
- Ecosystem: combined physical and biological components of an environment.
- Ground level Ozone: an air pollutant created by the interaction of nitrogen and VOC's in the presence of sunlight.
- VOC's: Volatile Organic Compounds. Highly reactive compounds in the air that can be either natural or man-made.

Objectives: Students will:
1) explain how ground level ozone can injure plants;
2) describe a biomonitoring project.

National Standards:
- Content Standard A: Science as Inquiry;
- Content Standard C: Life Science;
- Content Standard F: Science in Personal and Social Perspectives;

Materials:
- Color copies or projected images of leaves
- Data Sheet

Background:
Ozone Bio-monitoring Garden Project

An Ozone Bio-monitoring Garden is a way schools can take part in an important study to determine the effects of ozone on plant populations. The study will help to understand the relationship between foliar ozone injury and the growth of plants. The results of the study may be used to inform decision makers so adequate protective measures can be developed to improve the quality of the air we breathe. Results can be compared by tracking one leaf over the growing season and comparing a plant's growth over several years.

Ozone is formed when nitrogen oxides (NOx) combine with volatile organic carbons (VOCs) in the presence of sunlight to form an unstable gas that harms humans, plants and animals. Humans suffer through lung ailments leading to permanent lung damage and reduced immune system function. Plants show foliar damage and slowed growth. This adversely impacts the agriculture and forestry industries as well as plants in nature. Impacts to animals and aquatic systems have not yet been adequately studied.

Much can be done to reduce tropospheric (ground level) ozone by reducing energy use. Switching to more energy efficient appliances, using alternative, cleaner fuels when available, riding a bike or walking instead of driving, driving the most fuel efficient vehicle possible, and using mass transportation are all ways to reduce energy consumption. Working with local, regional and national decision-makers to develop the best possible standards to protect air quality for the benefit of public health and the environment is another important way to reduce ozone and improve air quality.

Monitoring

Ozone produces a type of injury on plant leaves that is unique and easy to diagnose. Typical symptoms:
- Appear after late June (except in high elevations areas which have shown symptoms in late May)
- Are found on most mature leaves first (so if you see what appears to be symptoms only on the newest leaves near the top of the plant, what you are seeing isn't ozone related).
- Are seen on the upper leaf surface, if you turn it over and it goes through, it is probably insect or

other damage.
• Appear as purplish-black spots (called stippling or purpling) that DOES NOT cross leaf veins. If spots do cross veins, it is damage likely caused by insects.

Introduction:
Explain to the students that they will collect data on photographs of leaves from one plant growing in Great Smoky Mountains National Park. In the field, data is only collected on the 8 lowest leaves and is done weekly.

Procedure:
1: Have students practice their estimation skills on 5 leaves by visiting the website **http://www.nature.nps.gov/air/edu/O3Training/index.cfm**. It is suggested that you train on Common Milkweed since it is in color. Ozone damage appears on the leaf as brownish-red stippling (dots).

2: Hand each student or groups of students one of the data sheets.

3: Either project images of each leaf, starting with the lowest leaf, or make color copies of the plant page for each student.

4: Have students estimate the percentage of ozone damage on each leaf. The plant they are collecting data on is Cut-leaf Coneflower (*Rudbeckia laciniata)*.

Wrap Up:
Have each group compare their answers. Did they all estimate the same percentages of ozone damage? Probably not. When data is collected in Great Smoky Mountains National Park throughout the summer, we are left with a trend for the entire growing season. Even if one set of data collectors make mistakes, we will still get an overall trend that shows the plants health. You can track a real plant through the growing season by going to the Hands on the Land website http://www.handsontheland.org/monitoring/projects/ozone/ozone_bio_search.cfm

Under "Report, Graphs and Maps", use the drop down list next to "Animate a plant's foliar injury over time" to select "Purchase Knob". Next click the "Graph" button.

This next page will allow you to animate one plant over the entire growing season. To view a plant, select a "Plant ID" from the drop down list. CB0209 is the Crownbeard plant 02 from the year 2009.

Drag the scroll bar under the drawing of the plant to see it change over the growing season. A red color indicates that a leaf is missing. Black indicates that the leaf is still there but is completely dead. Purple indicates ozone damage, yellow indicates chlorosis and green indicates a healthy leaf.

You will notice errors in the data since a plant can't recover from ozone damage, chlorosis or dead tissue. You will also notice that even with errors, you can still see the trend of ozone damage through the season.

Ask students why they think it is important to monitor plants for ozone damage?
The damage impacts the plants ability to photosynthesize as chlorophyll is lost. This also impacts the nutritional value of the plant if it is eaten by animals. Research has shown that plants with ozone damage are not as able to protect themselves against insect infestations or diseases.

Assessment:
Students can be graded on both the practice described in procedure 1 and the accuracy of their final data.

