

Juniper Decline in Natural Bridges National Monument and Canyonlands National Park

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Abstract—Extensive foliar damage to Utah juniper (*Juniperus osteosperma* [Torr.] Little) has been observed in southern Utah. The distal foliage becomes chlorotic and dies. While junipers are plagued with a number of disease problems, no pathogenic agents or soil minerals appear to be responsible for the decline. Some chlorotic branches were due to insect twig cutters, but these insects do not appear to be the cause of decline. Juniper decline could be the combination of drought and temperature stress, which reduce the water resources and increase the uptake of salts by the trees. This effect, along with the crystal formation of iron, magnesium, and calcium could result in decline symptoms.

The pinyon-juniper woodland is a widespread vegetation type in the southwestern United States that is estimated to cover from 30 to 40 million hectares (Allred 1964, Tausch and Tueller 1990). The pinyon-juniper vegetation provides a source of fuel, building materials, charcoal, pine nuts, Christmas trees, and folk medicines (Tueller et al. 1979, Hurst 1977, Lanner 1975, Cronquist et al. 1972, Gallegos 1977). About 80% of the acreage is grazed by livestock and wildlife (Clary 1975, Bunderson et al. 1986b). In Utah, this ecosystem is a large component (62,705 km² or 28.6%) of the vegetation (Kuchler 1964). Particularly, in the Utah National Parks, the pinyon-juniper woodlands are valued for their watershed, aesthetic, and recreational values (Gifford and Busby 1975).

Over the past several years an extensive foliar damage to Utah juniper (*Juniperus osteosperma* [Torr.] Little) has been observed in the Natural Bridges National Monument. The characteristic pattern is for distal foliage to become chlorotic and die. Mortality progresses along twigs until whole branches or the entire tree dies. Reports of similar foliar damage have been reported in Canyonlands National Park, Arches National Park, Mesa Verde National Park, Colorado National Monument, areas near Cedar

City in southwestern Utah and in eastern Nevada, which would indicate that the foliar damage is a widespread problem. The cause for the foliar damage is not known. The loss of juniper trees in the national parks in southern Utah would have a dramatic ecological impact and would be an aesthetic blight in the parks. There is a need to determine the cause of the decline of Utah junipers.

In 1985, Bunderson et al. collected Utah juniper foliage and soil samples from 17 sites previously selected by Perry Plummer of the USDA Forest Service as typical of pinyon-juniper communities in Utah. Bunderson and Weber (1986) analyzed 255 Utah juniper (*Juniperus osteosperma*) trees for foliar mineral composition, total soluble carbohydrate and total chlorophyll content. The foliar concentrations of N, P, and K were consistent with other forest species. The concentration of Ca varied while the amount of Na and Fe were present at higher concentrations.

The soil mineral composition of the 17 sites was determined (Bunderson et al. 1985). The results suggested that Utah juniper was salt sensitive. The three growth limiting factors were nitrogen, phosphorus, and potassium.

The diseases associated with Utah juniper at the 17 different sites were also determined (Bunderson et al. 1986a). The most common rust was *Gymnosporangium inconspicuum* followed by *G. nelsoni*, *G. kernianum*, and *G. speciosum* (Peterson 1967). Needle blight and tip dieback were two unidentified diseases that were common at the different sites. In some sites, 80% of the trees had needle blight and tip dieback (Bunderson et al. 1986a). The parasite, mistletoe, weakened juniper trees and in many cases resulted in death of the junipers (Hreha and Weber 1979).

Materials, Methods, and Study Sites

There are several possible hypotheses for the cause of juniper decline.

1. Pathogenic agents (viruses, mycoplasma, bacteria, fungi, mistletoe, and insects).
2. Nonpathogenic factors (minerals, salts, etc.).
3. A combination of drought, higher salts, and temperature stress.

