Abstract: Southwestern dwarf mistletoe (Arceuthobium vaginatum subsp. cryptopodum) occurs on more than one-third of the commercial ponderosa pine forest in Arizona and New Mexico. Annual volume loss from this disease is estimated at 150-200 million board feet on National Forests in the Southwestern Region. The simulated yield program SWYLD2 is used to help evaluate impact of southwestern dwarf mistletoe. A survey procedure and data summary program have been designed to compile input for the SWYLD2 program. This program provides resource managers with simulated yield tables for dwarf mistletoe-infested stands of ponderosa pine. Yield tables help quantify timber volume loss, and allow resource managers to examine various management alternatives and their effects on dwarf mistletoe levels.

Southwestern dwarf mistletoe (Arceuthobium vaginatum subsp. cryptopodum) is the most destructive disease on ponderosa pine in the Southwest. This disease occurs on all National Forests in Arizona and New Mexico. Andrews and Daniels (1960) calculated southwestern dwarf mistletoe to be present on at least 2.5 million acres of commercial ponderosa pine forest in Arizona and New Mexico. Annual volume loss from this disease is estimated to exceed half of the annual allowable cut on National Forests in Region 3. Principal hosts for southwestern dwarf mistletoe include ponderosa pine, Pinus ponderosa var. scopulorum, P. ponderosa var. arizonica, and Apache pine, P. engelmannii. The adverse effects of southwestern dwarf mistletoe have been quantified in several ways. Mortality estimates have been made for infested stands, potential safety hazard in recreation areas has been evaluated, and timber volume loss has been quantified on a stand basis. The latter is perhaps the most useful tool for evaluating dwarf mistletoe effects over large areas.

Three factors contribute to timber volume loss: growth reduction, tree mortality, and defect. Growth reduction is the most important and most difficult value to estimate. Heavily-infected trees may sustain a 30-60 percent growth reduction, compared to non-infected trees. The amount of reduction depends on time and intensity of infection, tree size and age, site factors, and many other aspects of tree environment.

Tree mortality is the second most important volume loss factor. Mistletoe-caused mortality can be difficult to quantify due to invasion of infected trees by insects. Assigning the primary mortality factor often becomes impractical. Andrews and Daniels (1960) estimated annual mortality losses in mistletoe-infested ponderosa pine at 55-75 million board feet in the Southwest.

Defect caused by dwarf mistletoe is related to grain distortion and resin impregnation at infection sites. This aspect of volume loss is seldom measured, and its overall importance is not well-defined for Southwestern forests.
Commonly used evaluation techniques, such as measurement of volume loss, frequently estimate only one of the many effects resulting from a dwarf mistletoe infestation. For example, expressing adverse effects of dwarf mistletoe in terms of cubic foot loss per acre emphasizes the timber production aspect. It becomes more difficult to apply cubic foot loss to deterioration of wildlife habitat, recreational opportunity, or watershed productivity. In fact, what is an adverse effect on one resource may be beneficial to other resources. When a disease such as dwarf mistletoe alters the forest environment, questions must be answered to determine the total effects on all resources and resource users. These effects, when identified and quantified, constitute the impact of a forest disease. Can we measure this complex of effects? Do we have the expertise to evaluate such a vast array of factors? What terminology do we use to express positive and negative effects? These questions must be answered before impact evaluation can be realized.

There may be some confusion about who has responsibility for impact evaluation of dwarf mistletoe. In the U. S. Forest Service, personnel in Forest Insect and Disease Management cooperate with designated National Forest System personnel to develop impact data on dwarf mistletoe. In the Southwest, a forest disease specialist provides an assessment of the effects dwarf mistletoe is and will be having on infested stands (biological evaluation). This information is provided to the resource manager, so that, jointly, an impact evaluation can be prepared. Resource managers call on other specialists to help evaluate impact of dwarf mistletoe on other resources. In essence, a team of specialists provides input to the resource manager relative to mistletoe effects and their area of specialization. The resource manager then combines this information and completes the impact evaluation. An important factor to note is that we, in Forest Insect and Disease Management, really do not evaluate impact of a forest disease per se. We evaluate the current status of a disease, quantify certain effects of that disease, project the disease situation into the future, whenever possible, and assess or recommend potential control measures.

More finitely, in relation to southwestern dwarf mistletoe, we most frequently estimate only timber volume loss in an infested stand. This quantity then, constitutes our major input in the impact evaluation process.

Dwarf mistletoe evaluation efforts in the Southwest have been concentrated in high priority resource areas. Such areas are characterized by high-timber production potential (i.e., site index and accessibility) high-value recreational opportunity, or areas of special interest to resource managers (i.e., difficult regeneration areas). Economics define these types of areas as locations where adverse effects of dwarf mistletoe can be efficiently reduced. If a resource manager does not have sufficient funds to control dwarf mistletoe, there is little benefit in quantifying those effects. Exceptions occur in areas where quantifying disease effects can alter priorities (i.e., dollars and personnel). Eventually, we hope to participate in evaluating impact for all dwarf mistletoe-infested stands, but a system of priorities must be followed to obtain maximum benefit from our efforts.

Current Region 3 evaluations of southwestern dwarf mistletoe use the simulated yield program SWYLD2 (Myers et al. 1976, Edminster and Hawksworth 1976). This program provides resource managers with simulated yield tables for dwarf mistletoe-infested stands of ponderosa pine. Yield tables help quantify timber volume loss caused by dwarf mistletoe. Resource managers can examine various management alternatives and their effects on dwarf mistletoe levels. In addition, they can better evaluate the benefits and consequences of controlling dwarf mistletoe.