Answer Key:

Leaf 1: 76 - 100%
Leaf 2: 51 - 76% (high end)
Leaf 3: 51- 76% (low end)
Leaf 4: 26 - 50% (high end)
Leaf 5: 7-25%
Leaf 6: 1 - 6%
Leaf 7: 1 - 6%
Leaf 8: 0%

Extensions:
Monitor sensitive plants in your area either by planting them in your schoolyard or out in the wild. Go to **http://www.nature.nps.gov/air/edu/O3Training/index.cfm** for a list of sensitive species.

Resources:
Ozone Biomonitoring Study on Hands on the Land
http://www.nature.nps.gov/air/edu/O3Training/index.cfm

Lesson II: Ozone Damage Data Sheet

Monitoring Life in Great Smoky Mountains National Park

Group Name: _____ **Date**: _____

Plant species: _____ **Plant ID #:** _____

TOP OF PLANT

8

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

7

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

6

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

5

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

4

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

3

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

2

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

1

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

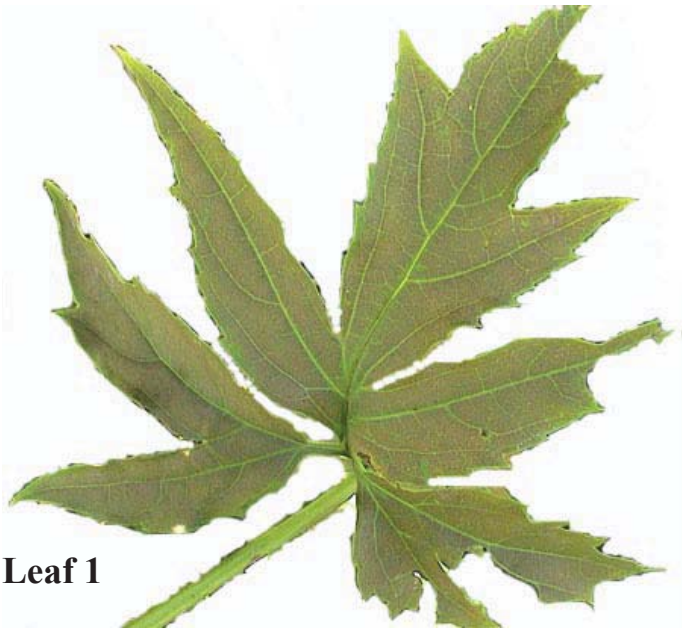
Observations

Rate the % of ozone symptoms covering the entire leaf
P= purpling (reddish-purple injury spots caused by ozone)

BOTTOM OF PLANT

Cut-leaf Coneflower (Plant ID CC0409)

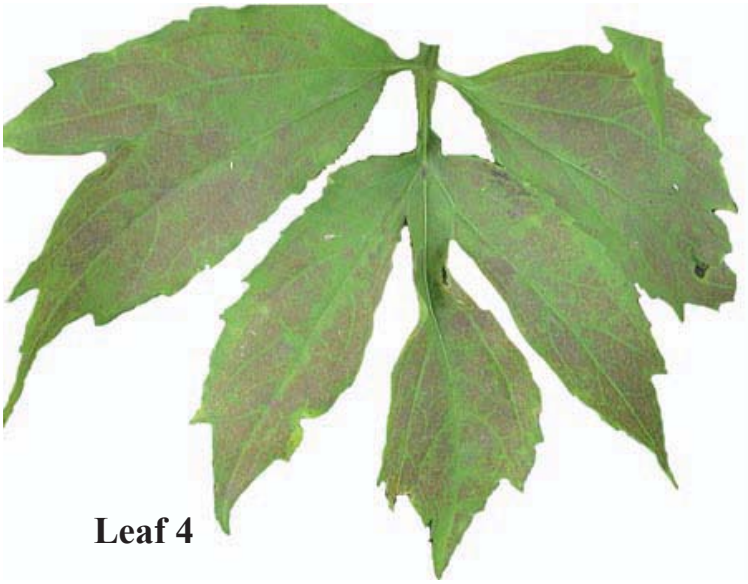
Note: Leaf 1 is the lowest leaf on the plant



Leaf 1

Leaf 2

Leaf 3

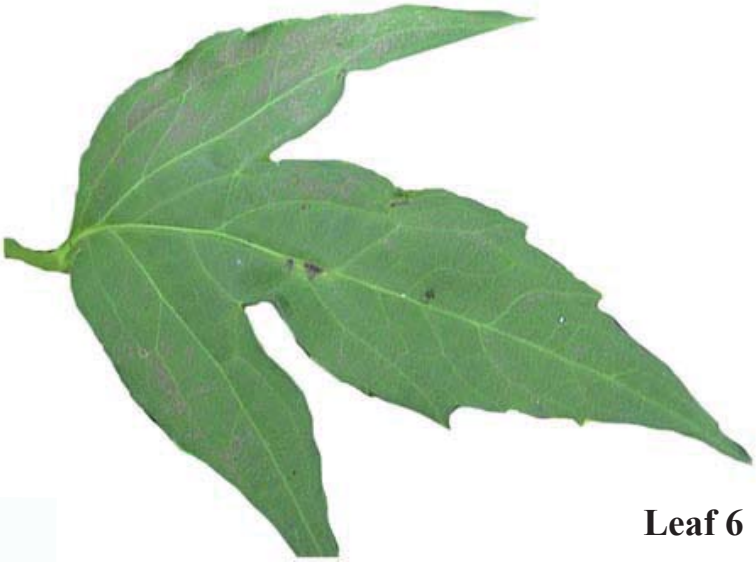


Leaf 4

Cut-leaf Coneflower (Plant ID CC0409)

