Species Identification, Management, Host Range, Distribution and Morphology of Mistletoes in Durango, Mexico: A Collaborative Effort Between Forest Health Protection, Northern Arizona University, West Virginia University, Comisión Nacional Forestal (CONAFOR) and Instituto Politecnico Nacional, Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional Personnel

Final Report to International Activity Team

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Purpose:

The purpose of this collaborative work was to provide technical assistance in the identification and management of the numerous mistletoe species that occur in Durango, Mexico to Mexican land managers and to expand the current knowledge of their morphology, host range and distributions. Prior to the trip, discussions with Dr. Jaime Villa-Castillo, National Director of Forest Health for the Commision Naciónal Forestal (CONAFOR) indicated that Ing. Sergio Quinonez Barraza, Regional Director of Forest Health for CONAFOR Region 3 (Durango, Chiuahua and Sinaloa, Mexico) was interested in receiving assistance in the identification and management of mistletoes, particularly with dwarf mistletoes that occur in his region.

Description:

Robert Mathiasen Assistant Professor of Forest Plant Pathology, Northern Arizona University, Shawn Kenaley, Doctoral Candidate, University of West Virginia and Brian Howell, Biological Technician, Lakewood Service Center, Forest Health Monitoring, USDA Forest Service, traveled to Durango to meet with and assist CONAFOR personnel and their collaborators regarding mistletoe-related issues.

Our travel itinerary included:

1. Travel from Mazatlan to Durango along the Devil's Spine Highway on July 7, 2005. Numerous species of mistletoes were observed in the Genera Arceuthobium, Phoradendron, Psittacanthus, and Cladocolea.

2. We traveled from Durango to Santiago Papasquiero on July 8.

3. On July 9 we traveled north to Altares with a local forestry technician and examined populations of various dwarf mistletoes in the area, identifying the mistletoe and the host and discussing these with the technician. We collected and measured plants from two populations of *Arceuthobium globosum* subs. *globosm.* We then returned to Durango.

4. From Durango we traveled south on the road to La Flor on July 10 hoping to find additional populations of *Arceuthobium globosum* subsp. *globosum* to collect and measure, but were unsuccessful.

5. We attended a meeting with CONAFOR personnel at their main office in Durango on July 11. In this meeting Ing. David Hernández Gómez, Director General of CONAFOR Region 3, and his Vice Director, Biol. Fernando Pizarro Gurrola, gave a presentation on the general forestry operations within the region and the role that CONAFOR plays as a consulting and funding agency. Our objectives were discussed with the above as well as with Ing. Quinonez. After the meeting, Brian Howell gave an interview with a local television station discussing the cooperation between the USDA Forest Service FHP and CONAFOR and the objectives of the trip. After the meeting, we visited the Herbarium which is

located on the campus of the Instituto Politecnico Nacional Certro Interdisiplinario de Investigación para el Desarrollo Integral Regional. We met with Dr. María Soccorro González Elizondo, curator of the herbarium. We spent the afternoon examining collections of *Arceuthobium* sp. and checking the accuracy of their identifications as well as those of the host tree, based on morphological characters. We noted that many of the collections appeared to expand upon the current body of literature regarding the distribution and host range of a number of species. We suggested initiating a collaborative study further examining their collections and publishing any novel findings.

6. We traveled with Ing. Quinonez to El Salto on July 12 and met with Ing. José Guadalupe Barrios Fellez, Director of Unidad De Prestación de Servicios Ejidales de "El Salto" DGO. A.C. (a private forestry consulting firm that works with the Ejidos in the area surrounding El Salto), to discuss forest management and dwarf mistletoe issues in the area where his firm operates (Figure 1). We then went into the field with a number of forestry technicians to examine mistletoe infestations in their ejidos and to discuss management issues. We discovered that they are mandated by law to utilize a multiple entry, uneven-aged management approach which maintains some overstory trees in each entry. This approach has been used for years and is very successful in managing the pines of the region, but is a poor strategy for dealing with dwarf mistletoe infested stands. No exemption for the treatment of mistletoe infested stands exists under current law. At the same time, no studies have been done to evaluate the growth impacts of infection by dwarf mistletoes in this area. Having recently conducted a growth impact study similar to the one required in this area (Howell and Mathiasen 2004), we suggested that they initiate a similar study focusing on the most widespread and apparently damaging mistletoes in the area (*Arceuthobium vaginatum* subs. *vaginatum* and *A. globosum* subs. *globosum*). Data from this study could be used to support a petition to the legislature to allow an exemption from the uneven-aged management system for the management of dwarf mistletoe infested stands. The interest in this study was at the time and remains high among both CONAFOR and local officials. Throughout the day, we collected and measured additional populations of *Arceuthobium globosum* subs. *globosm*.