In order to evaluate the extent of juniper decline, reference transects were established in Natural Bridges

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National Monument and in the Needles area of Canyonlands National Park. At each site, 40 Utah juniper trees were randomly selected by the quarter method (Phillips 1959). Each tree was measured for height, trunk diameter, signs and symptoms of diseases, insect damage, nonparasitic injury, decline symptoms, vigor, and percent of decadence. Tissue samples were taken from five trees at each site by clipping 5 terminals at equidistant points around the tree. The samples were ground using liquid nitrogen and a mortar and pestle. The ground samples were frozen until analyzed. Nitrogen and phosphorus were determined by the Kjeldahl procedure using sulfuric acid digestion (Horwitz 1980) and the concentrations of the following minerals (K, Ca, Mg, Na, and Fe) were determined by using nitric-perchloric acid digestion and atomic absorption spectroscopy (Johnson and Ulrich 1959). Total chlorophyll of leaf tissue was determined by the dimethyl sulfoxide method of Hiscox and Israelstam (1979). Plant tissues from the different sites were analyzed for major elements. Healthy, diseased green and diseased yellow leaves were analyzed for major elements. Three soil samples were taken from each transect at each site. Each of the three soil samples was the composite of soil obtained from three dig spots at the sample location. The soils were dried, ground, and analyzed for mineral composition, pH, soil texture, moisture, and soil type. The data obtained from the soil and tissue analyses were analyzed by statistical methods using Statview II and Data Desk computer statistical packages.

Classic isolation of organisms (bacteria, mycoplasma and fungi) using standard isolation procedures was done (Kelman 1967). No particular organism was consistently isolated. Since some mycoplasma can not be cultured, roots of healthy and symptom-expressing trees were observed for mycoplasmas. Endomycorrhiza and ectomycorrhiza have been reported to be present on Utah juniper (Reinsvold and Reeves 1986, Reeves et al. 1979, Klopatek and Klopatek 1987). The mycorrhiza increase the water absorption and mineral uptake capacity of Utah juniper. Soil and fine roots from the Utah junipers growing at the different transects were collected and the amount of VA (vesicular-arbuscular) mycorrhiza was determined using the methods of Schenck (1982). Samples of healthy and diseased twig and root tissue were fixed in 0.1 M sodium cacodylate buffer (pH 7.2-7.4) for 2 h at room temperature. After fixation, samples were washed 6 times with 1:1 vol./vol. water-buffer solution and post fixed and stained with buffered 1% osmium tetroxide for 2 h at 0-4 °C. The samples were then stained overnight with aqueous 0.5% uranyl acetate, dehydrated in a graded series of ethanol and embedded in Spurr's resin. Sections were cut using a Sorvall MT 2B ultramicrotome, stained with Reynold's alkaline lead citrate and examined with a Phillips EM 400 transmission electron microscope (Upadhyay et al. 1991). Sections (3 m thick) were also cut and analyzed with energy dispersive X-Rays using an Oxford instrument (LinK Analytical Group) eXL with the Pentafet ST detector on a JEOL-JSM 8L10A Scanning electron microscope. The thick sections were mounted on glass slides on aluminum stubs.

Predawn water measurements were made in the Natural Bridges and Needles area. Branch stems were collected and placed in sealed containers. The water in the branch stem samples were analyzed by isotope mass spectrometry in Elringer's laboratory at the University of Utah to obtain the delta values.

Results and Discussion

Juniper decline was so common in all the transects in Natural Bridges and in the Needles area of Canyonlands that it was difficult to find a healthy tree (table 1). Many other diseases were detected in the transects as shown in table 1. The average values of different diseases were obtained by sampling 240 trees in the seven transects of the Natural Bridges area and 200 trees in the Needles area.

Hypothesis one: pathogenic agents.