Note: Leaf 8 is the highest leaf on the plant

Leaf 5



Leaf 6

Leaf 7

Leaf 8

Bio-monitoring

*** Information in this section is adapted from "Using Sensitive Plants as Bio-indicators of Ground-Level Ozone Pollution Implementation Guide", by Irene Ladd and Susan Sachs*

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Plant Observation Materials Set Up

A few simple materials are needed to assess ozone foliar injury. Gather the needed materials in a designated container to consistently transport them to the garden when doing plant observations.

Materials Needed

- ◻ **Meter Stick** to measure the height of the plant.
- ◻ **Small Flat Board** to assist in making height measurements. The board will be placed under the meter stick for stability on the soil surface while measuring.
- ◻ **10x Magnifying Glass** to carefully examine leaves for initial stippling, small insects and fungus.
- ◻ **Ozone Injury Field Guide** to help identify the percentage of ozone damage. Print the field guide (pages 42-43) and laminate or place it in a sheet protector.
- ◻ **Office Tags** to identify leaves or make your own leaf tags using the template provided in this toolkit (see page 40).
- ◻ **Black Fine Point Marker** to mark the "A" leaf of opposite leafed plants.
- ◻ **Pencils**
- ◻ **Clipboard** for Data Sheets (pages 38-39) to record observations.
- ◻ **Digital camera** for periodically recording the progressions of symptoms (optional).

Students from Shamrock Gardens Elementary in Charlotte, NC look at photos of leaves with ozone injury.

Setting up Plant IDs and Making Leaf Tags

Once the design of the garden has been established and cut-leaf coneflower rhizomes or plants have been planted, it usually takes 1-2 years for a coneflower plant to reach robust full growth. When the plants have reached full growth, then each plant will need to have an ID.

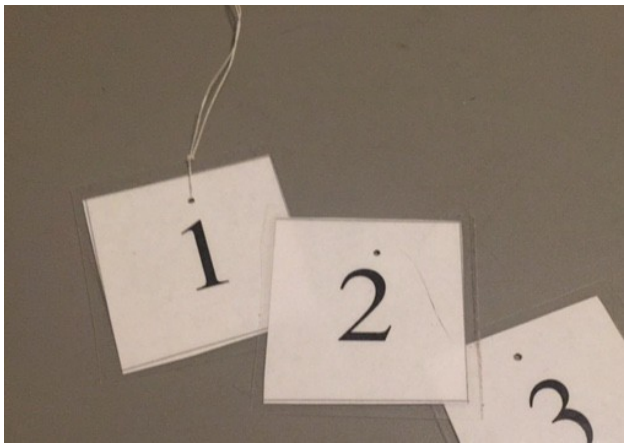
Note: Cut-leaf coneflower is an herbaceous perennial. Once established they will live for many years. Every fall the plants die back to the ground, but they are still alive in the soil. They will begin growing again when the weather warms up in spring. Cut-leaf coneflower may get over six feet tall and will have a lot of yellow flowers in mid-summer. Late May is a great time to set up your plant ID's and label the leaves as described below.

Use stakes or metal plant tags to ID each of your plants. For cut-leaf coneflower the plants are identified as CF and given a number. Label the first plant as CF01, second as CF02, third as CF03 and the fourth as CF04, etc. Give the same plants the same numbers each year. Use CB for crownbeard and MW for common milkweed. Select at least four to ten plants to monitor throughout the ozone season.

The metal plant tag CB07 is on the stem of the seventh crownbeard, plant in the garden.

Labeling Cut-leaf Coneflower Leaves

1. Start with CF01 (your first plant) for leaf tagging. Leaf tagging will make future data collection easier and more accurate.
2. Obtain eight leaf tags for CF01. These tags are available at office supply stores, or make your own. Label the tags with leaf numbers, e.g. 1, 2, 3, 4, 5, 6, 7, 8. (Some sample numbers are given on page 40 that can be used to make your own leaf tags.) Label just the first eight leaves or pairs of leaves coming off the main stem from the bottom.



As shown in the photo, numbers should be printed and laminated for outdoor use. Punch a small hole in the top and put a string through it. Use the string to tie the number carefully onto each leaf. These will last one growing season.

