DOI: https://doi.org/10.29298/rmcf.v12iEspecial-1.1076

Review article

Aportaciones del INIFAP en materia de plagas y enfermedades forestales

INIFAP contributions on forest pests and diseases

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Resumen

El objetivo de este trabajo es proveer información sobre las principales aportaciones que ha hecho el Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP) en materia de plagas y enfermedades forestales, durante sus primeros 35 años de existencia. El estudio se basa en una revisión bibliográfica que comprende el periodo desde la fundación del Instituto Nacional de Investigaciones Forestales, antecesor del INIFAP, hasta el presente. Destaca la aportación de ambos institutos sobre el conocimiento taxonómico, biológico y de control de insectos descortezadores de coníferas (*Dendroctonus* spp. e *Ips* spp.), moscas sierra de las coníferas (*Zadiprion* spp., *Neodiprion* spp. y *Monoctenus* spp.), así como de otros defoliadores del orden Lepidoptera y algunas plagas exóticas. En cuanto a enfermedades forestales, son notables los estudios de diagnóstico de los agentes causales de pudriciones y royas, principalmente hongos (*Fusarium* spp*., Rhizoctonia* spp*., Cronartium* spp*, Colletotrichum* spp.) y el diagnóstico, impacto y control de plantas parásitas, tanto en bosques naturales como en arbolado urbano y plantaciones. En los últimos años, sobresale la contribución del INIFAP con conocimientos que fundamentan la Norma Oficial Mexicana NOM-019-SEMARNAT 2017, alusiva a la prevención y control de insectos descortezadores; y el estado del arte sobre las moscas sierra de las coníferas. Este esfuerzo se ha dirigido, fundalmente, al diagnóstico y control de plagas y enfermedades forestales; sin embargo, los investigadores del INIFAP enfrentan el reto de generar información y tecnología que permita prevenir y mitigar los efectos del cambio climático en la salud de los bosques.

Palabras clave: Enfermedades forestales, hongos patógenos, insectos defoliadores, insectos descortezadores, plagas forestales, salud forestal.

Abstract

This paper aims to give information on the main contributions that the *Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias* (INIFAP) has made on forest pests and diseases during its first 35 years of existence. This study is based on a literature review that comprises a time since the foundation of the *Instituto Nacional de Investigaciones Forestales,* that precedes INIFAP, to present days. The contribution of both institutes, with knowledge on the taxonomic, biological, and control of conifer bark beetles (*Dendroctonus* spp. and *Ips* spp.), conifer sawflies (*Zadiprion* spp., *Neodiprion* spp. and *Monoctenus* spp.) as well as other tree defoliators of the Lepidoptera order and some exotic pests is outstanding. Regarding forest diseases, there are notable studies on the diagnosis of causal agents of rots and rusts, mainly fungi (*e. g. Fusarium* spp., *Rhizoctonia* spp., *Cronartium*, *Colletotrichum* spp.), and the diagnosis, impact, and control of parasitic plants in natural forests, urban trees and tree plantations. In the last years, the INIFAP contribution of knowledge that supports the NOM-019-SEMARNAT 2017 Official Mexican Norm, allusive to the prevention and control of bark beetles, and on the state-of-the-art on conifer sawflies stands out. This effort has been mainly oriented to the diagnosis and control of forest pests and diseases; however, INIFAP researchers face the challenge of generating information and technology that allows to prevent and mitigate the effects of climate change on forest health.

Key words: Forest diseases, pathogenic fungi, foliar insect, bark beetles, forest pests, forest health.

Fecha de recepción/Reception date: 31 de enero de 2021
Fecha de aceptación/Acceptance date: 13 de mayo de 2021

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Introduction

Forest sanitation is responsible for giving attention to the presence of forest pests and diseases (CCAD, 2017). According with FAO (2018), 70 % of the total global forest area is affected by pests and diseases. In the context of natural ecosystems, the designation of the term "pest" has an anthropocentric connotation; since many insects and organisms so named maintain the dynamics of plant communities and major ecological processes, without which forests would simply stagnate or would have poor biodiversity (Schowalter *et al.,* 1997; Schowalter, 2012). In other areas, such as commercial forest plantations or urban forests, the ecological role of insects and pathogens is secondary, as attention to avoid economic damage is a priority. Under these different scenarios, it is imperative for scientific and academic institutions to conduct relevant studies in order to develop management strategies.

