Initiation of Investigations Evaluating Growth Impacts of *Arceuthobium vaginatum* subsp. *vaginatum* on *Pinus cooperi* in Durango, Mexico: A Collaborative Effort Between USDA Forest Service, Forest Health Protection, Comisión Nacional Forestal (CONAFOR) and Instituto Politecnico Nacional, Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR)

Final Report to the International Activity Team


Brian Howell[1], Mary Lou Fairweather[2], Holly Kearns[3]

[1] USDA Forest Service, Forest Health Protection, Region 2, Lakewood Service Center, Lakewood, CO
[2] USDA Forest Service, Forest Health Protection, Region 3, Arizona Zone, Flagstaff, AZ
[3] USDA Forest Service, Forest Health Protection, Region 1, Coeur d'Alene Field Office, Coeur d'Alene, ID

Purpose:

Federally mandated management guidelines for the pine forests in Durango, Mexico require that specified amounts of overstory trees be maintained during stand entries whether or not the management units are infested with dwarf mistletoes. This requirement is preventing foresters in Durango from effectively reducing levels of dwarf mistletoe infection and may actually be responsible for increasing rates of spread and intensification of dwarf mistletoes in these economically valuable and intensively managed forests. Because no data are available that clearly demonstrate that dwarf mistletoe infection is or is not causing growth and/or economic losses in these forests, managers have not been able to modify the required management guidelines for dwarf mistletoe-infested stands. The purpose of this collaborative work was to provide technical assistance in the methodology required to conduct investigations into the growth impacts associated with *Arceuthobium vaginatum* subsp. *vaginatum* on *Pinus cooperi* in Durango, Mexico to Comisión Nacional Forestal (CONAFOR) and Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR) personnel The methodology recommended for use in this project is similar to that employed by Howell and Mathiasen (2004) (See Appendix A for proposed methodology). Once the level of growth impacts have been assessed, the resulting data will allow managers to assess the economic implications of the impacts and better judge whether alternative management strategies should be considered in dwarf mistletoe-infested stands.

Description:

USDA Forest Service, Forest Health Protection employees Brian Howell, Biological Technician, R2, Lakewood Service Center; Mary Lou Fairweather, Plant Pathologist, R3, Arizona Zone; and Holly Kearns, Plant Pathologist, R1, Coeur d'Alene Field Office, traveled to Durango to meet with and assist CONAFOR personnel and their collaborators regarding the initiation of this project. Our objectives were to ensure that all relevant government agencies and land managers were supportive of the project and to provide any training required to enable those involved with the project to see it through to a positive outcome.

Funding for the project has been provided by CONAFOR and USDA Forest Service International Programs to purchase tree-ring measuring equipment and employ a technician to perform the tree-ring measurements associated with stem analysis. Funding for the travel of Forest Health Protection (FHP) personnel was provided by the FHP International Activity Team. Assistance in the field has been arranged to be provided by Unidad De Conservación y Desarrollo Forestal Prestación de Servicios Tecnicos Forestales (UCODEFO) technicians as well as by technicians from each of the three Ejidos involved in the project.

Our travel itinerary included:

9/16/06	We arrived late in the evening in Durango and were met at the airport by Sergio Quinonez, Forest Health Specialist for CONAFOR. Sergio served as our primary contact, and he is in charge of supervising this project and seeing it through to completion. Sergio made all of the arrangements regarding cutting permits, etc. and coordinated all of the meetings described below.
9/17	We visited various sites around El Salto, familiarizing ourselves with the many tree and dwarf mistletoe species in the area and returned to Durango
9/18	We met with Martha González-Elizondo from the Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR) to discuss the tree-ring measurement and data analysis procedures required for the project. CIIDIR will house the tree-ring measuring equipment in their herbarium, and all measurements and stem analysis calculations will be conducted there. When we visited, not all of the measuring equipment had arrived, but Martha assured us that the remaining equipment was on its way. We discussed stem analysis procedures as well as procedures for quantifying growth reductions once stem analysis has been conducted. We also discussed software that conducts all of the major stem analysis calculations and issues relating to data configurations, etc. We provided CIDIIR with a number of publications relevant to this project. We also met with L.I. Victor Joel Martinez Martinez, Regional Director of the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), Maria Mayela Estrada Casas, Forest Health Specialist with SEMARNAT, Armando Delgado Anchondo and Pedro Hernandez to explain the objectives of the study. It was essential that SEMARNAT support this project as they are the regulatory body that will ultimately make policy decisions regarding whether management tools can be modified in dwarf mistletoe-infested stands. The meeting went well, and all involved look forward to seeing the results of this study. After gathering provisions, we traveled to El Salto where we stayed in cabins owned by Ejido La Victoria.
9/19	We spent the morning meeting with Ing. José Guadalupe Barrios Tellez, the Director of UCODEFO and Ing. Armando Chavez Alemán, technician with UCODEFO, discussing the project and its objectives. UCODEFO is a forestry consulting firm that works with the surrounding Ejidos to develop and implement forest management plans. They work with most of the Ejidos in the area and are interested in this project because they see firsthand the impacts that dwarf mistletoes have on their managed stands. Ing. Barrios Tellez volunteered the use of the facilities of UCODEFO for the drying and storage of tree cross-sections in preparation for stem analysis. He also volunteered the time of some of the UCODEFO technicians to assist in the completion of the project.

In the afternoon we went to Ejido Chavarria Viejo to look at potential study sites. After examining several sites, we encountered one that appeared to have sufficient trees of varying levels of dwarf mistletoe infection to conduct the study. At each site we required 15 trees in DMR classes 0, 2, 4 and 6 for analysis. We trained all of the technicians present in the Hawksworth 6-class dwarf mistletoe rating (DMR) system (Hawksworth 1977). At the chosen site we began selecting trees for sampling. We began felling trees, and trained all present on the methods for collecting, labeling and recording the position of cross-sections to be used in stem analysis.

We returned to UCODEFO where we met Jose Luis Aguilar Vitela, agricultural parasite specialist with the state of Durango, M. Mayela Estrada Casas, Forest health specialist with SEMARNAT, and Israel J. Avila Flores, a contractor working for CONAFOR. This group came up to El Salto from Durango to learn about and assist with the project. They all worked with us for the next two days.

9/20 We met with Roberto Belarmino Guevara Comissioner of the Ejido La Victoria to discuss the project and to confirm permissions to conduct destructive sampling within the Ejido. We visited a couple of possible study sites in Ejido La Victoria and found one to be suitable. We began assigning DMR’s to trees and marking them for sampling.

To ensure that we had sufficient time to establish three suitable study sites we left the site in Ejido La Victoria and looked for a site in Ejido El Brillante. We found a suitable site and began field work.

9/21 We returned to the study site in Ejido El Brillante, finished marking trees for sampling, and continued felling trees and collecting cross-sections for stem analysis.

9/22 We returned to the study site in Ejido La Victoria and continued assigning DMR’s and marking trees for subsequent sampling. We returned to Durango.

9/23 Day off

9/24 We returned to the United States.

Specific Accomplishments:

Figure 1. Rating dwarf mistletoe infection in *Pinus cooperi*.

1. We worked closely with CONAFOR, SEMARNAT, State of Durango and CIIDIR personnel. We presented all involved with the project with an overview of the project's objectives and ensured that all stakeholders were supportive of the project.

2. We identified three suitable study sites and began field work at each of these sites.

3. We trained field workers in the methods for all aspects of field work to ensure the collection of high-quality field data.

4. We discussed laboratory methodology and data analysis techniques with those who will be involved in these aspects of the study. We provided literature describing these techniques.

5. We discussed silvicultural options for management in mistletoe-infested stands. One particularly promising option involves species conversion from *Pinus cooperi* to *P. leiophylla* in stands where *Arceuthobium vaginatum* subsp. *vaginatum* appears to be causing growth reductions. While *A. vaginatum* subsp. *vaginatum* has the broadest known host range of any dwarf mistletoe (Hawksworth and Wiens 1996), *Pinus leiophylla* appears to be immune (or perhaps a rare host) and can tolerate the same site conditions as *P. cooperi.*

Figure 2. Felled and bucked tree with labeled cross-sections.