While a number of diseases were recorded such as rusts, witches broom, mistletoes, and insect galls, none was consistently associated with twig blight and tip dieback. Efforts to isolate a bacterial or fungal pathogen from the leaves of the diseased juniper were not successful. Analyses of root tissue provided no evidence for mycoplasma in the vascular tissue. No viruses were observed with the electron microscope in thin sections of the diseased tissue. While fungal diseases such as rusts were found, there was no correlation between rusts and juniper decline. Juniper roots did not contain any pathogenic fungi, but mycorrhizal fungi appeared to be present on healthy roots. Mistletoe was detected but was not associated with the twig blight and tip dieback. Insect galls and insect borers were present in the transects (table 1) but there was little correlation with juniper decline.

In the Needles area of Canyonlands, twig cutter larvae which girdle the tissue beneath the bark were identified as *Styloxus bicolor*. The number of insect twig cutters is shown in table 1 for the Needles area. In contrast, little twig cutter activity was observed in the Natural Bridges

Table 1—Diseases observed in Natural Bridges and Needles areas.

Diseases	Ratings	Nat Bridges	St. error	Needles	St. error
Needle blight	Tree rating*	1.30	.038	00.68	0.079
Tip dieback	Tree rating	0.86	.082	01.01	0.086
Senescence	Tree rating	2.40	.101	00.81	0.219
Needle cast	Tree rating	0.57	.112	00.80	0.127
Wood rot	Tree rating	0.00	.000	00.00	0.000
Foliage fungi	Tree rating	0.01	.107	00.14	0.009
Rust galls	No/tree	0.86	.154	00.19	0.127
Fusiform rust	No/tree	0.44	.149	00.01	0.008
Witches broom	No/tree	0.02	.012	00.58	0.079
Mistletoe	No/tree	0.05	.002	00.31	0.113
Insect tree cutters	No/tree	0.00	.000	06.80	1.672
Insect bores	No/tree	0.05	.002	01.31	0.045
Pear insect galls	No/tree	0.06	.167	02.08	0.467
Burr insect galls	No/tree	0.64	.020	10.16	2.093

*Ratings show percent of tree affected: 0=0%; 1=1-20%; 2=21-40%; 3=41-60%; 4=61-80%; 5=81-100%; 6=dead (no foliage).

Table 2—Composition of soils from transects in Needles and Natural Bridges area.

Soil analyses of transects in Canyonlands and Natural Bridges				
Elements	Nat. bridges	St. error	Needles	St. error
Soil pH	7.83	0.045	8.18	0.100
% sand	69.90	1.720	74.87	1.617
% clay	15.66	1.510	11.06	0.897
% silt	15.37	1.230	0.53	1.349
% moisture	4.06	0.195	3.21	0.106
% OM	1.17	0.135	1.01	0.104
ppm NO3-N	2.14	0.132	1.53	0.157
ppm Fe	1.85	0.156	1.56	0.170
ppm K	88.28	12.911	85.00	15.373
ppm Ca	9539.00	156.243	6637.00	181.888
ppm Mg	410.00	56.626	98.33	9.779
ppm Na	42.48	13.819	3.90	2.941

area. The twig cutters contributed significantly to chlorotic branches on the juniper trees; however, the symptoms of twig blight were different and not due to twig cutting insects. Twig blight was also present on branches of trees in the Needles area of Canyonlands not infested with twig cutters.

Hypothesis two: nonpathogenic agents (minerals).

The elemental composition of the soil from the different transects was determined (table 2). Juniper decline did not correlate highly with any single element in the soil. The elemental composition of the tree tissue was determined (table 3) and the concentration of the individual elements in the tissues did not correlate highly with the juniper decline.

Hypothesis three: a combination of drought, higher salinity, and temperature stress.

