Observations of Mal del cipres in the Patagonia Region of Argentina
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Paul Hennon, Pathologist, State and Private Forestry, Alaska Region

I visited the western area of the Patagonia region of Argentina during late November and early December, 1999 to observe the "mal de cipres" forest disease. Cipres (*Austrocedrus chilensis*) is an important native forest tree that grows along a climate gradient from the Andes Mountains east to the steppe in Argentina. The cause of mal del cipres is not understood and it appears to share a number of similarities with our yellow-cedar (*Chamaecyparis nootkatensis*) decline in Alaska. Both affected tree species are in the Cupressaceae and grow at high latititude. Most of my trip was funded by a grant from Consejo Nacional de Investigaciones Cientificas y Technicas, which is essentially the National Science Foundation of Argentina. I was hosted by Dr. Mario Rajchneberg at the institute in Esquel known as CIEFAP (Centro de Investagcion y Extension Forestal Andino-Patagonico). Graciously, Mario took more than two weeks out of his schedule to show me the decline phenomenon in numerous cipres forests in Patagonia.

Mario has ininitiated considerable work on the etiology (study of causes) and ecology of the mal de cipres disease. Attached is a daily account of observations that I made as Mario and I examined the disease in a number of forested settings. I will make frequent comparisons between the mal del cipres disease in Argentina and the yellow-cedar decline problem in Alaska.

In summary, mal del cipres is almost certainly an underground problem with roots or soils. The symptoms (i.e., death of tissues) in the roots clearly precede those in the bole or crown in dying trees. This is also the case for yellow-cedar decline. Mario has isolated a number of fungi from the roots of dying cipres trees; the presence of two brown rot fungi (*Postia* and *Coniophora* ) are particularly common. These fungi may or may not be pathogenic, but they do colonize dead roots with remarkable speed and cause many dying trees to break at the root collar before or just after death. By contrast, decay of dead roots of yellow-cedar is very slow and snags remain standing for up to a century after death. An inoculation trail of the two brown rot fungi on cipres could be made by implanting artificially-colonized wood in the coarse roots of mature cipres trees. Additional sampling for Pythiacious fungi (i.e., *Phytophthora* and *Pythium*) is also encouraged. Stream or soil baiting and a new simple molecular detection technique could be used to evaluate if any of these fungi are associated with dying trees. The historical onset of mal del cipres appears to coincide with the mass introduction of exotic conifers to Patagonia, mainly of conifer species brought from the Northwest of North America. It is conceivable that an aggressive root disease pathogen was introduced with planting stock.

The apparent association of the disease with human activities, including cattle grazing, may hint at possible causes. Interestingly, the several healthy cipres forests that we found tended to be remote, relatively pristine forests with little exposure to cattle. The disease is also associated with a climatic gradient with disease stands occuring in the wet, western areas near the Andes Mountains and unaffected stands in the more arid forests bordering the steppe. One of Mario's next research steps is to gather data from a transect along this gradient to determine which specific site factors, including human activities, may be associated with the presence or intensity of the disease. Results from that work would provide a good foundation of understanding about the mal del cipres disease that would be the basis generating hypotheses for future studies.

I hope to continue interaction and collaboration with Mario. I will be revising the summary above and more detailed daily accounts below into a report that will be published in a

newsletter from Mario's institue, CIEFAP. In addition, we intend to invite Mario to come to Alaska to observe our research on the etiology, epidemiology, and recovery of yellow-cedar decline.

A table that contrasts mal del cipres in Argentina with yellow-cedar decline in Alaska is displayed below. Also, a day-by-day description of my observations of mal del cipres follows.