Summary

Working together with CONAFOR, SEMARNAT, State of Durango and CIIDIR personnel we selected greater than one-half of the trees needed for the dwarf mistletoe growth impacts project. Approximately 20 of those trees were felled and bucked for processing, which allowed us to develop the methodology for tracking the samples. Everyone was shown the techniques for identifying mistletoe infection levels in trees and the importance of good record keeping. We feel confident the project will be carried to completion and the results will provide data that will prove helpful in developing management guidelines for stands of *Pinus cooperi* infested with *Arceuthobium vaginatum* subsp. *vaginatum*.

Figure 3. Cross sections labeled and ready for processing

Literature Cited:

Hawksworth, F.G. 1977. The 6 class dwarf mistletoe rating system. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. General Technical Report RM-48: 7 p.

Hawksworth, F.G., Wiens, D., 1996. Dwarf Mistletoes: Biology, pathology, and systematics. USDA For. Serv. Agric. Handb. 709.

Howell, Brian, Mathiasen, R.L., 2004. Growth impacts of *Psittacanthus angustifolius* Kuijt on *Pinus oocarpa* Shiede in Honduras. Forest Ecology and Management. 198, 75-88.

Appendix A

Effects of Dwarf Mistletoes on Growth of Pines in Durango, Mexico
Suggested Investigations

Prepared by:

Brian Howell
Forest Health Management
USDA Forest Service
Lakewood, Colorado

And

Robert Mathiasen
School of Forestry
Northern Arizona University
Flagstaff, Arizona

Background

Dwarf mistletoes (*Arceuthobium* spp., Viscaceae) are parasitic flowering plants that infect conifers throughout the western United States, Canada, and Mexico (Hawksworth and Wiens 1996). Several investigations on the effects of dwarf mistletoe infection on the growth of commercially important conifers in the United States and Canada have clearly demonstrated that severe infection causes large growth reductions in diameter, height, and volume. These studies are summarized in Hawksworth and Wiens (1996, Chapter 5) and by Geils and others (2002, Chapter 5). Although many investigations quantifying the effects of dwarf mistletoe infection on tree growth have been completed in the United States and Canada, few investigations of this type have been completed in Mexico (Geils and others 2002). So far the only work, of which we are aware, examining dwarf mistletoe infection on tree growth was for *Pinus hartwegii* infected by *Arceuthobium vaginatum* and *A. globosum* in central Mexio (Andrade and Cibrian 1980). This study used a variety of methods to quantify the effects of dwarf mistletoe infection on tree growth and found that severe infection greatly reduces growth. Although this study and those conducted in the southwestern United States have demonstrated that severe dwarf mistletoe infection reduces volume growth, no investigations of this nature have been conducted in northern Mexico, where some of the most productive and commercially important pine stands occur. Observations in the southwestern United States suggest that pines growing on highly productive sites do not suffer the same large growth losses that pines growing on less productive sites (Hawksworth and Wiens 1996, Geils and others 2002). Because the pine forests in many parts of northern Mexico represent highly productive sites, particularly those in Durango, the effects of dwarf mistletoe infection may not be as great as those reported for central Mexico or the southwestern United States. However, we don't know if this assumption is correct because no studies quantifying dwarf mistletoe infection on pine growth have been conducted in Durango.

Dwarf mistletoes are common and infect several species of pine in Durango and they are considered to be the most important disease agent in these commercially valuable pine forests. Currently, because no quantitative data on the effects of dwarf mistletoe infection on pine growth is available for Durango, Federally mandated management guidelines for the pine forests in Durango require that specified amounts of overstory trees be maintained during stand entries whether the management units are infested with dwarf mistletoes or not. This requirement is preventing foresters in Durango from effectively reducing the levels of dwarf mistletoe infection in these intensively managed forests and may actually be responsible for increasing the rates of spread and intensification of dwarf mistletoes in these economically valuable forests. Because no data are available that clearly demonstrate that dwarf mistletoe infection is or is not causing economic losses in these forests, managers have not been able to modify the required management guidelines for dwarf mistletoe-infested stands. Because no data are available on the effect of dwarf mistletoe infection on pine growth in Durango, personnel responsible for mandating pine management regulations are reluctant to modify the general forest management guidelines for dwarf mistletoe-infested pine stands. Evidently, the assumption is that severe dwarf mistletoe infection does not affect tree growth in these very productive pine forests. Therefore, foresters managing the pine forests of Durango need data from the pine forests in their region so they can determine if the management of dwarf mistletoe-infested pine stands should be modified with the objective of more effectively reducing the level of dwarf mistletoe infection and thereby decreasing the negative effects of dwarf mistletoe infection. Or we need to demonstrate that the current assumption that dwarf mistletoe infection does not negatively affect tree growth in Durango is correct.