The southwestern part of Utah has been experiencing a severe drought over the past several years followed by a period of increased rainfall. However, rainfall in Natural Bridges and Needles areas have not reached high levels (figure 1). From 1991 to 1992, there was a reduction in the amount of twig blight in Natural Bridges National Monument. In 1993 there was a small increase in twig blight, but it was lower than the 1991 level. Prior to 1991 there had been a drought for several years. 1992 was a

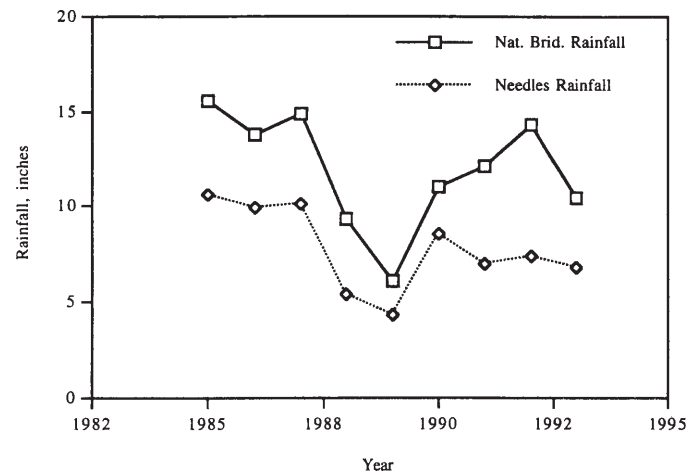


Figure 1—Amount of rainfall in Natural Bridges and Needles area.

wet year. The rainfall in 1993 was 28% lower than in 1992. This suggests an association of the disease symptoms with the rainfall level in Natural Bridges National Monument.

As drought occurs, salts tend to move up to the upper layers of the soil. Since Utah junipers are salt sensitive, it is possible that these combinations could be contributing to the decline problem. Mycorrhiza were present in the root samples collected. No correlation of mycorrhizal populations with juniper decline was obtained.

Isotope analyses of the water in the juniper trees in Natural Bridges National Monument indicated that the water in the trees was coming mainly from the ground water, not the summer surface rains (table 4). In the Needles area, the isotope analyses of the water in the juniper trees indicated that the water was coming mainly from the surface water such as the summer rains (table 4).

The element composition of healthy, green diseased and yellow diseased leaves was determined by atomic absorption spectrometry. Yellow diseased leaves had high concentrations of iron, calcium and magnesium (figure 2, 3, and 4).

Thin sections of healthy, green diseased and yellow diseased leaves were made and observed with the electron microscope. Crystals were detected in the yellow diseased

Table 3—Mineral composition of the juniper leaves.

Leaf analysis data for the juniper decline transects				
	Nat. bridges	St. error	Needles	St. error
% Ca	0.97	0.06	0.63	0.03
% K	0.23	0.01	0.28	0.01
% Mg	0.11	0.01	0.08	0.01
% N	0.44	0.01	0.63	0.03
% P	0.04	0.01	0.04	0.01
Cu ppm	1.37	0.06	4.95	0.16
Fe ppm	66.39	1.65	37.06	5.59
Mn ppm	11.54	1.14	15.61	2.60
Zn ppm	11.93	0.46	8.37	0.57

Table 4—Water sources in juniper stems.

Comparison of the -delta values of water from stem sap in junipers in the Needles area of Canyonlands National Park and Natural Bridges area				
Treatment	Needles area		Natural Bridges area	
	Delta values	St. error	Delta values	St. error
Ground water	-96.00	3.0	-96.00	3.0
Summer rain	68.00	3.1	68.00	3.1
Healthy	85.67	5.9	-93.50	3.9
Diseased	-73.83	6.1	-99.33	3.6

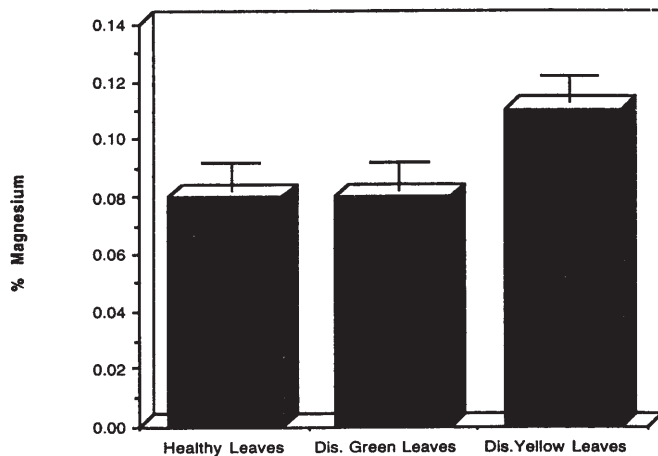


Figure 2—Magnesium concentration in healthy, diseased green, and diseased yellow leaves.