3. Start at the bottom of the stem and label the first leaf with tag 1. It is important to recognize that leaves may fall off the plant but they still should be counted and included in data collection. To determine if a leaf is missing, feel along the stem of the plant for a small knob, this is a leaf node and indicates that a leaf used to be there and was lost.
4. Continue up the plant labeling the first eight leaves. Cut-leaf coneflower has alternate leaves.
5. Repeat steps 1-4 for each of the remaining cut-leaf coneflower plants you will monitor.
6. Label the other ozone sensitive plants you have in your garden and want to monitor. Now that your plants are tagged with an ID, you are ready to begin the observation period!

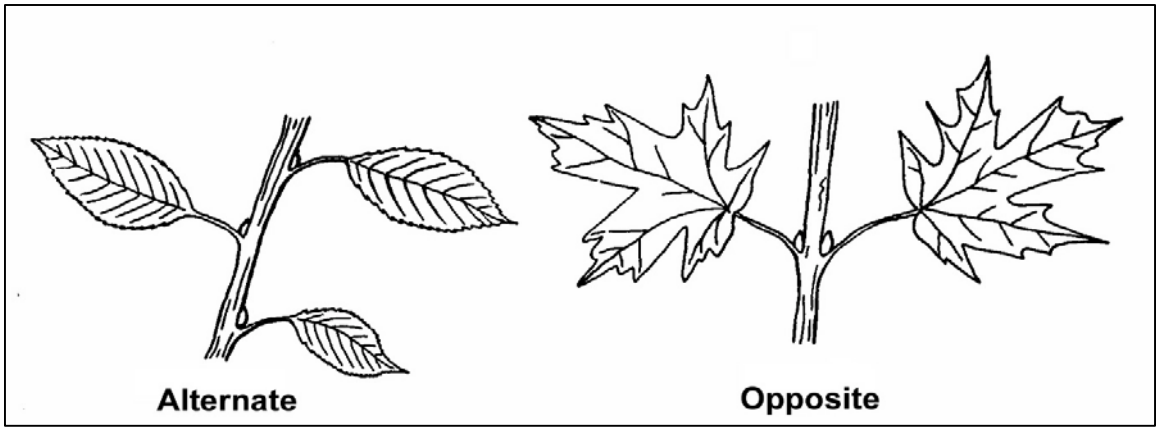
The photo on the left illustrates a cut-leaf coneflower plant with the leaves tagged. Notice that the numbers get bigger as you go up the plant.

Having the leaves numbered makes data collection easier and more accurate. Leaf number 1 will be the first leaf at the base of the stem. It is the oldest leaf on that plant. It will be the first leaf that will be checked for ozone damage. Everyone will know which leaf is number one.

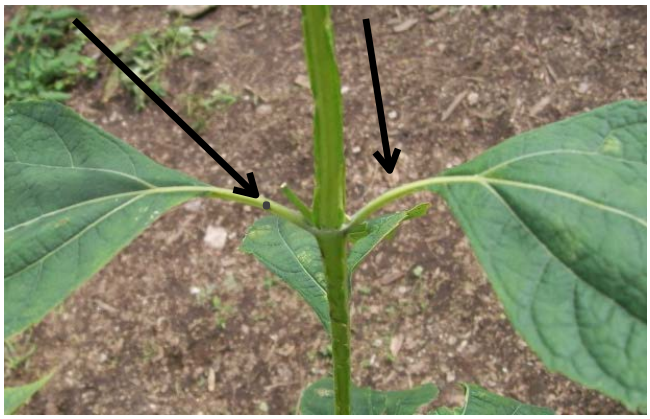
Sometimes a leaf may die and fall off. Even if leaf number one is missing, you still count it as the first leaf. You will just note on your data sheet that leaf number one is missing.

Alternate Leaf versus Opposite Leaf Plants

Plants have different ways their leaves are arranged on the stem. Two simple patterns are alternate leaves and opposite leaves. Each type of leaf arrangement has their own data sheet.



"A" leaf has a black dot "B" leaf doesn't



Note: For plants with opposite leaves like crownbeard, you also need to identify leaves as "A" or "B".

Using a permanent marker, place a black dot on the "A" leaf as shown in the image to the left.

Controlling the Growth of Your Plants

If needed, you can control the spreading of your ozone garden plants by digging up some of the roots at the end of the season and trimming back excess growth. You may want to let a second plant grow next to each of the original plants to double each species for data gathering.

Ozone Garden Data Collection - Written Instructions

Ozone pollution season in North Carolina is from April-October. Data collection can start in May (once plant has at least three sets of leaves coming off the main stem) and continue until the plant produces mature seeds, or until the first frost in the area. Try to collect data once every 2-3 weeks if possible, or at least once a month. The data collection should be done in pairs, with one person recording the data and one person taking the measurements. This method helps accuracy.