The objective of this study was to provide information on the main contributions of the *Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias* (INIFAP) (National Institute of Forest, Agricultural and Livestock Research) on forest sanitation, during its first 35 years, either on natural forests, plantations and urban trees, starting from the works carried out in the *Instituto Nacional de Investigaciones Forestales* (INIF) (National Institute of Forest Research) that preceded it until the time of creation of the current institution.

INIF, a predecessor institute

Since its foundation in 1958, *the Instituto Nacional de Investigaciones Forestales* (National Institute of Forest Research) (INIF), privileged research on pests and diseases, and thus created the forest entomology and phytopathology laboratories in Mexico City (INIF, 1982), and assigned research personnel in the area of forest protection in some Regional Research Centers in the country.

From 1959 to 1985, INIF's Forest Sanitation research focused mainly on studies of identification, biology and direct combat of pests and diseases in central and southern

Mexican temperate forests, although it also addressed aspects of pests and diseases in urban forests of Mexico City. The contributions of Justina Perusquía Ortiz are particularly interesting in this period, since she described all the species of *Dendroctonus* spp. known to Mexico, their geographical distribution, as well as their natural enemies (Perusquía, 1978, 1982). This genus comprises the pest species of greatest ecological and economic importance in the temperate forests of the Northern Hemisphere.

The contributions of Federico Islas Salas on the biology and combat of the pine bark beetles *Dendroctonus adjunctus* Blandford, *Dendroctonus mexicanus* Hopkins and *Dendroctonus frontalis* Zimmerman (Coleoptera: Curculionidae: Scolytinae), particularly in Mexico City, State of Mexico, *Puebla*, *Guerrero* and *Jalisco* (Islas, 1968, 1980a), are considered an effort of enormous national significance. Islas (1980b) also validated the effectiveness of physical-mechanical control methods for these insects, consisting on felling and debarking infested trees, and "felling and abandonment", the latter being a method in which the early felling of infested trees, without removing the bark, stimulate the action of natural enemies and competitors. The effectiveness of this practice was confirmed in the *Nevado de Colima* National Park, state of *Jalisco*, where the suppression of the *D. adjunctus* population was observed from the natural predators, competition with secondary species, and desiccation (Villa 1985, 1993).

Other control methods explored by INIF research dealt with the use of attractant semiochemicals for bark beetles (frontalina, brevicomina and trans-verbenol) for the creation of trap trees, as well as the validation and adaptation of old methods of insecticide injection, fungicides, bactericides and entomopathogens, originated in Europe in the 16th and 17th centuries (Vité *et al*., 1974; Islas, 1980a). Although the application of some insecticides on the tree boles was also experimented, since the beginning, INIF recommended not to use them in natural forests because they are toxic to other organisms (Islas, 1980b).

INIF also promoted the study of the group of defoliating insects known as "conifer sawflies" (Hymenoptera: Diprionidae), whose first reports in Mexico date from 1912

and 1930 (May, 1976). Pine defoliation caused by these insects in the 70's in *Michoacán*, and the early 80's in the state of *Chihuahua*, resulted in the determination of three species of sawfly (*Zadiprion vallicola* Rohwer, *Neodiprion* sp. circa *gillettei* Rohwer, and *Neodiprion fulviceps* Cresson), as well as detailed knowledge of its biology and control (Cisneros, 1970; Mayo, 1976; Castro, 1981; Islas and Muñiz, 1985). Later studies updated the status of these species, and reclassified them as *Zadiprion falsus* Smith, *Neodiprion omosus* Smith and *Neodiprion autumnalis* Smith respectively (Smith and Wagner, 1986; Smith, 1988).

In the urban context, the contribution of Gutiérrez and Muñiz (1984) on the identification of the main forest species and insect pests that affect the *Chapultepec* Forest in Mexico City, was one of the first contributions in this field.

In regard to the study of forest diseases, the work carried out by Rodolfo Salinas Quinard is worth mentioning, who directed the Forest Pathology Laboratory and was a devoted researcher in the area of insects and forest diseases at INIF. His main scientific contributions include the development of laboratory methods to assess the resistance of wood to decay (Gómez *et al*., 1969; Pérez and Salinas, 1977), and techniques to detect fungi associated with *Dendroctonus* spp., causing the blue-staining wood (Salinas and Macías, 1979). Another aspect studied was the identification and combat of the complex of microorganisms (*Fusarium* and *Rhizoctonia*) that participate in the damping-off of seedlings, a disease that affects the production of forest species in nurseries (Gómez and Yáñez, 1963; Gómez, 1970), as well as the diseases that harm *Pinus radiata* D. Don (Salinas and Gómez, 1975). The results of some of these studies on forest diseases made possible to publish the first catalog of the fungi culture collection of INIF (Salinas, 1982).