The objectives of the investigations we are recommending be conducted in pine stands in Durango are to use stem analysis to evaluate the impacts of dwarf mistletoe infection in terms of height and volume growth of individual trees through time and to evaluate the effectiveness of the 6-class dwarf mistletoe rating system for quantifying the degree of growth loss in Durango, Mexico. The effects of the two most common dwarf mistletoes in commercial pine forests of Durango, *Arceuthobium vaginatum* subspecies *vaginatum* and *A. globosum* subspecies *globosum*, should be examined.

Study Areas

Possible study sites will be selected with the assistance of forestry technicians from El Salto, Durango and members of local ejidos near El Salto. Study areas will be on forested lands managed by ejidos. A total of three study areas representative of pine forests being intensively managed by ejidos will be selected near El Salto infested with Mexican dwarf mistletoe (*Arceuthobium vaginatum* subspecies *vaginatum*).

Methods

Tree selection at each study site will be based on crown class (dominant and co-dominant trees) and severity of dwarf mistletoe infection (dwarf mistletoe rating, Hawksworth 1977). A total of sixty trees (dominants or codominants) will be sampled at each of the three study areas; 15 trees from DMR class 0, 2, 4, and 6.

The following measurements will be taken for each tree:

1. Diameter at breast height (dbh to the nearest 0.1 cm) measured with a diameter tape
2. GPS coordinates (UTM or Lat/Long) and elevation measured with a GPS unit
3. Basal area measured using a relaskop from a point 1 m north of the tree (nearest 1 m^2/ha).

Every attempt will be made to select trees at each site so that trees from all DMR classes are intermixed and in close proximity to each other in order to minimize potential site-related confounding factors that might influence rates of tree growth.

Trees will then be felled and cross-sections (approximately 6 cm thick) will be collected from the main bole of each tree at 30 cm and 1.37 m above the ground and then at two-meter intervals to within three m of the top. The height of each cross-section will be measured to the nearest cm. Cross-sections will be assigned a number designating the tree and cross-section location.

Cross-sections will be taken to the Herbarium at the Instituto Politecnico Nacional Certro Interdisiplinario de Investigación para el Desarrollo Integral Regional, for processing which will include drying and sanding cross-sections using a series of sandings using 80-400 grit sandpaper. One average radius (long radius plus short radius/2) will be marked on cross-sections with less than a 20% difference between the long and short radii, and two average radii will be marked on cross-sections where this difference exceeds 20%. False rings will be identified as described by Stokes and Smiley (1996).

True ring widths will be measured to the nearest 0.1 mm. Measurements of true rings will be from the pith outward. All true ring width data will be entered into a Microsoft Excel spreadsheet for analysis.

The following stem analysis variables will be obtained for each tree and year: height, total volume, volume increment, cambial surface area, and specific volume increment (Duff and Nolan, 1953; 1957). Annual heights between cross-sections will be calculated using Carmean's equation (Carmean, 1972) and heights between the top cross-section and the top of the trees will be calculated using Newberry's revision to the Carmean equation (Newberry, 1991). Annual total volume will be calculated assuming a conical frustum between cross-sections for portions of vertical annual growth represented by two cross-sections (Peine et al., 1981). Annual total volume will be calculated assuming a cone for portions of vertical annual growth represented by an individual lower section and an upper height value (Peine et al., 1981). Volume increment will be calculated by subtracting the previous year's total volume from the current year's total volume. Annual cambial surface area will be calculated similarly to annual total volume, using surface area rather than volume formulas. Specific volume increment (SVI) is defined as the annual volume increment divided by the cambial surface area that produced it (Duff and Nolan, 1957) and will be calculated by dividing the current year's annual volume increment by the previous year's annual cambial surface area. Specific volume increment allows for direct comparison of growth rates of trees of different sizes and is a sensitive measure for assessing growth responses to forest pest activity (Piene et al., 1981).