1. Obtain a data sheet for the plant you are measuring. Make sure to write down the names of the people taking the observations, the date, the garden location and the specific plant being measured (plant ID #) and plant species.
2. Measure the height of the plant with the meter stick in centimeters. Place a small flat board at the base of the plant, place the meter stick on the board, and hold the meter stick parallel to the plant. Measure from the base of the plant to the bottom of the highest, most open leaf. If the leaf hasn't opened yet, measure to the base of that undeveloped leaf. Or if the plant is in bud or flower, hold the plant straight and measure to the top of the tallest bloom on the main stem. Record the height on the data sheet.
3. Data collection will begin at the base of the plant with leaf one and will work up to leaf eight.
4. Count the total number of leaves (or leaf pairs) coming off the main stem. Do not count all the leaves on the plant, just those directly coming off the main stem. Only count leaves that are at least 65% expanded. Do count leaf scars where leaves have fallen off. Record this number onto your data sheet.
5. Starting with leaf one, check if the leaf is present or is missing. Then each leaf will be rated on the data sheet for purpling ("P") with one the following six codes: (a laminated Ozone Injury Field Guide on pages 42-43 can help you estimate the amount of ozone damage when you are in the garden.)

<u>Six Classes of Ozone Leaf Injury</u>

1 = leaf is present, no purpling (0%)
2 = 1% - 6% purpling
3 = 7% - 25% purpling
4 = 26% - 50% purpling
5 = 51% - 75% purpling
6 = 76% - 100% purpling

Class 1 P
No damage

Class 6 P
Complete damage

** Purpling estimation skill practice can be found at www.nature.nps.gov/air/edu/O3Training/index.cfm

6. Complete purpling data for the remaining seven tagged leaves on the plant. Use caution when checking the back of the leaf, especially if you notice any symptoms. These leaves will become fragile and will break off easily. Get down close and gently turn the leaf over to make your observation.
7. Record any other observations about the leaf, e.g. fungus, insect damage, dead leaf tissue or overall appearance.
8. 2-4 groups should collect data for each plant so that the results can be verified.
9. If a leaf breaks off or has broken off, make sure to assign it the appropriate leaf loss code:
   Leaf Loss Code:
   7 - leaf gone with no prior symptoms
   9 - leaf gone with prior purpling (the brownish purplish dots called stippling)
10. When a leaf falls off, carry its last data entry over into all of the following data collection entries. This is to show leaf loss on a graph or other visualizations as opposed to leaf improvement. For example, if a leaf had 51-75% purpling before it fell off, carry that rating over into future data collection with the leaf loss code of 9. This will show that the leaf fell off and didn't "get better". A rating of 0% isn't accurate.

> Note: If a plant is drought stressed the stomata (the small pores in the leaf that allow gases to enter or leave) will be closed to prevent plant water loss. If this occurs then the plant will be unable to take in ozone, which also enters leaves through their stomata. **The ozone garden should be watered when rainfall is in short supply.**

A school ozone garden in Charlotte, NC, July 2014

Ozone Garden Data Collection

Pictorial Instructions (Version I)

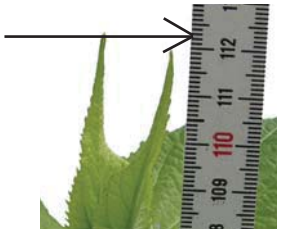
A. Two most important pieces of data in data collecting:

1. Collector name or group name
2. Date of data collection

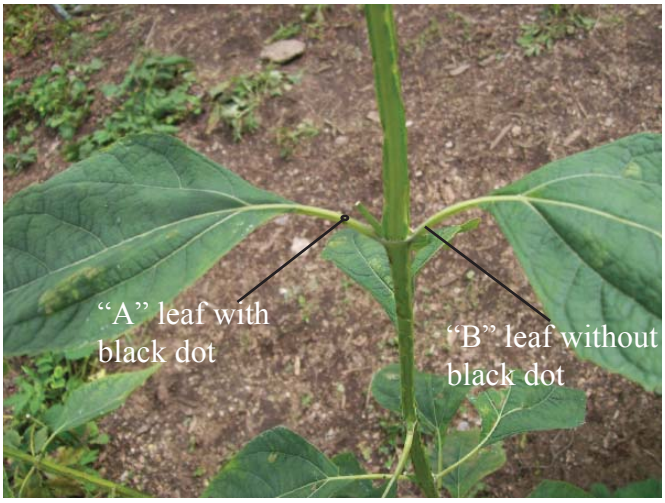
B. Find the plant ID# with the metal hang tag