Application of the SWYLD2 program is restricted to even-aged or two-storied stands that are at least 90 percent ponderosa pine. Stands not meeting these requirements are not necessarily precluded from the mistletoe evaluation process, but our assessment lacks the predictive aspect.

Basic input in the SWYLD2 program is relatively uncomplicated. Stand condition variables needed for SWYLD2 input include: site index, average age, height and d.b.h., number of trees per acre, and stand DMR or percent trees infected with dwarf mistletoe. Stand DMR is the average dwarf mistletoe rating, based on the six class system, for all trees in a stand. These values must be provided for both stories in a two-storied stand. We have designed a survey procedure for gathering this information in even-aged or two-storied ponderosa pine stands.

Sample points are located on a grid throughout the survey area. Grid interval varies with stand size. A 4- by 4-chain grid may be used in a 200-acre stand, while a 10- by 10-chain grid may be selected for use in a 1,000-acre area. Fixed and variable radius plots (B.A.F.) are established at each sample point. The sample consists of all live trees 4.5 feet tall to 5.9 inches d.b.h. on the fixed plot, and live tally trees 6.0 inches d.b.h.
and larger on the B.A.F. plot. Presence/absence of dwarf mistletoe or dwarf mistletoe rating (DMR) and d.b.h. are recorded for all sample trees. A sketch map of plot locations is made during the survey for later use in showing dwarf mistletoe distribution. A specified number of age and height measurements are taken to estimate site index. Age and height measurements are also taken from a specified number of codominant or dominant trees in each story of the stand. Data are recorded on forms specifically designed for rapid transfer of information into a computer summary program.

Field data are then processed through the SWSUMMARY computer program. This program was designed to accommodate data from the previously outlined survey. SWSUMMARY prepares stand summary tables and calculates SWYLD2 stand condition variables from survey data. The program also summarizes age and height information for three sets of selected trees. These selected trees represent (1) maximum site potential of the stand, (2) average age and height of overstory dominant and codominant trees, and (3) average age and height of understory "dominant" and "codominant" trees. The summary tables provide a stand inventory and are useful in determining SWYLD2 management options.

Resource managers develop various management options and combine them with stand condition variables to produce simulated yield tables. Comparison of various management alternatives helps the resource manager quantify effects of dwarf mistletoe in an infested stand.

A cost analysis was made for eight survey areas completed in 1977. A 10- by 10-chain grid was used for all surveys. Cost estimates are based on field crew of two forestry technicians (i.e., $4/hr./technician) working 40 hours per week. Average cost, including travel time from Ranger District office to survey area, was 30¢ per acre. Pure survey cost, excluding travel to the survey area, averaged 23¢ per acre. Reducing the grid interval from 10- by 10-chains to a closer spacing will increase survey cost. However, we estimate that even at a 4-chain interval, survey cost will not exceed 75¢ per acre. The range in survey cost from 23¢ to 75¢ per acre appears reasonable for use of an intensive forest management tool.

Once the resource manager has a set of yield tables displaying volume loss caused by dwarf mistletoe over a rotation, various degrees of control can be simulated. Management alternatives which best meet the resource manager's needs can then be selected for implementation. SWYLD2 output is expressed in total cubic foot volume, merchantable cubic foot volume, and board foot volume on a per-acre basis. These values can be converted into dollar estimates by each individual resource manager. Individual conversion to dollar values is essential as market values vary with accessibility to production facilities, access to a labor force, etc. Once loss estimates are converted from cubic or board foot volume to dollar value, resource managers can determine the cost of dwarf mistletoe control; then, a cost/benefit ratio can be determined. Often, impact on other resource values can be quantified and compared with mistletoe control costs at various management intensities.

The final step in the evaluation process deals with follow-up on mistletoe evaluations. When a resource manager implements a silvicultural treatment, as projected by the SWYLD2 program, Forest Insect and Disease Management personnel may resurvey the stand. Follow-up survey data provide an assessment of how well simulated stand conditions match on-the-ground conditions. When actual conditions do not match those projected, an attempt is made to determine where the discrepancy occurred. In addition, simulations are made for the residual stand after treatment. Thus, the resource manager has an opportunity to correct inadequate treatments and to reassess the dwarf mistletoe situation for future years. This, in turn, provides more finite information for future timber management planning.

Through this follow-up procedure, for instance, we have found that maximum diameter limits and/or spacing restrictions in precommercial thinnings result in poor mistletoe control. These factors also can make simulation of such treatments less reliable. Such information is valuable to the resource manager who has based an impact evaluation on SWYLD2 projections.

As forest management continues to intensify, use of simulated yield programs will increase. Yield simulations, such as those provided by the SWYLD2 program, will continue to help the resource manager evaluate the impact of a forest disease such as southwestern dwarf mistletoe.

Dwarf mistletoe poses an unquestionable threat to the potential of forest resource production in the Southwest. Various techniques have been used to quantify the magnitude of this threat. Of the techniques used, summarizing timber volume loss over a designated time period appears to be the most efficient. The simulated yield program SWYLD2 has provided the methodology to complete this task. Resource managers can now begin to assess, in a more finite manner, the overall effects of dwarf
mistletoe on all resources. Thus, the capability to evaluate impact of southwestern dwarf mistletoe is in the final development stages.

LITERATURE CITED