Figure 1. Meeting with local forestry consultants in El Salto (left) and discussions in the field with local foresters (right).

7. On July 13 we spent the day with Ing. Quinonez, returning to the El Salto area to identify and examine a number of species of dwarf mistletoe and their hosts in the field. We also collected and measured additional populations of *Arceuthobium globosum* subs. *globosm.*

8. On the morning of July 14 we visited with Ing. Quinonez to look at his collection of dwarf mistletoe photographs from around the region. Many represented previously undocumented locations and host species. We suggested that he work with Dr. Soccoro and ourselves on the study discussed in 5 above. We then returned to the El Salto area to finish collections of *Arceuthobium globosum* subsp. *globosum*. In the afternoon we returned to the Herbarium in Durango where Dr. Mathiasen and Brian Howell gave interviews to a television crew that was filming a documentary regarding the work done at the herbarium in relation to plant collections, plant identification, and research on the native flora of Durango.

9. We returned to Mazatlan on July 15 for our return flight on July 16. Off of the Devil's Spine highway on our way to Mazatlan, we discovered *Cladocolea cupulata* and *Psittacanthus macrantherus* infections on previously undocumented hosts.

Specific Accomplishments:

1. We worked closely with CONAFOR personnel and in particular with Ing. Quinonez and provided technical assistance regarding identification of mistletoes and their management.

2. We collected measurements of *Arceuthobium globosum* subsp. *globosum* and *A. globosum* subsp. *grandicaule* for an ongoing study of the taxonomic classification of the group that these dwarf mistletoes fall within.

3. We assisted Dr. Soccorro at the Durango Herbarium by going through her collections of *Arceuthobium* spp. and checking the accuracy of the identifications of the dwarf mistletoes and their host species. Several collections of dwarf mistletoes that were misidentified were annotated with the correct names.

4. We initiated a collaborative study with Dr. Soccorro at the Durango Herbarium and Ing. Quinonez looking at the distributions and host range of dwarf mistletoes found in their herbarium and photographic collections. With this study, we hope to expand the current understanding of distribution and host range of these mistletoes, as many of the collections found at this herbarium are from remote locations and on hosts previously unreported in the literature.

5. We proposed a study (to be funded and conducted by CONAFOR) examining the growth reductions caused by *Arceuthobium globosum* subsp. *globosum* and *A. vaginatum* subsp. *vaginatum* when they infect commercially important pine species in Durango. This study proposal has been drafted by Howell and Mathiasen and has been well received by Dr. Villa and Ing. Quinonez. They look forward to initiating field work in 2006 (see appendix A for the full text of this proposal).

6. We identified new hosts for *Cladocolea cupulata* (Kenaley et al. in review) (appendix B) and *Psittacanthus macrantherus* (Howell et al. in preparation) (appendix C) and are in the process of publishing these findings.

7. We gave interviews to the local media and to a television documentary crew explaining our work while emphasizing the benefits of cooperation between agencies in the international forestry community.

Literature Cited:

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.

Howell, Brian, Kenaly, S.C., Mathiasen R.L., First report of *Psittacanthus macrantherus* on *Pinus devoniana* and *Quercus castanea* in Mexico. Plant Disease. In Preparation.

Kenaley, Shawn, Howell B.E., Mathiasen R.L., 2005. First report of *Cladocolea cupulata* on *Pinus douglasiana* and *Pinus herrerai* in Mexico. Plant Disease. In Review.

Appendix A

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

Prepared by:

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And

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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 this if 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 should be examined; *Arceuthobium vaginatum* subspecies *vaginatum* and *A. globosum* subspecies *globosum*.

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 ten study areas representative of pine forests being intensively managed by ejidos will be selected near El Salto; five infested with Mexican dwarf mistletoe (*Arceuthobium vaginatum* subspecies *vaginatum*) and five infested with rounded dwarf mistletoe (*A. globosum* subspecies *globosum*).

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 21 trees (dominants or codominants) will be sampled at each of the ten study areas; 3 trees from each of the seven dwarf mistletoe ratings classes, 0-6.

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 Herbario (**name of the herbario needed here**), for processing wich 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 G_{ie} and the three-year periodic average for the infected tree in each pair will be treated as G_{io} (Mallet and Volney, 1999).