C. Measure the HEIGHT of the plant

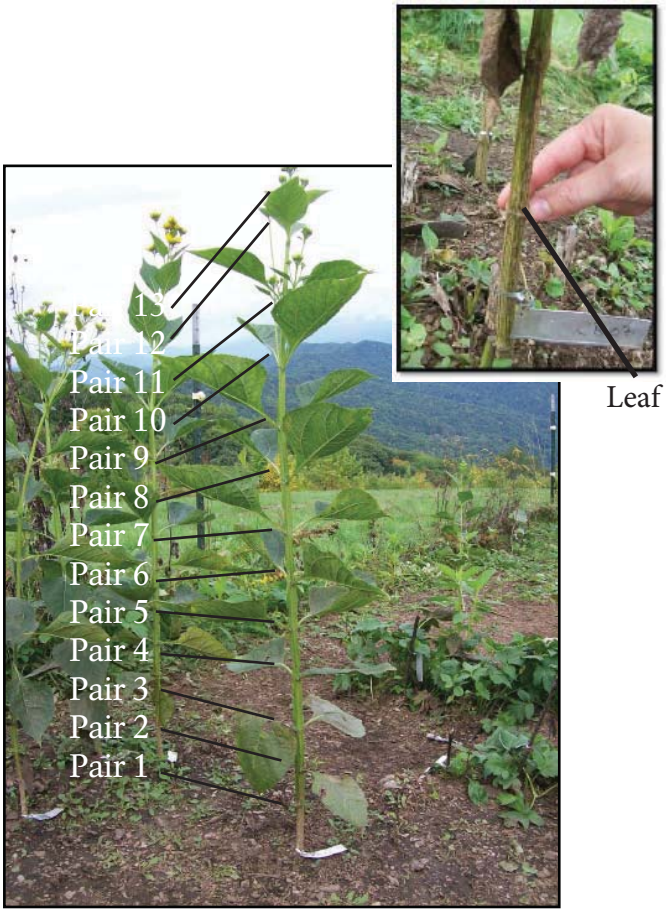
1. Use the metric side of the ruler (the side with the small numbers)
2. Measure from the base of the plant (beginning at zero) to the tallest leaf pair or bloom (if flowering) of the plant (apex) on the main stem



D. For plants such as Crownbeard, opposite leaves are identified as "A" leaf or "B" leaf



E. Count the # of leaf pairs that come off of the main stem, start at the base of the plant (make sure to count the pairs that may be missing at the base of the plant, leaf scars)



F. Observations

NO BUD OR FLOWER

IN FLOWER

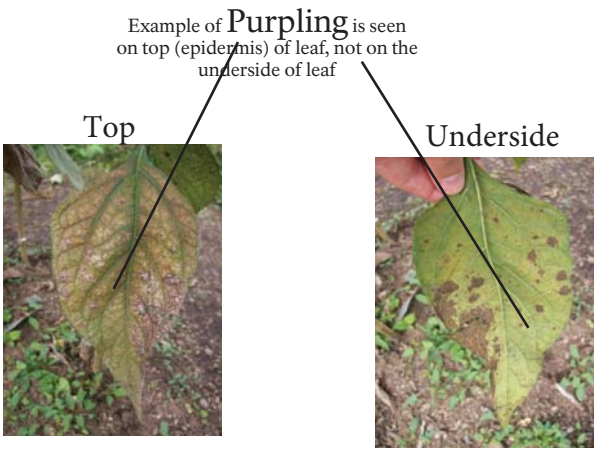
IN BUD

Ozone Garden Data Collection

Pictorial Instructions (Version I, page 2)

G. Estimate the percentage of total leaf area of each leaf that has foliar injury area using the NPS foliar injury scale

P = Purpling or Stippling

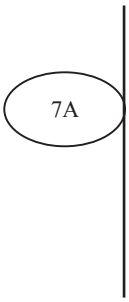


If the leaf is not present check box "leaf gone"

✓	Leaf gone	P
1	0%	
2	1-6%	
3	7-25%	
4	26-50%	
5	51-75%	
6	75-100%	
notes		

If leaf is present estimate the percentage of foliar area injury in the purpling category. An example of the rating is shown regarding the leaf 7A on the right side of the page

	Leaf gone	P
1	0%	
2	1-6%	✓
3	7-25%	
4	26-50%	
5	51-75%	
6	75-100%	
notes		



H. Hints:

1. Use caution when checking the back of the leaf, especially if you notice any symptoms. These leaves will become fragile and will break off easily.
2. For plants with opposite leaves, each facing pair of leaves is one set. For alternate leaf plants, such as the coneflower, count only the leaves coming off of the main stem.

Leaf 7A

Ozone Bio-monitoring Garden Data Sheet - Alternate Leaves

Group Name: _____ **Date**: _____

Garden Location: _____ **Plant ID #:** _____

Plant species: _____ **Plant height (cm):** _____

Total # of leaves on the entire plant: _____

Observations (in flower, in bud...) _____

_____

TOP OF PLANT

8

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

7

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

6

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

5

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

4

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

3

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

2

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

1

leaf present ☐ missing ☐

	0%	1-6%	7-25%	26-50%	51-75%	76-100
P						

Observations

BOTTOM OF PLANT

Rate the % of ozone symptoms covering the entire leaf
P= purpling (reddish-purple injury spots caused by ozone)