INIFAP contributions

Contributions regarding forest pests

During the first years from INIFAP's creation, forest health research followed the inertia of the predecessor institute. Jaime Villa Castillo took up as an important line of research the use of semiochemicals for the attraction and monitoring of the bark beetles *D. mexicanus* and *D. adjunctus* in the state of *Jalisco*, where he demonstrated that frontalin and alpha-pinene significantly attracted these two species, and he was able to define the flight peaks for both (Villa, 1992a). Regarding the chemical control of bark beetles, the aforementioned researcher experimented in the field the effect of phosphine fumigation on logs wrapped with plastic. His results indicate that, although this pesticide caused bark beetle mortality, the death of their natural enemies also occurred collaterally, a critical aspect that must be considered in the chemical control of forest pests (Villa, 1992b).

Another contribution of INIFAP in its initial years was made by Blas Enrique Díaz Ortiz, who carried out one of the most complete studies on cone and seed boring insects of conifers of the *Sierra de San Pedro Mártir,* state of *Baja California*. In this work, 16 species and their impact on seed production were determined. It was concluded that, in general terms, the damage caused by this group of insects is superficial and not the main cause of the scarce natural regeneration of *Pinus* spp. and *Abies concolor* (Gordon) Lindl. ex Hildebr in that ecosystem. Among the most common seed and cone borers, several species of *Conophthorus* Hopkins, *Earomyia* Zetterstedt, *Cydia* Hübner, *Dioryctria* Zeller, and *Argyresthia* Hübner genera were discovered and described (Díaz, 1988a, 1988b).

For the state of *Chihuahua*, two years after the creation of INIFAP, Raúl Narváez Flores detected in 18 localities, within *Bocoyna* and *Guerrero* municipalities, the presence of *Cydia phyllisi* Miller, a cone borer of *Picea chihuahuana* Martínez, an endangered conifer. In his study, Narváez (1988) determined an average affectation of 85 % in cones, 21 % in seeds and 37 % in vain seeds. In addition, he defined the

life cycle of this moth and its development times and thus established the appropriate period (October to April) to carry out the mechanical control, consisting of the collection and burning of infested cones that fall to the ground.

Starting in 2002, a strong impulse was given to the study of forest pests and diseases in INIFAP, with the creation of the Sectorial Fund for Forest Technological Research and Innovation, constituted by National Forestry Commission (Conafor) and the National Council of Science and Technology (Conacyt), which was added to the financing of state-level institutions. Thus, several INIFAP researchers attended to the research demands of this fund, and proposed the solution of problems from an integrated pest management approach, in order to define ecologically acceptable options.

In this context, are notable the contributions of Alfredo Sánchez Salas, Luis Mario Torres Espinoza, Antonio Cano Pineda and Oscar Ulises Martínez Burciaga, researchers from *Saltillo* Experimental Field, who partly filled gap of knowledge on the conifer bark beetle species inhabiting the states of *Coahuila* and *Nuevo León* (Sánchez *et al.,* 2003); defined the flight and attack periods of *Dendroctonus pseudotsugae* Hopkins, *D. adjunctus* and *Dendroctonus brevicomis* LeConte in the *Sierra de Arteaga*, and the appropriate treatments for their control (Torres *et al.,* 2004).

A mention should be made to the work of researchers from the *Centro de Investigación Regional Norte-Centro* and *Centro de Investigación Regional Pacífico Centro,* who determined the flight periods of several bark beetle species in the states of *Chihuahua, Durango, Coahuila, Jalisco, Michoacán* and *Aguascalientes*, and provided bases for the monitoring of these insects through the use of semiochemicals (Sánchez *et al.,* 2007, Vázquez *et al*., 2007).

In more recent times, Sánchez *et al*. (2012a) validated the effect of the anti-aggregation pheromone MCH for the prevention and disruption of the attack of *D. pseudotsugae* on *Pseudotsuga menziesii* (Mirb.) Franco in *Durango* and *Chihuahua*, which constitutes a non-polluting technology for the prevention and control of outbreaks caused by this insect. Rivera-Dávila *et al.* (2021) demonstrated that the anti-aggregation pheromones MCH and verbenone are practically non-toxic for forest

inhabiting organisms, soil, and water, so they are suitable volatile compounds to prevent the attack of *D. pseudotsugae*, in the first case, and to species of the frontalis complex in the second.