The age of initial infection of each tree will be estimated by dissecting several of the largest witches' brooms nearest the bottom of the tree and aging the infection using the methods described by Scharpf and Parmeter (1975). The age of the oldest infection will be subtracted from the current year (2006 or 2007) and the result used at the year of initial infection during subsequent analysis.

Data Analysis

To examine growth losses associated with dwarf mistletoe infection, trees will be paired in groups of healthy and moderately infected trees and healthy and severely infected trees by similar ages to compare three-year SVI growth reductions. Age will used as the pairing factor for SVI comparisons because SVI is not tree size sensitive, but may be age sensitive. Pairing will also be conducted by similar heights at time of infection to compare three-year periodic height increment reductions because trees of similar heights in a given year are likely to experience similar subsequent height growth. Pairing will be conducted by similar volume at time of infection to compare three-year periodic volume growth because current volume is the best predictor of future volume growth.

In order to examine the impact of the duration of mistletoe infection on tree growth, three-year periodic growth will also be examined. Moderately and severely infected trees (TMR 2 and 4) will be individually paired with healthy trees. In each case, average three-year increments will be examined for individual trees for one three-year period prior to infection and for all complete three-year periods after infection occurred. Growth reductions ($\underline{G_r}$) will be calculated for each pair of trees for each period examined using equation (1) where the three-year periodic average for the healthy tree in each pair is treated as $\underline{G_{ie}}$ and the three-year periodic average for the infected tree in each pair will be treated as $\underline{G_{io}}$ (Mallet and Volney, 1999).

$$G_r = (G_{ie} - G_{io})/G_{ie} \qquad (1)$$

95% confidence intervals will be constructed for each study site to compare differences between groups of trees for average height increment and volume increment for the final year of growth between all trees. Trees will initially be analyzed by each DMR class, but may have to be group into DMR classes: 0, 1-2, 3-4, and 5-6. Confidence intervals will be constructed using JMP statistical software (Sall et al., 2001).

References

Andrade Escobar, V., Cibrian Tovar, D., 1980. Evaluacion de poblaciones de muerdago enano (*Arceuthobium globosum* Hawks y Wiens y *A. vaginatum* Willd.) en bosques de *Pinus hartwegii* Lindl. En Zoquiapan, Edo. De Mexico. En: Primer simposio nacional sobre parasitologia forestal; 1980, Febrero 18-19. Uruapan, Michoacan: Sociedad Mexicana de Entomologia: 238-253.

Carmean, W.H., 1972. Site index curves for upland oaks in the Central States. For. Sci. 18, 10-120.

Duff, G.H., Nolan, N.J., 1953. Growth and morphogenesis in the Canadian forest species. I. The controls of cambial and apical activity of growth in Pinus resinosa Ait. Can. J. Bot. 31, 471-513.

Duff, G.H., Nolan, N.J., 1957. Growth and morphogenesis in the Canadian forest species. II. Specific increments and their relation to the quantity and activity of growth in Pinus resinosa Ait. Can. J. Bot. 35, 527-572.

Hawksworth, F.G., 1977. The 6-class dwarf mistletoe rating system. USDA For. Serv., Gen. Tech. Rep. RM-48, 7 p.

Hawksworth, F.G., Wiens, D., 1996. Dwarf Mistletoes: Biology, pathology, and systematics. USDA For. Serv. Agric. Handb. 709.

Mallett, K.I., Volney, W.J.A., 1999. The effect of Armillaria root disease on lodgepole pine tree growth. Can. J. For. Res. 29, 252-259.

Newberry, J., 1991. A note on Carmean's estimate of height from stem analysis data. For. Sci. 37, 368-369.

Piene, H., MacLean, D.A., Wall, R.E., 1981. Effects of spruce budworm caused defoliation on the growth of balsam fir: Experimental design and methodology. Can. For. Serv. Marit. Reg. Inf. Rep. M-X-128. 19 p.

Sall, J., Lehman, A., Creighton, L., 2001. JMP Start Statistics. Second Edition. Duxbury, Pacific Grove.

Stokes, M.A., Smiley, T.L., 1996. An introduction to tree-ring dating. The University of Arizona Press, Tucson.