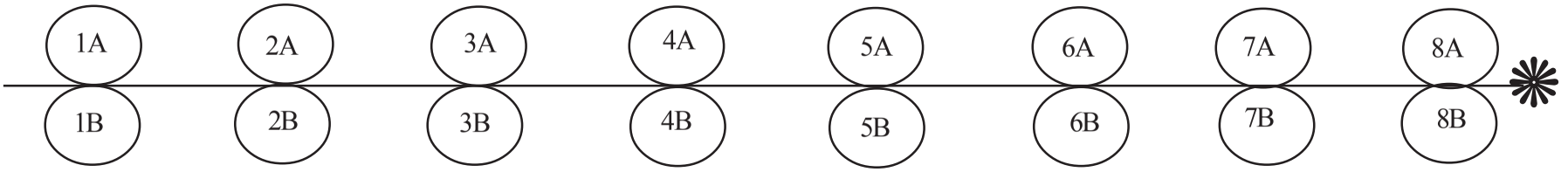
Ozone Bio-monitoring Garden Data Sheet - Opposite Leaves

School: ______________________________ **Date**:____________ **Plant species:** _____________ **Plant ID #:** _________________

Plant height (cm): ______________ **Total # of leaf sets on the entire plant:** __________ **Observations** (in flower, in bud...) ___________

Current 1 hour ozone: ___________ ____

	leaf gone	P		leaf gone	P		leaf gone	P		leaf gone	P		leaf gone	P		leaf gone	P		leaf gone	P		leaf gone	P
1	0%		1	0%		1	0%		1	0%		1	0%		1	0%		1	0%		1	0%	
2	1-6%		2	1-6%		2	1-6%		2	1-6%		2	1-6%		2	1-6%		2	1-6%		2	1-6%	
3	7-25%		3	7-25%		3	7-25%		3	7-25%		3	7-25%		3	7-25%		3	7-25%		3	7-25%	
4	26-50%		4	26-50%		4	26-50%		4	26-50%		4	26-50%		4	26-50%		4	26-50%		4	26-50%	
5	51-75%		5	51-75%		5	51-75%		5	51-75%		5	51-75%		5	51-75%		5	51-75%		5	51-75%	
6	75-100		6	75-100		6	75-100		6	75-100		6	75-100		6	75-100		6	75-100		6	75-100	
notes			notes			notes			notes			notes			notes			notes			notes		



	leaf gone	P		leaf gone	P		leaf gone	P		leaf gone	P		leaf gone	P		leaf gone	P		leaf gone	P		leaf gone	P
1	0%		1	0%		1	0%		1	0%		1	0%		1	0%		1	0%		1	0%	
2	1-6%		2	1-6%		2	1-6%		2	1-6%		2	1-6%		2	1-6%		2	1-6%		2	1-6%	
3	7-25%		3	7-25%		3	7-25%		3	7-25%		3	7-25%		3	7-25%		3	7-25%		3	7-25%	
4	26-50%		4	26-50%		4	26-50%		4	26-50%		4	26-50%		4	26-50%		4	26-50%		4	26-50%	
5	51-75%		5	51-75%		5	51-75%		5	51-75%		5	51-75%		5	51-75%		5	51-75%		5	51-75%	
6	75-100		6	75-100		6	75-100		6	75-100		6	75-100		6	75-100		6	75-100		6	75-100	
notes			notes			notes			notes			notes			notes			notes			notes		

This document can be found in the Hands on the Land Ozone Garden Implementation Guide: bit.ly/1NAkvg2

1	2	3	4	5	6	7
1	2	3	4	5	6	7
1	2	3	4	5	6	7
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8	8	8	8	8	8	8

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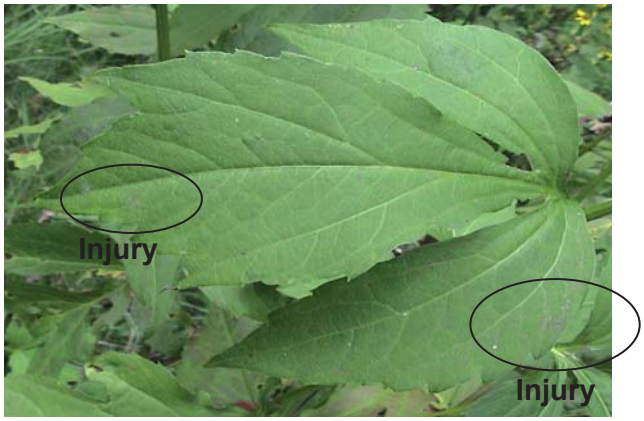
Ozone Injury Field Guide