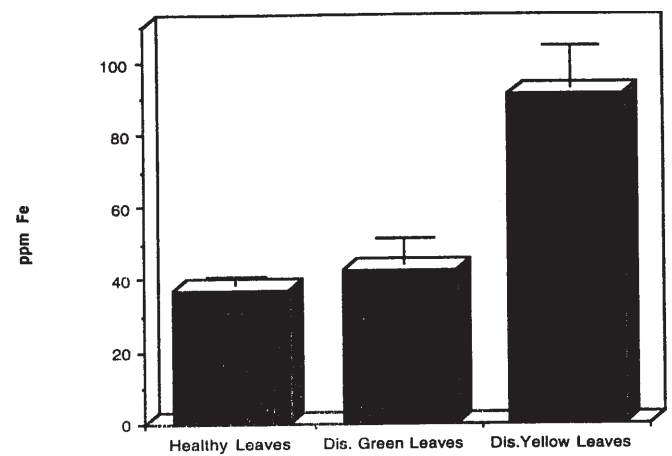


Figure 4—Concentration of iron in healthy, diseased green, and diseased yellow leaves.

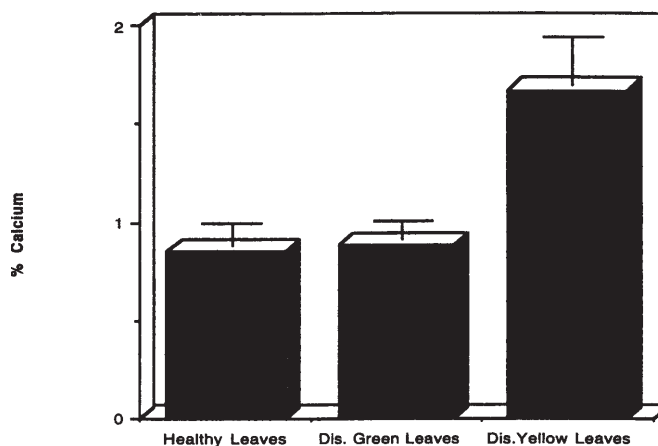


Figure 3—Concentration of calcium in healthy, diseased green, and diseased yellow leaves.

tissue (figure 5). The crystals and tissue were analyzed with energy dispersive X-ray microanalysis. The elements chlorine, osmium and uranyl were detected but were due to the fixatives and stains used. The major elements detected were silicon, aluminum, calcium, potassium, sodium and magnesium. The elemental analyses do not determine whether the elements are in certain complexes. It is possible that silica complexes of elements such as calcium, iron and magnesium could make the elements unavailable to the growing plant tip. The resulting effect would be a deficiency symptom of chlorosis (Brown, 1978). Young tips are probably the most susceptible areas because they need the minerals for new growth.

Summary

While junipers are plagued with a number of disease problems, no pathogenic agents appear to be responsible for the decline problem. There do not appear to be any



Figure 5—Thin sections of yellow leaves of diseased junipers showing the presence of crystals.

high correlations with high or low amounts of minerals in the soil.

Some of the chlorotic branches that were present are due to insect twig cutters. While the twig cutters are a problem, they do not appear to be the cause of decline.

One logical explanation of juniper decline is that the combination of drought and temperature stress reduce the water resources and increase the uptake of salts by the trees. This effect along with complexing of iron, magnesium and calcium to form complex crystals result in decline symptoms. While ground water appears to be the major water source for Natural Bridges, the long drought

could have reduced the ground water reserve and it is slowly being replenished.

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