## COMPARISON OF TWO FOREST DECLINES TO TREE SPECIES IN THE CYPRESS FAMILY

| | ***Austrocedrus* in Argentina** | ***Chamaecyparis* in Alaska** |
|---|---|---|
| Disturbance/origin of forest | Cipres is an aggressive colonizer after fire, forming almost single-species and single-cohort forests | Yellow-cedar occurs in stands mixed with other species in multiple-cohort |
| Age of dying trees | 50 to 150 years old | 100 to 1000 years old |
| Crown symptoms | Entire crown affected; slowly with last live foliage at distal tips of branches or rapidly with full compliment of foliage reddish brown; "distress cone crop" sometimes occurs | Essentially the same as for cipres except that "distress cone crop" does not occur |
| Root symptoms | Root symptoms precede crown symptoms; brown rot is conspicuous on roots of many dying trees. Necrotic phloem lesions sometimes occur at or above the root collar. | Root symptoms precede crown symptoms. Fine roots die first, followed by necrotic phloem lesions in coarse roots and narrow vertical phloem lesions above the root collar |
| Role of biotic agents | Two brown rot fungi are likely secondary, but inoculation trials could test this. Also, *Phytophthora* and *Pythium* could be further evaluated by baiting and new molecular detection techniques | All evidence indicates that fungi, insects, nematodes, and viruses appear to be secondary at best and not the primary cause of tree mortality |
| Onset of disease | Began in the early 1960s, perhaps earlier | Began about 1880 to 1900 |
| Distribution of disease | In wetter regions of Patagonia throughout most of cipres' natural range | On over 200,000 ha, confined to most of Southeast Alaska, not elsewhere in cedar's range |
| Development of disease | Annual mortality rate is high with concentrations of trees dying in brief time intervals (e.g., one decade) | Annual mortality rate is lower with dead trees accumulating over a century because they persist standing for so long |
| Site factors | Disease frequent in wet areas; does not occur in western arid areas of the steppe; human activity and cattle may be contributing factors | Wet, poorly drained sites at low to middle elevations; onset date and pristine conditions argue against human involvement |
| Natural fate of dead trees | Frequently break at the root collar and fall before or shortly after tree death | Nearly always remain standing for 80 years or more after tree death |
| Regeneration problems | Grazing by cattle severely limits natural regeneration of cipres on affected sites | Browsing by deer severely limits natural regeneration of cedar on affected sites |
| Use of dead trees | Landowners frequently remove trees continually as they die; cipres wood used locally in building for interior and exterior uses | Managers or beginning to prepare timber sales to salvage dead trees; most cedar wood exported to Japan |
| Short-term management (where feasible) | Salvage dead trees individually as they die; replant to exotic conifers | Salvage dead trees in larger timber sales; allow residual conifers of other species to grow |
| Longer-term management (where feasible) | Plant openings to exotic conifers or, less often, allow cipres to regenerate | Allow succession to occur favoring development of other conifers already on the site |

Mon., 11/29
I observed Mal del cipres while departing Barilouche by jet. Numerous dead trees could be seen on the island in front of the city and along the mainland to the south. From the air, all mortality appeared to be more recent than for our yellow-cedar decline as dead trees had their full compliment of branches.

After arriving in Esquel, Mario introduced me to several scientists at CIEFAP. Mario reviewed the current state of knowledge on Mal del cipres.

Tue., 11/30
Mario and I spend most of the day observing mal del cipres in an 80-year-old forest that regenerated primarily to cipres after a fire. This land is owned by Mr. Dougi and Paloma Berwyn. Most cipres forests are apparently single-cohort and the species is an aggressive colonizer of sites that are burned. All dead cipres trees would be classified as snags 1 and 2 by the yellow-cedar decline snag class system used in Alaska. The landowners were removing dead trees as they die, so it is difficult to determine how long the trees have been dying here. Dead trees are removed to provide timber and reduce hazard of fire. Some areas have nearly complete mortality over a hectare or more. As cipres is the predominant tree, the tree removal has resulted in large openings. Some of the openings have been planted to Monterrey pine. Landowners are unlikely to plant cipres because of the threat of continued mortality to the species.

Some trees die standing and then are either harvested or they break at major roots and fall. Some trees break in the same manner when they are still alive, but with crown symptoms of decline. The appearance of these snapped trees is reminsant of Douglas-fir that is killed by Phellinus weirii. All trees that break at the roots have extensive brown rot caused by two fungi, *Coniophora* and *Postia*. Of the trees that die standing and are harvested, the same brown rots can be observed on the cut surface of by digging and cutting into primary roots. There is now a question of whether these fungi may be pathogenic (i.e., they kill the roots) or saprophytic (i.e., something else kills the roots and they colonzie dead tissue). The hypothesis that they are pathogenic could be tested by an inoculation trial of wooden dowls colonized by each of these fungi (and control, non-infected dowls), implanted in coarse roots of large healthy cipres trees. The development of lesions in the phloem or substantial decay in the sapwood could be taken as evidence of pathogenic abilities for these fungi; development of decay limited to heartwood would indicate more saprophytic behavior.