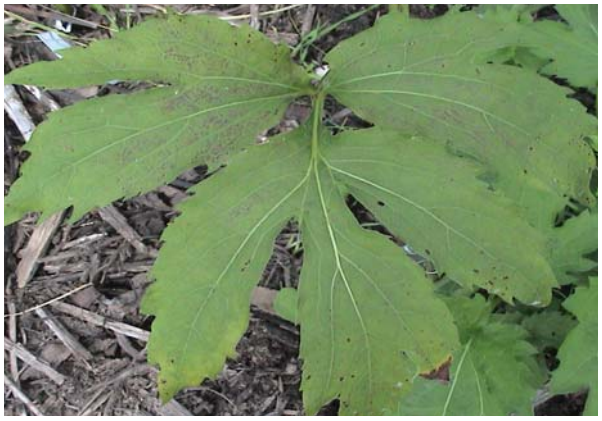
Estimating foliar leaf injury on Cut-Leaf Coneflower and Crownbeard

Injury level 1
0%



Lower end of Injury
level 2 (1-6%)

Upper end of Injury
level 2 (1-6%)



Lower end of injury
level 3 (7-25%)

Upper end of injury
level 3 (7-25%)

National Park Service Categorization Method

Lower end of injury level 4 (26-50%)

Upper end of injury level 4 (26-50%)

Lower end of injury level 5 (51-75%)

Lower end of injury level 5 (51-75%)

Must notice the small green Areas that make this leaf a high Level 5 as opposed to a 6

Complete foliar injury

Injury level 6 76-100%

Remember: Stippling (also known as purpling) is only on the top surface of the leaf and does not cross the leaf veins.

Classroom Follow Up Activities

These activities can be used in conjunction with the data collection to learn about ozone gardens and bio-indicators.

1. At the end of the growing season, have students make graphs showing changes to one leaf or one plant they monitored over the growing season.
2. What percentages of purpling did you find?
3. What patterns, if any, do you see in where the purpling has occurred?
4. What conclusions can you draw based on the data you collected?
5. What questions do you still have about ozone damage?
6. What is necrosis?
7. What are the effects of ground-level ozone exposure on humans?
8. What is the effect of chlorosis (leaf yellowing) on a plant? If the cells are no longer green, how does that affect the rate of photosynthesis?
9. Plants bring in ozone through their stomata. What role do stomata provide for plants? Are stomata open 24 hours a day? When are they most fully open? When is ground-level ozone the highest? (Older students can review research papers that are posted on the Hands on the Land website.)
10. What are the agricultural crops that are sensitive to ozone? (A Google search will bring up many results.) What effects could crop damage have on a region's economy?
11. Visit www.smogcity.com. At this website, students can manipulate weather conditions, human population and emission sources to see how they interact to change ground-level ozone conditions. Go to the "What You'll Learn" section to come up with focused experiments for your students.
12. What is happening with new laws concerning ground level ozone? What is the North Carolina Clean Smokestacks Act and what types of emissions does it affect? Is there any new or pending legislation in neighboring states?

*Adapted from Great Smoky Mountains Ozone Bio-monitoring Garden Resources

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Additional Resources

The Great Smoky Mountains National Park and the NC Division of Air Quality partner each year on an advanced air quality workshop in the Great Smoky Mountains National Park.

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Additional Resources

Ozone Gardens and Bio-monitoring

- Hands On the Land Ozone Bio-monitoring: bit.ly/1NK2vhe
- Hands On the Land Ozone Garden Project Implementation Guide: bit.ly/1NAkvg2
- National Park Service Ozone Training: www.nature.nps.gov/air/edu/O3Training/index.cfm
- EPA publication called "What You Need to Know About Ozone and Your Health": http://www.epa.gov/airnow/health/smog.pdf
- NASA Ozone Garden Project: http://aura.gsfc.nasa.gov/outreach/ozonegarden.html
- Saint Louis Ozone Garden Project: bit.ly/1WJwxYw

Articles on Ozone Gardens

- Using Citizen Scientists to Measure the Effects of Ozone Damage on Native Wildflowers from NSTA's Middle School Science Classroom: bit.ly/1MEHrfn
- The Plants in this Garden Tell You When the Air is Dirty: bit.ly/1MEHzvd

Air Quality Resources, Training, and Workshops

- Environmental Protection Agency (EPA): https://www.epa.gov/ozone-pollution
- Air Quality Index: http://www.airnow.gov/
- NC Division of Air Quality's Air Awareness Teacher Page (Grades K-12): http://ncair.org/airaware/edu

Ground Level Ozone: Advanced Air Quality Workshop, Western NC

The Great Smoky Mountains National Park and the NC Division of Air Quality partner each year on an advanced air quality workshop. The first day is held at the Appalachian Highlands Science Learning Center in the Great Smoky Mountains National Park. The second day is at Clingmans Dome (weather permitting). Instructors include air quality experts from NC Division of Air Quality and National Park Service.

Each person in the workshop will take home the presentations, activities, lessons, and more. Earn 1.2 CEU's and/or 10 hours of NC EE certification in criteria I, II, or III. The workshop, usually offered in August. Camping is available at the Appalachian Highlands Science Learning Center. For more info or to register for the workshop, contact Keith Bamberger at NC Division of Air Quality, keith.bamberger@ncdenr.gov or (828) 296-4500.

End Document