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

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.

Appendix B

First report of *Cladocolea cupulata* on *Pinus douglasiana* and *Pinus herrerai* in Mexico. S. Kenaley, Department of Plant Pathology, West Virginia University, Morgantown, WV 89503; B. Howell, Forest Health Management, USDA Forest Service, Lakewood, CO 80225; and R. Mathiasen, School of Forestry, Northern Arizona University, Flagstaff, AZ 86011

The mistletoe *Cladocolea cupulata* Kuijt (Loranthaceae) has been reported parasitizing pines (*Pinus* spp., Pinaceae) in central Mexico (1). Thus far, the only reported pine hosts in Mexico have been *Pinus jaliscana* Perez de la Rosa and *Pinus lumholtzii* Robins. & Fern. from the state of Jalisco (2,3). We found this mistletoe parasitizing *Pinus douglasiana* Mart. and *P. herrerai* Mart. along Route 40 in Durango approximately 8 km east of El Palmito (23^{o} 35' 54" N, 105^{o} 50' 45" W, elevation 2000 m). We also found the mistletoe on *Pinus douglasiana* along Route 40 at several locations west of El Palmito in the state of Sinaloa. Infected trees only had 1-5 mistletoe plants on them and the mistletoe appeared to be having no effect on the growth of the infected trees. No mortality associated with mistletoe infection was observed for either of these mistletoe-host combinations. As far as we know, this is the first report of this mistletoe parasitizing *Pinus douglasiana* and *P. herrerai* and the first report of this mistletoe from Durango and Sinaloa (1, 3). Specimens of *Cladocolea cupulata* on these pines from Durango and Sinaloa have been deposited at the Deaver Herbarium (ASC), Northern Arizona University, Flagstaff (Accession numbers 79532, 79533, and 79536).

References: (1) Kuijt, J. The genus *Cladocolea* (Loranthaceae). J. Arnold Arboretum 56: 265-335, 1975; (2) Chazaro, B. Los muerdagos del Estado de Jalisco. Biosphera 1: 3-7, 1990; (3) Geils, B., J. Cibrian Tovar, and B. Moody. Mistletoes of North American Conifers. USDA Forest Service, Gen. Tech. Rep. RMRS-GTR-98, 2002.

Appendix C

First report of *Psittacanthus macrantherus* on *Pinus devoniana* and *Quercus castanea* in Mexico. B. Howell, Forest Health Management, USDA Forest Service, Lakewood, CO 80225; S. Kenaley, Department of Plant Pathology, West Virginia University, Morgantown, WV 89503; and R. Mathiasen, School of Forestry, Northern Arizona University, Flagstaff, AZ 86011

The mistletoe *Psittacanthus macrantherus* Eichl. (Loranthaceae) is an important parasite of pines (*Pinus* spp., Pinaceae) in Mexico (1). It has been reported to parasitize *Pinus engelmannii* Carr., *P. herrerai* Mart., *P. lawsonii* Roezl ex Gord. & Glend., *P. lumholtzii* Robins & Fern., *P. oocarpa* Schiede, and *P. pseudostrobus* Lindl. (1). In July 2005 we found this mistletoe parasitizing *Pinus devoniana* Lindl. and *Quercus castanea* Nee near Route 40 in Sinaloa, Mexico approximately 12 km west of El Palmito (23^{o} 30' N, 105^{o} 07' W, elevation 1900 m). The mistletoe was common in *P. devoniana* and some trees were severely infected (> 10 plants per tree). However, no mortality associated with mistletoe infection in *P. devoniana* was observed. Only one infected tree of *Quercus castanea* was observed in this area and it was not severely infected. We also observed this mistletoe on *Pinus douglasiana* Mart. along Route 40 west and east of El Palmito, but no specimens were collected because plants were very high in the crowns of the infected trees. As far as we know, this is the first report of this mistletoe parasitizing *Pinus devoniana*, *P. douglasiana*, and Q. *castanea* (1). Specimens of *Psittacanthus macrantherus* from *P. devoniana* and *Q. rugosa* have been deposited at the Deaver Herbarium (ASC), Northern Arizona University, Flagstaff (Accession numbers 79534 and 79535).

References: (1) Geils, B., J. Cibrian Tovar, and B. Moody. Mistletoes of North American conifers. USDA Forest Service, Gen. Tech. Rep. RMRS-GTR-98, 2002.