Regardless of pathogenicity of these fungi, large tree roots develop extensive decay before or just after tree death. This is is a vastly different situation than for yellow-cedar where trees remain standing for 80 years or more because of the slow development of saprophyitic decay in roots.

Why is the decay apparently so rapid in cipres in Argentina? Here are several hypotheses: 1) the environment is favorable for decay (i.e., long season of high soil temperature and adequate moisture, 2) the two brown rot species are fast-growing, aggressive decayers of wood, 3) the heartwood of these roots is poorly protected by its chemistry.

Differences in decay rates between the wood of the two species and between Argentina and Alaska could be tested by a reciprical study of underground wood decay. Pieces of bole or roots taken from live trees could be placed in soil and the subsequent weight loss

tested as a measure of decay. In such a study, both species should be placed in the soil in both Argentina and Alaska.

The spatial pattern of diseased within the stand appears somewhat aggregated, but not clearly associated with any obvious factor of site or microsite. The regeneration appears to be clumped in this stand with two, three, or four trees growing together, but Mario suggests that the species only regenerates by seed.

The crown symptoms of dying cipres trees resemble those in yellow-cedar. Some trees die relatively slowly with crowns thinning until the last remaining foliage is at the distal end of branches. Other trees die quickly and appear with a nearly-full compliment of foliage attached but reddish or brownish in color. This variation in symptom expression and rate of development is quite similar to yellow-cedar. The "distress cone crop" that is common in cipres does not appear in yellow-cedar, however.

After digging roots from dead, dying, and apparently healthy trees, one has to wonder if any of these cipres trees is without extensive root mortality!

Wed., 12/1
Mario and I drove from Esquel to the Provential Forestry district office. We observed a number of conifer species planted from the Pacific Northwest of North America: Douglas-fir (locally called Oregon pine), lodgepole pine, pondersa pine, Port-Orford-cedar and rows of *Cupressus macrocarpa*. The presence of Port Orford-cedar could be particularly ominous because of the threat of introduction of *Phytophthora lateralis*. The *C. macrocarpa* was suffering from a shoot and branch dieback, typical of *Seiridium cardinale* infection. Cankers on the branches were callusing. We collected diseased branches and later found conidia similar to S. cardinale, except the two appendages were missing. The conidia may have been old and the appendages fallen off.

Nearby was a Douglas-fir plantation showing exceptional growth and vigor. The tree performs well as long it is not planted on sites that are too dry where it can be found killed by drought. Scattered Douglas-fir trees died in the region during a dry season one year ago. The perception among forest managers in this area is that the introduced conifers will outperform the native trees in timber production.

We then visited a mal del cipres site with many dead trees removed as we saw yesterday. Dome digging of the root systems of dying trees reveals necrotic lesions developing from dead roots extending to the root collar. Even trees with marginal crown sytmptoms (i.e., more than half the crown is still green) have most roots dead, evidence that the initial mortality factor is indeed below-ground. We discussed the possiblity of inoculation trials with *Coniophora* and *Postia*, the two brown rot fungi that are hypothetically, pathogenic. We also discussed a decomposition study (i.e., "stake study") and to explain the apparently large difference in decays of the roots of dead and dying cipres and yellow-cedar trees.

We then drove to a dam in the Los Alerces National Park where we saw mal del cipres on hillsides. The young trees colonizing this site seem to be less affected by mal del cipres.

We then drove to the main entrance of the Park and stopped at the lake for a view across to the most natural area of cipres growth known. We observed an extremely healthy cipres-dominated forest that covered hundreds of hectares except for two areas close together. One area appeared to be less than a hectare in size, the other covered several hectares. The later area had evidence of spread: older mortality had fallen near the middle and more recently-killed trees appeared on the periphery. No roads occur in the

area and no trees are logged; thus, this would be an excellent area for future study and permanent plots to monitor change and study causes.