During the last decade, in some studies conducted at INIFAP, on the chemical ecology of insects, researchers have determined suitable semiochemicals for monitoring and mass trapping *D. frontalis* and *D. mexicanus* in the *Sierra Gorda,* state of *Querétaro* (Sánchez *et al.,* 2017; Sánchez-Martínez and Reséndiz-Martínez, 2020). The adoption of technologies on bark beetles, generated by this institute, is reflected in the content of the Official Mexican Standard NOM-019-SEMARNAT-2017 (Semarnat, 2018), which establishes the guidelines for the monitoring, prevention and combat of conifer bark beetles in Mexico, which uses as technical foundations several of the publications generated by this institution (Semarnat, 2018).

INIFAP has also sought solutions for phytosanitary problems in Protected Natural Areas, where conventional mechanical-chemical control methods often have legal and sociocultural limitations. In these cases, tree injection methods have been resumed, but with technology that minimizes injuries at the injection sites and that avoids the exposure of insecticides outside the tree bark to not contaminate the environment (Espinosa *et al*., 2014 ; Sánchez *et al*., 2014; Gochez-López *et al.,* 2018).

Another important contribution of INIFAP refers to the monitoring quarantine pests, as was the case of the red gum lerp psyllid (*Glycaspis brimblecombei* Moore) and the pink hibiscus mealybug (*Maconellicoccus hirsutus* Green), exotic insects that constituted research demands by Conafor-Conacyt Fund in the first decade of this century. In the case of *G. brimblecombei*, Sánchez and González (2006) developed a methodology for the detection, reproduction and augmentation of the populations of *Psyllaephagus bliteus* Riek, a natural parasitoid of this psyllid. As for *M. hirsutus*, an insect that affects *Tectona grandis* L. f. and several wild and ornamental plants, González-Gaona *et al.* (2010), validated the effectiveness of the sex pheromones of this insect, identified and synthesized by Zhang *et al.* (2004) and Zhang and Amalin (2005), with which they mapped their geographical

distribution in the Pacific region of Mexico, defined the main hosts and provided scientific foundations for their biological control.

Regarding other groups of insects of forest value, the contribution of INIFAP on the study of conifer sawflies (Hymenoptera: Diprionidae), as well as previously unknown oak and coniferous wood-boring insects, stands out. In the first case, the description of the new species *Zadiprion ojedae* Smith & Sánchez-Martínez, the update of the taxonomic key of the *Zadiprion* Rohwer genus (Smith *et al.,* 2012), the description and biology of the new species of *Monoctenus sanchezi* Smith (Smith *et al.,* 2010), the knowledge of the biology of *Neodiprion autumnalis* and *Zadiprion ojedae* (Sánchez *et al*., 2012b) and the updating of knowledge on the identification and distribution of all species of conifer sawflies known to date in Mexico (Coria-Avalos *et al.*, 2014; González and Sánchez, 2018).

Currently, the National Forestry Commission considers researchers from the *Pabellón* Experimental Field and the National Center for Disciplinary Research in Conservation and Improvement of Forest Ecosystems (Cenid Comef) as references for the training of its technical staff on bark beetles and coniferous sawflies. Equally notorious in these research centers has been the identification, distribution and control of the oak borer *Megapurpuricenus magnificus* LeConte (formerly *Crioprosopus magnificus*) (Sánchez-Martínez *et al.,* 2010a; Sánchez *et al*., 2014); the identification and biological aspects of the pine borer *Sirex obesus* Bradley; and the identification of the bark beetle of Montezuma bald cypress (*Taxodium mucronatum* Ten.) *Eudociminus mannerheimii* Boheman (Sánchez-Martínez *et al*., 2010b).

Contribution on forest diseases

INIFAP has focused mainly on the study of forest diseases that affect natural forests and urban forests; in the latter case, with special interest in those of Mexico City (Reséndiz *et al.,* 2019).

Public trees are considered an essential element within urban areas due to the multiple socio-cultural and environmental benefits, such as aesthetic value and provision of shade in recreational areas, its function in reducing water runoff, and its role as air quality improvers, among others (Urcelay *et al.,* 2012). In this sense, Francisco Reséndiz Martínez and Rodolfo Salinas Quinard continued with the study of the pathogens that affect *Pinus radiata*; the mycoflora that harm *Abies religiosa* (Kunth) Schltdl. *et* Cham. of the *Desierto de los Leones* Cultural and Recreational Park in Mexico City and on a possible new rust that attacks *Pinus montezumae* Lamb. (Reséndiz and Salinas, 1989; Salinas, 1989).