It is interesting that this relatively unaffected forest is one of the only forests that does not have a nearby road. A road does occur on the other side of the lake where mal del cipres is common along its extent.

Question: did the great effort to introduce conifer species that occurred earlier in the century (about 50 years ago?) introduce a root pathogen?

Thu., 12/2
Mario, Alina Greslebin, and I drove for about 1.5 hours through the steppe to Lake Epuyen. Alina is becoming an expert in cordicoid wood decay fungi, those with smooth hymenia. Forest Ranger Ms Tiziana accompanied us by boat to a cipres stand with permanent lots. Mal del cipres had killed most trees close to the shore of the lake, but the mortality stopped about 100 m back from the lake where a relatively healthy cipres forest occured. I did not detect any site change from the dead to healthy forest. Soils in both areas were deep sandy deposits and well-drained as determined from a soil probe. This area regenerated to cipres following a fire about 60 years ago. This appeared to be a productive site as trees had good height and little taper relative to trees in other stands. Because of competition among trees, the cipres had relatively clear boles. Even though these were permanent plots, dead trees were removed and this resulted in a large clearing near the shore. Ms. Tiziana noted that many trees had stem decay, likely the result of wounds and broken tops, as both were more common here in the remaining trees than in other stands we have seen. Two dead cipres trees were found with bark removed, perhaps by woodpeckers searching for insects under bark (the large diameter galleries of the cerambicidae or buprestidae insect borers were present).

Interestingly, we observed little brown rot in the roots or stumps of these dead trees; this appeared to explain the infrequency of trees that uproot by broken roots. Most trees die standing on this site. The uncommon incidence of brown rots near the root collar would seem to indicate that these fungi are not the cause of mal del cipres, but it is still possible that they are killing roots distally and are not appearing near the root collar or on the stump surface.

We visited another mal del cipres stand ont the other side of the lake near a recent large forest fire. The forest here was younger or on a poorer site. Workers were cutting dead cipres, limbing them, burning limbs on site, and dragging the boles out by oxen. We excavated the roots of several trees; again we found little in the way of brown rots in the roots or on stump surfaces. One green tree with almost no crown symptoms had all roots dead and necrotic lesions in the phloem extending up the bole. This tree will soon be dead. The necrotic lesions and quick death indicate the the possibility of *Phytophthora lateralis* or another Phytophthora species here. Perhaps Mario could send Everett Hansen or Michael McWilliams seeds or seedlings of cipres and they could test resistance of the species. Or, Mike could visit Argentina and assist with direct isolations from dying trees. In a section on *Phytophthora lateralis* in the new Hansen and Lewis book on conifer diseases, the authors mention a simple ELISA test for *P. lateralis* which could be employeed here.

We also visited a stand of cipres that extends upslope from the river that flows out of Lake Epuyen. The mal del cipres problem exists in the cipres forest around the river where the ground is rather flat, but the forest across the river from the highway extends far upslope near large rock outcrops and cliffs. The cipres in this forest appears to be unaffected by mal del cipres. This area would be another good reference stand for a healthy cipres

forest. Again, this healthy forest appears to be somewhat isolated from human activity and there are no nearby roads.

Fri., 12/3
Mario and I discussed our re spective research programs to determine the possibility of future collaboration. One example would be a reciprical study of the deterioration of wood in the ground. We would like to explore the reason for the rapid decay of cipres roots in Argentina compared with the slow deterioration of cedar roots in Alaska. A reciprical study on deterioration rates of buried cipres and cedar wood in both locations could address the hypotheses that we generated.

In the afternoon, I gave a talk on yellow-cedar decline at Mario's institute, CIEFAP. This was a powerpoint presentation with 60 images, each with an accompanied text box that I had translated to spanish. My talk generated many excellent questions and we continued questions and answers for more than an hour after my talk concluded.