Salinas Quinard also provided insights into the life cycle, signs, and damage of *Cronartium conigenum* Hedgc rust. & N. R. Hunt in pines of the *Sierra Madre Oriental, Sierra Madre Occidental,* and southeastern Mexico, in collaboration with scientists representing the North American Forestry Commission (Peterson and Salinas, 1967; Southerland *et al.,* 1987).

In more recent times, scientists from Cenid Comef have continued studies of the sanitary condition of green areas in Mexico City. For example, Velasco *et al.* (2002) recorded a higher incidence of pests (ca. 9 to 19 %) than diseases (ca. 4 to 14 %) in the forests of Mexico City, in which *Pinus hartwegii* Lindl. was most attacked species by pests, with 8.7 %, and by diseases with 7.6 %. In this study it was found that the main pest was not an insect but the squirrel *Sciurus* sp., and that the most important disease was that caused in the foliage by *Lophodermium* sp.

In another detailed investigation of mistletoes in 16 municipalities of Mexico City, Arriola *et al.* (2012) found *Cladocolea loniceroides* (Van Tieghem) Kuijt, *Phoradendron velutinum* (DC.)

Oliv. and *Struthanthus interruptus* (Kunth.) BI. as the most important parasitic plants. They were present in eight municipalities, with infestation percentages below 5 %, in most cases, which can be kept under control by mechanical pruning.

Velasco *et al.* (2013) made a complete inventory of the trees in the *Bosque de San Juan de Aragón*, Mexico City, which included not only the evaluation of the sanitary condition, but also of other variables that interact with the health of trees and the urban forest as a whole; among them, the species, age, vigor and mechanical damage. Their results indicate that, despite registering a low diversity of species, the general condition of the *San Juan de Aragón* Forest is admitted as good, and pruning was recommended for around 5 200 trees that required it at the time.

In this line of research, Reséndiz *et al.* (2015) determined the agents of foliar diseases of trees of the *Tezozomoc* Cultural and Recreational Park in *Azcapotzalco*; and, Gutiérrez *et al.* (2019) identified the agents that affect the vegetation in the Second Section of the *Chapultepec* Forest.

With reference to the diseases that affect natural forests, Martínez *et al.* (2014) studied the effect of the dwarf mistletoe *Arceuthobium vaginatum* (Willd.) Presl. ssp. *vaginatum* in *Pinus hartwegii*, in the *Nevado de Colima* Volcano National Park, and concluded that the infestation by dwarf mistletoes reduced growth by 22 % in height, 9 % in diameter and 50 % in volume. In addition, they were able to specify that this parasitic plant affected in similar percentages the current annual increment and mean annual increment, which decreases the volume of wood produced and increases the technical rotation age of standing trees, by an average of 10 years. Based on this, they recommended the application of practices to prevent and combat the plant parasite, as well as the establishment of continuous monitoring sites.

Coria *et al.* (2010) experimented on the effect of diatomaceous earth and 2-chloroethyl phosphoric on *Arceuthobium globosum* Hawksworth & Wiens ssp. *grandicaule* on *Pinus pseudostrobus* Lindl. The treatments had the same suppression impact on the aerial part of *Arceuthobium globosum* ssp. *grandicaule* when diatomaceous earth was used. The death of the foliar area occurred 15 days after

treatment and the fall of the aerial part at 45 days. The greatest efficacy of this product occurred at 7.5 % in 200 L of water and no dose produced symptoms of phytotoxicity to the host plant.

Regarding disease studies in commercial plantations, INIFAP's contributions have been more limited; however, basic and diagnostic information has been generated. For instance, Bernal *et al*. (2009), determined the pathogen *Chrysoporthe cubensis* (Bruner) Gryzenhout & M. J. Wingf., as the cause of canker in eucalyptus plantations in the states of *Chiapas* and *Oaxaca*. The information on the causal agent is relevant because up to 70 % of the trees are affected by this fungus, which affects the production of commercial plantations. On the other hand, Gijón-Hernández *et al.* (2019) determined that the causal agent of necrotic lesions in new leaves, shoots and stems in the rubber crop [*Hevea brasiliensis* (Willd. Ex A. Juss.) Müll. & Arg.] corresponds to the *Colletotrichum gloesporioides* (Penz.) Penz complex. and Sacc., instead of *Microcyclus ulei* (Henn.) Arx. to which the rubber producers of *San Juan Bautista, Tuxtepec,* state of *Oaxaca* attributed the damages. These details in the correct identification of pathogens using traditional and molecular techniques are basic to implement the correct control measures for forest diseases.

Prospects and challenges

Research on pests and diseases carried out by INIFAP has been focused from a forest sanitation perspective, considering pest organisms as the direct cause of damage; with this, it has contributed to the taxonomic identification and, in some cases, has designed concrete measures for the direct control or the integral management of the causal agents. However, since the last decades of the 20th century, the concept of "forest health" emerged, which is broader and has an ecological perspective. Under this last meaning, although the economic damage that some organisms cause in forest production is recognized, the functions they perform in several ecological processes are

also valued, such as energy flow and plant succession, among others (Kolb *et al.,* 1991; Mistretta, 2002; Raffa *et al*., 2008).

The forest health approach, although already recognized, has been little adopted in the research carried out so far by INIFAP; however, it is necessary to incorporate it to be able to identify both proximal and ultimate factors that promote unusual behaviors in living beings to act as pests.

A healthy forest, from an ecological perspective, is a condition in which, for the proper functioning of the ecosystem, natural disturbances occur, but under a threshold that allows resilience and prevents a permanent loss of forest vegetation. Likewise, from the utilitarian point of view, a healthy forest is one that, even sustaining natural disturbances, provides forest ecosystem products and services for the good of society (Kolb *et al.,* 1991; Millar and Stephenson, 2015).

A recent trend in international forest health research refers to the study of the impact of climate change on the behavior of insects and pathogens that directly affect the vitality of forests (Moore and Allard, 2009). Several specialists point out that climate change is already affecting the biological development and population dynamics of pest insects in various parts of the world (Bentz *et al.,* 2010; Allen *et al*., 2010). There are recent cases of strange behavior of insects and pathogens that have caused an unprecedented mortality of millions of trees in millions of hectares (Allen *et al.,* 2010; Bentz *et al.,* 2010).

On the face of this phenomenon, some scientists predict the increase in generations per year of pest insects, and the colonization of species in new geographical areas (Williams and Liebhold, 2002; Carroll *et al.,* 2003; Bentz *et al.* 2010). Higher activity of pathogens that cause forest diseases is also predicted (Sturrock *et al.,* 2011). In the last decade there have been atypical outbreaks of bark beetles and defoliator insects in Mexico (del-Val and Sáenz-Romero, 2017; González and Sánchez, 2018; Cervantes-Martínez *et al.,* 2019), as well as diseases that cause tree decline and defoliation (Pérez *et al.,* 2017); however, specific research on climate change as a causal or contributory factor of atypical behavior of insects and pathogens is incipient in Mexico and, faced with this need, there

is a challenge for INIFAP to innovate in the way of approaching this issue, based on the concept of forest health and climate change scenarios.

Until now, the interactions between the abundance of the organisms considered pests and the state of the forests have been little explored from the point of view of species composition, structure, stand development stage or plantations, variables that influence behavior and impact of insects and pathogens, and in the resilience of urban forests, plantations and trees. It is insufficient to model the geographical distribution of pest organisms, and their impact, with only climatic variables and theoretical scenarios since, at a local scale, the effects of climate change are influenced by other intrinsic factors of the forest such as species diversity, age of the hosts, stand density, and the complexity in the forest structure (Bentz and Jönsson, 2015; Morin *et al*., 2018).

Based on studies that address these research issues, INIFAP will be able to provide not only diagnoses and direct control measures, but also recommendations and strategies aimed at preventing epidemic outbreaks, considering that climate change is occurring. For this, given the economic limitations that times are imposing on forestry research in Mexico, it is also necessary for INIFAP to resume and strengthen the technical and scientific exchange cooperation ties that it has established over the years with national institutions and institutions from other countries.

Acknowledgements

The authors thank Dr. Luis Ángel Rodríguez del Bosque and Dr. Rogelio Flores Velázquez for the invitation to write this review article.

Conflict of interests

The authors declare no conflict of interest with this publication.

Contribution by author

Guillermo Sánchez Martínez: bibliographic research on forest pests and writing of the manuscript; José Francisco Reséndiz Martínez: bibliographic research on forest diseases and writing of the manuscript.

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