Mon., 12/6
Today, I accompanied Mario and Gabriel Loguercio to a Nothofagus forest, or Canadon Huemules, in the mountains near Esquel. This is a 200-year-old forest that regenerated after a fire. The brown rot fungi wre in grea t abundance here in mature Nothafagus trees. Some of this heart rot may develop from roots, as butt rot appeared very common. Broken tops, dead tops, broken and dead branches, the killing of branches by mistletoe, and bole scars were all common and likely contribute to the astounding amount of decay. The dominant form of tree mortality in this forest is through bole failure, which is not surprising given the decay levels. One white rot fungus, a *Phellinus* species, was found, but brown rots predominate. This is interesting, as white rots are often more common as heart rots in some parts of the world, especially in hardwoods. This forest would appear to be at the understory reinitiation stage of stand development as described by Oliver and Larson, but frequent grazing by cattle eliminates Nothofagus regeneration in most areas. If allowed to proceed with natural stand development, the wood decay fungi would be responsible for speeding development to the next stage, true old-growth, by contributing scattered tree mortality.

Gabriel has the challenge of modeling carbon in these forests; the decay of live trees must be included in his sampling. Mario is assisting him in the identification of brown and white rots and in developing a classification system for the severity of decay (i.e., sound wood, incipient decay, and severl classes of advanced decay).

In the afternoon, we drove past plantations of ponderosa pine that were planted in the steepe (i.e., aforestation). The plantations were prunned. Apparently, some land owners receive funds from European countries for aforestation to offset their carbon emissions. The growth and condition of these trees looked vigorous.

We then hiked to a small patch of mature cipres trees with abundant natural regeneration extending along with the direction of the prevailing wind. The mature trees and the regeneration were healthy. Mario indicates that the mal del cipres probelm does not occur in these arid areas near the steepe. Does the environment here not favor the problem (e.g., it is too dry for the wet soil flooding hypothesis, or it is too dry for *Phytophthora* sporulation and dispersal), or are these populations healthy because they are discrete and can thereby escape from a root disease?

Tue., 12/7
Mario and I discussed his proposed research to investigate site factors that may be related to mal del cipres. This study would evaluate the severity of mal del cipres at numerous sites along one west-east, wet to dry climate gradient from the Andes

Mountains to the steppe. If successful, the proposed research would involve several scientists from CIEFAP Information on site features, stand characteristics, and human activities would be collected and contrasted with the presence/absence or severity of mal del cipres along this gradient. Data on the incidence of brown rot in the stumps of dead trees and the mechanism of tree death (uprooting vs standing) could be collected along with the other site features. This study would be a valuable step in the research program on mal del cipres so that claims about site and climatic factors can be substantiated and quantified.

Wed., 12/8
Mario and I began travelling from Esquel to Barilouche. Our first stop was at a forest reserve located between Esquel and Bolson. The forest was dying in a fashion typical of mal del cipres, except that this site had abundant cipres natural regeneration. Apparently, cattle are not permitted to graze in this area and this has allowed the tree species to regenerate. Interestingly, the regeneration (seedlings and saplings) was thriving and not being killed by whatever factor kills the mature cipres trees. Seedlings and saplings are not dying even when they grow in very close proximity to dead or dying cipres trees. This seems to contradict the hypothesis that a Phytophthora is the primary agent of death with mal del cipres.

We then observed several more stands near the town of Bolson. Again, the cipres regenerates when catle grazing is minimized. One very nice stand of 85 year old cipres trees had good height, little bole taper and clear lower boles. But here, the mal del cipres process had killed many trees and created openings where cipres had successfullly regenerated. Again, the regenerated seedlings and saplings were not dying.

We continued to drive through scenic mountains to Barilouche.

Thu., 12/9
I presented a talk on yellow-cedar decline at the University of Barilouche. As in Esquel, the audience asked penetrating questions about my research and there was interest in making comparisons between the two diseases.

I deeply appreciate the time that Mario so graciously set aside to spend with me during my visit. I learned much about the mal del cipres disease and, in the end, I think I took away more new knowledge than I dispensed. In addition, I am indebted to Mario for the manner in which he cared for me during the last few days of my trip when I fell ill. With a language barrier, I'm not sure what might have become of me if not for his assistance in getting me prompt medical attention.